EFFECT OF BACKGROUND MUSIC TEMPO ON DECISION MAKING OF RISK TAKING AND INTERTEMPORAL CHOICE

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EFFECT OF BACKGROUND MUSIC TEMPO ON DECISION MAKING OF RISK TAKING AND INTERTEMPORAL CHOICE

Abstract

The current research advance the economic perspective on individual decision making, involving choice under risk and intertemporal choice. This research aims to examine the relationship between background music tempo and behavioural tendency in choice under risk and intertemporal choice. Laboratory experiment was carried out to collect experimental data. Experimental data were collected from 119 subjects who participated in the laboratory experiment answering questionnaire with choice under risk and intertemporal choice problem. Three treatments were implemented during the subjects were answering the questionnaire: (1) The fast tempo music treatment, (2) The slow tempo music treatment and (3) The no music treatment. In the first two treatments, the subjects were presented with music stimuli from portable mp3 player. Result shows that fast tempo music has significant effect on choice under risk and intertemporal choice. In the presence of fast tempo music, subjects tend to exhibit higher risk level in chose choice under risk. Subjects also projected lower discount rate with the presence of fast tempo music. However, no significant different of choice under risk and intertemporal choice was found under condition of slow tempo music treatment and no music treatment. We concluded that fast tempo music has increased the arousal of subjects, then higher arousal induced risk taking behaviour.

KESAN TEMPO MUSIC LATAR BELAKANG TERHADAP KEPUTUSAN YANG MELIBATKAN RISIKO DAN PILIHAN DI ANTARA JANGKA MASA

Abstrak

Penyelikdikan ini mengkaji keputusan perseorangan yang melibatkan risiko dan pilihan di antara jangka masa dari segi ekonomik. Penyelidikan ini memeriksa hubungan di antara tempo musik latar belakang dan kecenderungan tingkah laku di dalam pilihan yang melibatkan risiko dan pilihan di antara jangka masa. Satu eksperimen dilakukan di makmal untuk mangumpul data ujikaji. Di dalam eksperimen yang dilakukan, 119 peserta mangambil bahagian untuk mengisi soal siasat yang termasuk pilihan yang melibatkan risiko dan pilihan di antara jangka masa. Sementara peserta menjawab soal siasat, tiga jenis rawatan musik dilaksanakan kepada peserta iaitu: (1) rawatan musik tempo pantas (2) rawatan musik tempo perlahan (3) rawatan tanpa musik. Untuk dua rawatan yang pertama, musik dimainkan kepada peserta dengan alat pemain musik mp3. Pengaruhan yang ketara didapati oleh rawatan musik pantas terhadap pilihan yang melibatkan risiko dan pilihan di antara jangka masa. Dalam keadaan mendengar musik tempo pantas, peserta cenderung untuk mengubah sikap kepada pengambilan risiko dalam pilihan yang melibatkan risiko. Dalam pilihan di antara jangka masa, peserta menunjukkan kadar diskaun yang lebih rendah dalam rawatan musik tempo pantas. Perubahan yang ketara tidak dapat diperhatikan semasa peserta membuat keputusan untuk pilihan yang melibatkan risiko and pilihan di antara jangka masa sementara berada dalam rawatan musik tempo perlahan dan rawatan tanpa musik. Kesimpulannya, musik bertempo pantas meningkatkan “arousal” peserta. Peningkatan “arousal” mendorong sikap mengambil risiko.

CHAPTER 1

INTRODUCTION

1.0 Introduction

Risk can be seen as relating to the probability of uncertain future events (Jones, 2005) . Risk is associated with the likelihood of an unfavorable outcome (Moskowitz & Bunn, 1987). Risk taking, in here after will alternatively mention as choice under risk as they carry the same meaning, was defined by Trimpop (1994) as any consciously, or non-consciously controlled behavior with a perceived uncertainty about its outcome, and/or about its possible benefits or costs for the physical, economic or psycho-social well-being of oneself or others. Choice under risk is defined as the choice made by people, where they receive one defined probability distribution (Fujikawa, 2007).

