A Case Study of the Application of Expected Utility Theory to Everyday Decision Making

Letong Guo*

Rossdale High School, Toronto, M2J4A6, Canada

*Corresponding author: xiaoiaioao@tzc.edu.cn

Abstract. This paper reviews the current state of research on the application of expected utility theory in daily decision-making and explores the effectiveness and limitations of the theory in different decision-making scenarios by systematically sorting out and deeply analyzing application cases in several fields. As a classical decision theory, the core of expected utility theory is to guide rational decision-making by assessing the expected utility values of different choices. This paper reviews the applied research on expected utility theory by scholars at home and abroad in recent years in various fields, such as consumer choice, financial investment, health management, environmental policy, etc., and reveals its role and shortcomings in explaining and predicting decision-making behavior. This paper argues that expected utility theory provides an important theoretical framework for understanding everyday decision-making, but its applicability in practical applications is constrained by a variety of factors. Future research needs to further explore the modifications and extensions of the theory to better adapt to complex and changing decision-making environments. Decision makers should consider situational factors, personal preferences and theoretical limitations in practical applications, and flexibly use expected utility theory for decision analysis. This paper not only deepens the understanding of expected utility theory, but also provides new directions and ideas for subsequent research, which is of great significance in guiding the actual decision-making process.

Keywords: Rational decision making; limitations; revision and extension.

1. Introduction

In the modern society where uncertainty abounds, decision making has become one of the core challenges for individuals, firms and policy makers. Expected utility theory (EUT), as a cornerstone in the field of risk and uncertainty decision making, has been a hot topic of research in economics, psychology and behavioral sciences since it was proposed by Neuman and Morgenstern in 1944 [1]. The theory describes the decision maker's preferred choices in the face of multiple possible outcomes through the expected utility function, which guides the determination of optimal decisions. However, with the depth of research, the limitations of EUT gradually emerge, especially in the effectiveness of its application in complex real-world environments. Therefore, it is of great significance to explore the practical application cases of expected utility theory in daily decision-making and its effectiveness to enrich decision-making theory and optimize the decision-making process.

In recent years, many scholars have conducted extensive and in-depth research around the application of expected utility theory. Simon revealed that there is a significant difference in the risk attitudes of decision makers when they are faced with gains and losses, i.e., they tend to be risk-averse when they gain and risk-seeking when they are faced with losses, a finding that challenges the risk-neutral assumptions in the EUT [2]. Kahneman and Tversky further verified the assumption of risk aversion in Expectancy Theory through tax evasion behaviour, revealing the changes of individual risk attitudes in different contexts [3]. The study by Gigerenzer started from a gender perspective and found that women show greater risk aversion when facing large probabilities in the gain region as well as small and medium probabilities in the loss region, which provides a new understanding of the role of gender differences in decision-making [4].

In addition, there are scholars who apply expected utility theory to specific fields, such as Gigerenzer and Todd explored how loss aversion and overconfidence affect corporate decision-making through the case study of Sony [5]. In public policy areas such as soil and water conservation,

sponge city construction, and irrigation district information, expected utility theory has also been used to assess the expected benefits of different governance measures or construction projects, providing a scientific basis for policy formulation [6-8]. These studies have not only verified the applicability of expected utility theory in different contexts, but also revealed its limitations and improvement directions in practical applications.

On the basis of the above studies, this paper aims to explore the specific application of expected utility theory in different decision-making situations and its practical effects through the case study of the application of expected utility theory in daily decision-making. By selecting representative cases, the paper analyses the role of expected utility theory in guiding the decision-making process in terms of mechanisms, influencing factors and challenges, with the aim of providing decision-makers with more scientific and rational decision-making tools and methods. The research not only helps to deepen the understanding of expected utility theory, but also can provide practical guidance for optimizing the daily decision-making process and improving the quality of decision-making.

In summary, expected utility theory, as an important theoretical tool for risk and uncertainty decision-making, has attracted much attention for its effectiveness and limitations in practical application. By combing and summarizing the existing studies, this paper aims to explore the specific application of the theory in daily decision-making and its direction of improvement, with a view to providing reference and reference for research and practice in related fields.

2. Theoretical Background

2.1. Concepts of Utility Theory

The core of expected utility theory lies in the concept of "utility", a quantitative representation of an individual's degree of satisfaction or preference. Under uncertainty, an individual chooses a course of action that maximizes expected utility by evaluating the probability-weighted utility of different outcomes [9]. First rigorously defined the expected utility function and demonstrated that individuals always make consistent and optimal decisions under certain assumptions (e.g., rational preferences, the axiom of independence, etc.).