Intertemporal choice is the decisions involving tradeoffs among costs and benefits occurring at different points in time (Stevens, 2010). Economics of intertemporal choice including making choice to deposit money in a bank and retain interest after a certain period, buy an insurance where benefits in the future.

In the current research, both risk taking and intertemporal choice were to be studied from economic perspective, where it was study under the circumstances that the decision of choice under risk and intertemporal choice that made by the subject has related to his personal wealth. Both choice under risk and intertemporal choice have much been involved in our daily decision making. Example include, short term and long term share market investment, purchasing of insurance policy, management of mortgage properties, starting an entrepreneurship etc. In daily life, we might have to make this economic decision under the environment which background music is presenting. Imagine that a casual business discussion that held at a Starbuck, consumers that involved in the discussion may be listening to the background music that played inside the shop while making business decision. Consumers too, make purchasing decision in retail shops that playing background music. Now an interesting question arise: To what extent this background music can influence the economic decision making. Narrowing the scope, one important element of music, music tempo – one important element of music, was selected as the independent variable of this study. This study will reveal the effect of background music tempo on decision making of risk taking and intertemporal choice.

Reviewing previous research on effects of music tempo in economic decision making, none of them has given strong arguments on the effects on music tempo in intertemporal choice and choice under risk (Dixon, Trigg, & Griffiths, 2007; M. D. Griffiths, 1993; M.D. Griffiths & Parke, 2005; Spenwyn, Barrett, & Griffiths, 2010). Several important economic theories such as Expected utility theory and Prospect theory are applicable to explain the phenomenon in this research. Therefore, this research can be meaningful to carry out to give a new perspective on economic decision making.

1.1 Background of the Study

Economists have been analyzing, both theoretically and experimentally, "choice under risk" and "intertemporal choice", as the analysis has much to contribute to the study of economics on rationality. On the one hand, previous and recent studies have designed and reported experiments on intertemporal consumption choice under certainty, hereafter referred to as intertemporal choice. The decision makers (DMs) often prefer a smaller short against long-term investments (Rambaud & Ventre, 2011). Suppose the DMs, who make choice between two options: An option A1, a sure gain of $101 in 101 days; an option B1, a sure gain of $100 in 100 days. Many of the DMs might prefer (A1). By decreasing day length, this choice problem could be reduced to the choice problem between: (a1) a sure gain of $101 tomorrow and (b1) a sure gain of $100 today. Many of the DMs might prefer (b1). Bartels and Rips (2010) show that the DMs prefer to receive $150 now over $500 in 25 years. The tendency that they prefer a smaller

amount of money now to a larger amount of money later has long been a topic of intertemporal choice.

On the other hand, much attention has been focused on choice under risk and its related "Allais-type" behavior (Allais, 1953) to exemplify deviations from rationality. Choice under risk is defined as the choice made by people, where they receive one defined probability distribution (Fujikawa, 2009). Kahneman and Tversky (1979) performed a choice experiment, where they asked the participants to choose between: (H1) an 80% chance to win $4 and (L1) a sure gain of $3. The results revealed that many of the participants preferred a safe option (L1). This preference for a certain payoff is termed as the *certainty effect*. In another experiment, Kahneman and Tverskey (1979) asked the participants to choose between (H2) a 20% chance to win $4 and (L2) a 25% chance to win $3. Many of the participants preferred (H2). This participants' response is well known as *Allais paradox*.

The aforementioned preference reversal phenomena raise an issue relevant to economic theory. It has been examined and reported in the tradition of Samuelson's (1937) model of discounted utility that explains patterns of intertemporal choice, and von Neumann Morgenstern Expected utility theory (von Neumann & Morgenstern, 1994) that is a rational choice model in economics. Despite these elegant models, recent and previous studies have provided evidence for a number of "anomalies" and "violations" in intertemporal choice and decision making under risk.

We must note here that the results and findings are inconsistent, despite many laboratory experiments conducted by researchers across countries.

1.2 Problem Statement

A number of researchers have focused on the effect of music tempo on decision making (Dixon, et al., 2007; M. D. Griffiths, 1993; M.D. Griffiths & Parke, 2005; Spenwyn, et al., 2010). However, there are no consistent results that explained the relationship between tempo of background music and behavior in choice under risk and intertemporal choice. Previous results are inconsistent in explaining whether the DMs tend to change their behavior in the presence of background music with different tempo. A conceptual analysis is needed in this thesis, as we consider (1) to what extent DMs tend to change their behavior in the presence of background music with different tempo and (2) to what extent DMs tend to obey Expected utility theory when making choices under risk in present of background music with different tempo? In this research, we shall examine whether the DMs obey these models with the presence of background music stimuli. This research shall also examine the changes of discount rate of the DMs under background music stimuli.

1.3 Objective of the Research

1. To investigate that background music's tempo affects human behavior in decision making in choice under risk and intertemporal choice;

2. To examine to what extent background music's tempo influences the DMs in determining degrees of risk aversion when engaging in decision making in choice under risk;

3. To examine the background music's tempo effects in determining discount rates when engaging in decision making in intertemporal choice.

4. To investigate to what extent background music's tempo facilitates people's rational decisions

1.4 Research Questions

This study is to understand and answer some questions raised to frame the direction.

RQ1 Do people change their behavior when the background music's tempo changes?

RQ2 Do people behave as risk averse or risk taking when the background music's tempo changes?

RQ3 Do people have different discount rate when the background music's tempo changes?

RQ4 Does background music's tempo disturb people in making rational decision?

1.5 Expected Outcome

The expected outcome of this study is to identify the correlation of music's tempo and decision making in choice under risk. The correlation of music's tempo and people's discount rate is investigated too. The finding on the magnitude of influence upon choice under risk and intertemporal choice under fast tempo music treatment, slow tempo music treatment and no music treatment also is expected. Result of significant differences within choice under risk and intertemporal choice also are expected comparing condition under fast tempo music treatment versus slow tempo music treatment, fast tempo music treatment versus no music treatment and slow tempo music treatment versus no music treatment. This research, in long term helps to understand the changes of human's economics behavior with the presence of background music.

1.6 Significant of the Study

Among the five senses of human being, we choose hearing as our subject where it can influence the decision making process. Relative to the other four senses (sight, taste, smell and touch) the DM's hearing is the easiest sense that can be manipulated by the environment. Background music is particularly a tool that can be incorporated into the decision making environment. In our real life, the DMs intentionally and unintentionally expose themselves in the environment in which background music is present. For example, background music is played in a grocery store while people are purchasing goods; it is played in the environment where people engage in financial decision making such as purchasing shares, bonds and insurance.

This research's result may assist people to influence the DMs by playing preference music with tempo that can affect the DMs' behavior. It can also suggest a new element for future researchers to look into when studying the stimuli that influence economic decision making.

1.7 Definition of Terms

Popular terms that are appeared in this thesis are defined and described as a follow:

i) Risk - subjective perception associated with the individual's preference, and a relative matter referring to the likelihood of a probabilistic event (Yang & Qiu, 2005).

ii) Choice under risk - choice made by people, where they receive one defined probability distribution (Fujikawa, 2007).

iii) Intertemporal choice - decisions involving tradeoffs among costs and benefits occurring at different points in time (Stevens, 2010).

iv) Music tempo - the speed at which a piece of music is performed (Kennedy, 1995).

v) Arousal - ability to mobilize metabolic energy to meet environmental or internal demands on behavior (Marrocco & Field, 2002)