2.2. Precondition of Utility Theory

Expected utility theory is based on the assumption of the rational decision maker, that is, the decision maker has complete information processing ability, can accurately assess various possible outcomes and their probability of occurrence, and makes optimal choices accordingly. However, this assumption is often difficult to fully satisfy, because human decision-making is often affected by a variety of factors such as emotion, cognitive bias, and limited rationality. The concept of limited rationality proposed by challenges the assumption of complete rationality and emphasizes the actual decision-making process of decision-makers in the presence of incomplete information and limited cognitive abilities [10-12].

2.3. Uncertainty with Utility Theory

Expected utility theory is particularly concerned with the effects of uncertainty and risk on decision-making. Under uncertainty, decision-makers need to rely on probabilistic assessments to predict possible future outcomes and make decisions by comparing the expected utility of different courses of action [13, 14]. The understanding of uncertainty was further enriched by distinguishing between measurable uncertainty and non-measurable risk [15, 16]. Exploring the different attitudes and decision-making behaviors of different individuals in the face of risk by constructing a utility function for risk aversion.

2.4. Extensions of Utility Theory

Despite its strong explanatory power in theory, expected utility theory faces many challenges in practical application. To make up for its shortcomings, scholars have proposed many extended models, such as prospect theory, cumulative prospect theory [17]. These theories better explain people's actual decision-making behaviors under uncertainty by introducing concepts such as reference point and loss aversion. Meanwhile, classical paradoxes such as Gilboa and Quiggin have also questioned the rationality assumption of expected utility theory and promoted the further development of decision theory [18, 19].

3. Application of Expected Utility

3.1. Formulation and Development

Expected Utility Theory (EUT) was first systematically introduced by John von Neumann and Oskar Morgenstern in Theory of Games and Economic Behavior [1]. The core idea of EUT is that rational decision makers, when faced with uncertainty about their options, will make optimal choices by evaluating and comparing the expected utility of each possible outcome [20, 21]. This theory not only provides a methodology for understanding and analysing how decision makers make choices in the face of uncertainty, but also provides a powerful tool for assessing and predicting decision outcomes. Over time, these concepts have been further extended by scholars such as Gollier, who introduced the subjective expected utility model, a model that allows for the inclusion of an individual's subjective probabilities to be taken into account, thus greatly expanding the scope of application of the EUT and providing a richer perspective for understanding how individuals make decisions in the face of uncertainty [22].

In comparing EUT with other behavioural models (e.g. Prospect Theory), Barberis pointed out the limitations of EUT in explaining real-world decision-making behaviours. Barberis argues that although EUT provides a powerful analytical framework, it is often incompetent in the face of complex and changing real-world situations. For example, people tend to exhibit risk-seeking behaviour in the face of losses, which contradicts the assumption in the EUT that rational decision makers always seek to maximise utility [23]. Similarly, Gigerenzer has emphasised the importance of EUT in decision theory, whilst recognising the need to develop alternative models that can more accurately capture the characteristics of human behaviour. Gigerenzer's work has placed particular emphasis on the uncertainty and ambiguity of the decision-making process, and how these can be better captured in theory [4]. These discussions have not only enriched researchers' understanding of EUT, but also provided new directions for the development of decision theory.

3.2. Application and Impact

Expected Utility Theory, EUT has been widely and deeply applied in many disciplines such as economics, finance, and public policy since its proposal. In the field of economics, EUT not only provides a powerful analytical framework for understanding how consumers make choices under uncertainty, but also provides a theoretical basis for understanding market behaviour and consumer preference dynamics [5]. As research continues, scholars have begun to explore how EUT can be combined with other economic models to more fully explain consumer behaviour in complex market environments. Hsee and Zhang has proposed a new analytical perspective by combining EUT with elements of behavioural economics to better capture the decision-making process of consumers in the face of uncertainty [6].

In the field of finance, EUT not only provides the theoretical foundation for Markowitz's portfolio choice theory, but is also a core component of Sharpe's Capital Asset Pricing Model (CAPM) [8]. These theories are indispensable tools for modern financial analysis, guiding investors and financial analysts in balancing risk and return. EUT also plays an important role in the public policy arena.