1.8 Organization of the Research Report

The research report is organized as follows: Chapter one is an introductory chapter aims to provide a general idea on the whole research including research problem, research questions, research objectives, the theories and the settings. Chapter two provides literature review relating to choice under risk, intertemporal choice and music tempo. Besides, it explains the development of the theoretical framework and research hypotheses based on the analysis of literature. Chapter three provides research methodology that includes research design, specification of population and sample, and development of measures and scales for the variables of the study. This chapter then explains questionnaire design and statistical techniques to be used in analyzing the data. Chapter four presents findings of the study that includes analysis of the collected data from survey and presentation of results. The thesis ends with Chapter five that provides discussion of the results of the study and their theoretical and managerial implications. In addition, the chapter presents limitations of the study and suggestions for future research.

CHAPTER 2

LITERITURE REVIEW

2.0 Introduction

Economists have been analyzing, both theoretically and experimentally, “risk taking” and “intertemporal choice”, as the analysis has much to contribute to the study of economics on rationality. On the one hand, previous and recent studies have designed and reported experiments on *intertemporal* consumption choice under certainty, hereafter referred to as intertemporal choice. In this chapter previous researches which related to music tempo on economic decision making, music tempo on human behavior, choice under risk, interemporal choice, economic experiments and at all literature interrelated to the research are reviewed, synthesized and criticized. Previous literatures are important to provide strong support in the explanation involved

in this research. Future more, theory which related to choice under risk and intertemporal choice such as expected utility theory, expected utility theorem, prospect theory are examined for the application of developing theoretical framework.

2.1 Risk Taking

The concept of risk has been a concern of human beings form the earliest days of history. Since the ancient society, farmers in Mesopotamia managed risk by taking out insurance on their production and loaning shares of their excess production for interest rates in return. Interest rates from 0% for friends to 33% for strangers reflect the perceived riskiness of loans. All ancient civilization left records about preventive measure (e.g., building and fire codes) against major problems and risks they were threatened with, such as natural disasters, epidemics, pollution, food contamination, transportation accidents and occupational injuries. It can be seen that the addressed problem is still of major importance today, as many as 4000 years after they were originally identified and regarded as problems (Trimpop, 1994).

Risk is associated with the likelihood of an unfavorable outcome (Moskowitz & Bunn, 1987). Trimpop (1994) defined risk taking as any consciously, or non-consciously controlled behavior with a perceived uncertainty about its outcome, and/or about its possible benefits or costs for the physical, economic or psycho-social well-being of oneself or others. Choice under risk is defined as the choice made by people, where they receive one defined probability distribution (Fujikawa, 2007). Risk is usually a subjective perception associated with the

individual's preference, and a relative matter referring to the likelihood of a probabilistic event. For the notion of risk in decision analysis, there are two main factors that determine the decision maker's choice of action: One is the uncertainty of outcomes resulting from uncertainty of occurrence of state; Another is decision maker's expected utility when taking a certain action (Yang & Qiu, 2005). A theoretical framework of the expected utility is presented in this thesis.

Freedom of decision making and improved availability of information provide people with more choice than ever before. Uncertainty and unpredictability have been a by-product of rapid economic globalization and faster social and technological change. Decision making under risk and uncertainty are abundant, and perceptions of risk affect these decisions. The decision that is made under risk is when probabilities that certain states will occur in the future are precisely, completely known (e.g., in a fair roulette game); the decision that made under uncertainty when the probabilities are not known (e.g., outcomes of sports events, elections or most real investments) (Fujikawa, 2009). Today, people withdraw their money out of financial investment when they judge the risks of losing them to be too high. Decisions made by government agencies and corporations have been affected by risk perceptions of individuals as citizens and consumers. Perception of risk of terrorist attack by airport authorities has cause them to tighten the securities rules, particularly the imposed of full body scanning for each of their passengers.

2.2 Intertemporal Choice

Intertemporal choice is the decisions involving tradeoffs among costs and benefits occurring at different points in time (Stevens, 2010). Decisions that have consequences in multiple time periods are intertemporal choices (Chabris, Laibson, & Schuldt, 2008). One example of intertemporal choice in our nature is found in the animal's foraging activity. During the activity of searching for food, a bird eating berries from a bush. Every berry it consumed depletes the patch and the average time required to search for next berries has increase. It has to decide between intertemporal choice when it should stop searching in that patch and move to the next patch. Leaving the patch too soon may waste an opportunity to enjoy a quick meal. Leaving too late may waste the time better used in searching in a new patch (Stevens, 2010).

Economists' attention to intertemporal choice began early in the history of the discipline. Adam Smith, who was a famous classical economist, raised the awareness to the influence of intertemporal choice for the wealth of nations. Scottish economist John Rae then examined the sociological and psychological determinants of intertemporal choice (Frederick, Loewenstein, & O'Donoghue, 2002). In the U.S. study, Warner and Pleeter (2001) found that the average individual discount rates implied by the observed choices were high relative to a priori expectations. Their linear model predicts average rates of 10.4% and 35.4% for officers and enlisted personnel, respectively. In Denmark, Harrison, Lau et al. (2002) estimated a 28% discount rate for their population. Economics of intertemporal choice is concerned with making

choice to deposit money in a bank, retain interest after a certain period and to buy an insurance where benefits in the future are expected.

Economists have noticed that, when given a choice between the same immediately benefit or future benefit, people prefer the immediate benefit. Investors, for instance, prefer short against long-term investments (Rambaud & Ventre, 2011). Another example, market evidence shows that people discount long-term costs (e.g., the higher energy costs associated with less expensive, lower efficiency home air conditioners) by more than what the market interest rate predicts (Thaler & Shefrin, 1981). This effect suggests that people temporally discount or devalue future payoffs. Economic theories propose a number of reasons to discount the future. First, inflation literally makes money less valuable. Also, individuals can invest currently available benefits. A $1 might be $3 tomorrow after invested in share market. Finally, the future is full of uncertainty. There might be unpredictable and uncontrollable event or disaster that might jeopardize the future rewards' value (Stevens, 2010). This behavior was defined as impulsitivity, which is choosing a smaller, immediate reward over a larger, delayed reward (Rachlin & Green, 1972).

Economists agreed that a hyperbolic function best explains the relationship between subjective value and delay (Myerson & Green, 1995; Rachlin, Raineri, & Cross, 1991). Mazur (1987) developed a model of delay discounting:

$$v_d = V/(1 + kd)$$

which v_d is the current subjective value of a delayed reward (the difference point), V is the value of the delayed reward, d is the delay duration, and k is an empirically-derived constant proportional to the degree of delay discounting. The higher the k value, the more rapidly the value of a reward decreases with delay to its delivery (Petry & Casarella, 1999).

2.3 Previous Literature on the Effects of Music in Non-economics Decision Making

Music is a most specialized, peculiar human cultural artifact (Andrade, 2004; Beament, 2001) and powerful stimulus to our behavior and decision making. One raises a question: Can background music affect our behavior? There has been much of the controversy pertaining to this question (Brayfield & Crockett, 1955; Jacob, 1968; McGehee & Gardner, 1959; Miliman, 1982; H. C. Smith, 1947; Uhrbrock, 1961). Burner and Gordon (1990) presumed that music affects human beings in various ways as long as they play music. Having accepted this presumption, previous researchers presented study on behavioral effects on music in decision making. There exists literature pertinent to the effects of music on behavior and decision making.

The effects of music in decision making are inconsistent, however. Corhan and Gounard (1976) premised that vigorous rock music should be associated with better performance than easy-listening music. Iwanaga and Ito (2002) conducted an experiment in which the participants

performed choice task in the presence of vocal music condition. Iwanaga and Ito (2002) reported that highest disturbance was observed under the vocal music condition. Wolf and Weiner (1972) asked undergraduates to perform a mental arithmetic task with having them listen to rock music, and showed that their performance in the task was neither decreased nor increased. The kinds of music used as background music varied: classical (Hilliard & Tolin, 1979), folk (Mowsesian & Heyer, 1973), hard rock (Wolf & Weiner, 1972), vocal and instrumental (Salamé & Baddeley, 1982), pop (Iwanaga & Ito, 2002). All of background music in these studies consisted of existing song (e.g., Mozart, well-known Japanese pop songs, and so on).

Most of the research involved in music and risk were concentrated in non-economic risk taking. For example, health-risk behavior was found to be correlated with increasing of adolescents' negative emotional response to music. Strong negative emotional response to music in particular was correlated with a history of greater risk behavior (violating curfew, physical fights and weapons, fire setting, animal abuse, stealing, alcohol use, drug use, and sexual activity including number of partners and condom use), particularly among whites and fans of rock or heavy metal music (Roberts, Dimsdale, East, & Friedman, 1998). In a research of adolescent's intension to take risk in traffic, result concluded that music video viewing was negatively associated with the assessment of the dangers of speeding and driving under the influence of alcohol (Beullens & Bulck, 2008). The less dangerous a particular behavior was perceived to be, the more likely respondents intended to exhibit this behavior in the future.

A research has examined the relationship of music tempo and gambling behavior. The result shows that higher tempo music increases the speed of betting. However, the researchers failed to proof that tempo of music could influence the risk taking behavior of gambling. The researcher explained these result as when the participants are not betting with real money, they reluctantly take responsible to the overall outcome since the outcome would not affect them financially (Dixon, et al., 2007).

Research conducted on a personal computer (PC)-controlled simulation driving shows that the higher the tempo of background music, the higher the tendency of virtual traffic violations. The researcher has explained the phenomenon as the high tempo music force human to process large amount of temporal events, occupying the memory storage and distract operation and optimum driving capacity (Brodsky, 2002).

2.4 Previous Literature on the Effects of Music in Decision Making in Choice under Risk and Intertemporal Choice

Previous authors conducted experiments in which the participants were asked to perform tasks in *hypothetical* situations, such as questionnaires and interviews (Eckel & Grossman, 2008; Harrison, Lau, & Williams, 2002; Lammers & van Wijnbergen, 2008). That is, the participants did not receive monetary payoffs, contingent on their performance in the experiments. Not only the authors but mainstream psychologists are more casual about defining their participants' incentives in experimental tasks. In fact, most psychologists feel no necessity to offer salient rewards: The admonition to the participants to "do their best" is acceptable (D. Friedman & S.

Sunder, 1994). Psychologists do not take into consideration an analysis of (monetary) costs and benefits of the participants' action in the experiments.

However, a large caveat must be issued here: Economists study costs and benefits of any action made by the DMs. As such, extrinsic rewards are one of most important determinants of decision making among experimental economists. It is inevitable to provide the participants with the financial rewards, which are contingent on their performance in the experiments. Professor Vernon L. Smith, the 2002 Nobel Prize winner in Economics, stated in his paper (V. L. Smith, 1991) that monetary incentives are commonly absent in the research of psychologists, and this makes their work vulnerable to the criticism that the result are not meaningful. Knutson and Peterson (2005) stated that money is a compelling incentive, in that most people will work for it. Hertwig and Ortmann (2001) contended that employing financial rewards is considered as one of experimental standards in economics. Camerer and Hogarth (1999) presented an analysis of the behavior of the participants' who were paid zero, low or high financial performance-based incentives. Camerer and Hogarth (1999) demonstrated that higher incentives do often improve the participants' performance. A convincing body of research demonstrated that the use of questionnaires can be problematic because the participants have no incentives to report their strategy reliably (Sonnemans, 1998). Offerman, Sonnemans, and Schram (1996) argued that the participants are not provided with an incentive to carry out the estimation task seriously in some non-economic experiments (Dawes, Orbell, Simmons, & van de Kragt, 1986; Rapoport, 1988; Suleiman & Rapoport, 1992). This argument is supported by some empirical evidence (Jamal &

Sunder, 1991; V. L. Smith & Walker, 1993) that the addition of rewards makes the result of experiments more reliable and reproducible. For example, in a post-experiment questionnaire in Offerman et al. (1996), half of the participants stated that they would have answered differently if no incentives had been provided. What the DMs say they would do in hypothetical situations does not necessarily correspond to what they actually do (D. Friedman & Cassar, 2004; Fujikawa, 2007). The proposed study avoids this shortcoming, and differs by providing the participants with clear, monetary incentives for revealing true beliefs. Although there is an assertion maintained by psychologists that running experiments with hypothetical questions is inexpensive, fast and convenient (Thaler, 1987), we did not obey the assertion in carrying out the proposed research.

2.5 Theoretical Approach on Risk taking

2.5.1 Expected Utility Theory

The study of decision making under uncertainty has been dominated by a single approach-the closely related theories of expected utility and subjective expected utility. As formulated and axiomatized by (von Neumann & Morgenstern, 1947), these theories rank among the most important in twentieth-century social science. They have had a profound influence on the manner, in which social scientists (in particular, economists, psychologists, statisticians, sociologist, and political scientists) describe choice under uncertainty. Moreover, they have provided the foundation for prescriptive approaches to decision making. In one area, however, expected utility and subjective expected utility have met with mixed success. This is represented by a host of choice behavior, conducted principally by psychologists but also by an increasing

number of economists. On the one hand, utility theory has been enormously fruitful in providing a framework within which choice can be studied. On the other, it has failed to predict certain phenomena, resulting in so-called choice paradoxes or anomalies.

Utility theory has nonetheless proven to be remarkably resilient to the experimental evidence that has accumulated against it. Indeed, Einhorn and Hogarth (Einhorn & Hogarth, 1981) make this remark despite the fact that recent alternative theories succeed in explaining several choice paradoxes (e.g., (Kahneman & Tversky, 1979) (Machina, 1982)). We believe that three contributed to the longevity of utility theory. (1) The criterion of maximizing expected (or subjectively expected) utility follows logically from a parsimonious set of axioms. In addition, each axiom specifies a reasonable principle (e.g. transitivity) such that has provides a description of how a "rational" actor might behave. (2) The theory has provided a useful framework for deriving empirically testable propositions in many areas of applied economics, for example, finance, marketing, political economy, and so on. (3) The theory is difficult to falsify with naturally occurring data since exogenous variables can be called on to explain violations of predictions. Moreover, tests of utility theory are not as rigorous as they seem in that specific alternatives to the theory are rarely considered.

2.5.2 The Expected Utility Theorem

A first advantage of the expected theorem is technical: It extremely convenient analytically. This, more than anything else, probably accounts for its pervasive use in economics. For analyzing attitudes of people toward risk, it is very easy to work with the expected utility

theorem and very difficult to do without it. Second advantage of the theorem is normative: Expected utility may provide a valuable guide to action. People often find it hard to think systematically about risky alternatives. However, assuming that an individual believes that her choice should satisfy the axioms on which the theorem is based (notably, the independence axiom), the theorem can be used as a guide in her decision process. The expected utility theorem can help us explain that how each individual would behave when facing risky alternatives. In many economic setting, individuals seem to display aversion to risk.

The utility function U: $L \rightarrow$ R with the expected utility form is called a von Neumann-Morgenstern expected utility function.

Definition 1. A utility function U: $L \rightarrow$ R has an expected utility form if there is an assignment of numbers $(u_1^k, \ldots, u_N^k)$ to the N outcomes such that for every simple lottery $L_k = (p_1^k, \ldots, p_N^k) \in L$ we have

$$U(L_k) = u_1^k p_1^k + \cdots + u_N^k p_N^k$$

for any K lotteries $L_k \in L$, $k = 1, \ldots, K$, and probabilities $(p_1^k, \ldots, p_N^k) \geq 0$, $\sum_{i=1}^{N} p_i^k = 1$

Definition 2. The utility function U: L $\rightarrow$ R has an expected utility form if and only if it is linear, that is, if and only if it satisfy the property that

$$U\left(\sum_{k=1}^{K} \alpha_k L_k\right) = \sum_{k=1}^{K} \alpha_k U(L_k)$$

for any K lotteries $L_k \in L$, $k = 1,\ldots, K$, and probabilities $(\alpha_1,\ldots,\alpha_k) \geq 0$, $\sum_{k=1}^{K} \alpha_k = 1$.

The expected utility hypothesis is considered in its general form, where no restrictions are imposed on $U(x)$ other than monotonicity in the case of money. The expected utility theorem is the most important result in the theory of choice under uncertainty. The theorem says that assuming the decision maker's preferences over lotteries satisfy the weak, complete ordering, continuity and independence axioms, which are described below, his/her preferences are representable by a utility function with expected utility form. The expected utility theorem makes a set of assumptions about preference orderings and proves that to obey the axioms.

The axioms are as follows:

1. The weak axiom: Suppose an individual choose alternatives x (and only that) when faced with a choice between x and y, we would be surprised to see her choose y when faced with a decision among x, y and a third alternative z. In words, the weak axiom says that if x is ever chosen when y is available, then there can be no budget set containing both alternatives for which y is chosen and x is not.

2. The complete ordering axiom: For any two lotteries, L_1 and L_2, the decision maker prefers either L_1 to L_2 or L_2 to L_1, or else is indifferent. Furthermore, suppose L_1 is preferred to L_2 and L_2 to a lottery, L_3, L_1 must also be preferred to L_3 (called transitivity). The preference relation $\succsim$ is rational if it satisfies the complete ordering axiom.

3. The continuity axiom: If L_1 is preferred to L_2 and L_2 to L_3, then there must exist some probability $p \in [0,1]$ so that the decision maker is indifferent between a sure amount L_2 and a lottery offering L_1 or L_3 with probabilities p and $(1-p)$, respectively.

Definition: $\forall L_1, \forall L_2, \forall L_3$.

$$L_1 \succsim L_2 \succsim L_3 \Leftrightarrow \exists \alpha \in [0,1] \qquad \alpha L_1 + (1-\alpha) L_3 \sim L_2$$

In words, continuity means that small changes in probabilities do not change the nature of the ordering between two lotteries. For example, if a "beautiful and uneventful trip by car" is preferred to "staying home", then a mixture of the outcome "beautiful and uneventful trip by car" with a sufficiently small but positive probability of "death by car accident" is still preferred to "staying home".

4. The independence axiom: The fourth assumption, the independence axiom, will allow us to impose considerably more structure on $U(\cdot)$.

If the DM is indifferent between alternatives x and y, then she should also be indifferent between two lotteries offering x and z in the first and y and z in the second, with probabilities p and $(1-p)$ in each lottery for any z and p value. The independent axiom is needed to be discussed further in the next subsection because it is not only an important one but also skeptical.

The weak and complete ordering axioms hold not only under certainty, where each alternative has one certain outcome but also under uncertainty, where each alternative has more than one outcome. Compared with the above, the continuity and independence axioms hold only under uncertainty.

Theorem 1. [The Expected Utility Theorem] Suppose that the rational preference relation, $\succsim$, which satisfies the complete ordering axiom, on the space of a lotteries L satisfies the continuity and independence axioms. Then $\succsim$ admits a utility representation of the expected utility form. That is, we can assign a number u_n to each outcome $n = 1, \dots, N$ in such a manner that for any two lotteries $L = (p_1, \dots p_N)$ and $L' = (p_1', \dots, p_N')$, we have

$$L \succsim L' \text{ if and only if } \sum_{n=1}^{N} u_n p_n \geq \sum_{n=1}^{N} u_n p_n'$$