Policy makers use EUT to assess the expected benefits and costs of different policy options, especially in areas that involve higher risk and uncertainty, such as climate change policy and health care [11].

In terms of empirical research, the application of EUT in investment strategy and risk management is becoming increasingly important. Gollier provided insights into how EUT can be utilised to identify optimal portfolio choices in different economic environments, demonstrating the theory's continued relevance and utility in contemporary financial decision-making [9]. Scholars have further applied EUT to modelling the impact of macroeconomic shocks on asset prices, providing investors with unique insights into how to use EUT to make decisions in the face of economic uncertainty [24, 25].

3.3. Example of Expected Utility

Ken wants to choose ice cream with different favors. There have 5 different favors strawberry, mango, vanilla, matcha and chocolate. All favors have different expected utility. If the maximum score of ice cream is 10 points, then every favor supplying possibilities must be considered. The supplying possibilities of Mango is 30% and the score is 10 points. The supplying possibilities of Chocolate, vanilla, matcha and strawberry are 25%, 20%, 15%, 10% respectively. The scores are 9 points to 6 points in order. Using the score of different favors time corresponding supplying possibilities and combine each result together can obtain expected utility.

$$Mango\ 10 \times 30\% = 3 \tag{1}$$

$$Chocolate\ 9 \times 25\% = 2.25 \tag{2}$$

$$Vanilla\ 8 \times 20\% = 1.6 \tag{3}$$

$$Matcha\ 7 \times 15\% = 1.05 \tag{4}$$

$$Strawberry\ 6 \times 10\% = 0.6 \tag{5}$$

The combination of these values can obtain Expected utility.

$$3 + 2.25 + 1.6 + 1.05 + 0.6 = 8.5 \tag{6}$$

At this time, the choices for Ken become clear. He can choose the maximum score which is the ice cream with Mango favor.

3.4. Limitations and Extensions

Expected Utility Theory (EUT), although widely used in several fields, faces a series of limitations One of the core assumptions of EUT is that individuals are able to process all relevant information completely rationally and make optimal decisions. However, this assumption does not always hold true, and cognitive biases and emotional factors play an important role in the decision-making process [13]. The Allais paradox is one of the limitations of EUT. It reveals that individuals often violate the independence axiom of EUT when making decisions [14]. Scholars such as Moscati revisited the Allais paradox in the context of behaviour economics, further pointing out the limitations of EUT in predicting the choices made by individuals in the real world. Prospect Theory proposed by Kahneman and Tversky as an important alternative model to EUT, which explains how individuals evaluate gains and losses when faced with them [16]. Many empirical studies have supported the predictions of Prospect Theory, especially in contexts involving loss aversion and risk-averse behaviour [17]. Loss aversion as described in prospect theory is more effective in explaining financial decision-making behaviour than EUT models [18]. Ellsberg's paradox likewise poses a significant challenge to EUT. This paradox highlights the phenomenon of fuzzy aversion, whereby individuals tend to prefer risks with known probabilities over risks with unknown probabilities, even though the potential loss of the latter may be higher [19]. Furthermore, decision makers, when faced with uncertainty, tend to prefer those options with known probabilities this questions the utility maximiation premise of EUT.

In the face of the limitations of expected utility theory (EUT), scholars have proposed a variety of extensions and alternative models, among which, Cumulative Prospect Theory (CPT) is one of the more influential extensions. CPT introduces the concept of cumulative probability weighting based

on the original prospect theory of Kahneman and Tversky. Barberis and Thaler utilised CPT to explain some anomalies in asset pricing, such as the long-standing equity premium puzzle. The study demonstrated the potential of CPT in explaining market behaviour and investor psychology. Meanwhile, Gul used CPT to model consumer preferences in uncertain environments, further confirming the effectiveness of CPT in describing the decision-making process of individuals in the face of uncertainty. These studies demonstrate the growing importance of CPT as a practical alternative model to EUT in both theoretical and empirical research [16].

In addition to CPT, Rank-Dependent Utility Theory (RDU) is an important theoretical extension. RDU corrects some of the deficiencies in traditional EUT by allowing probability weights to vary as outcomes are ranked. This theory argues that individual preferences for different outcomes depend not only on the utility of the outcome itself but are also influenced by the probability of the outcome occurring.

Despite the continuous emergence of new alternative models, expected utility theory (EUT) remains in the position of a foundational theory that is not only the cornerstone of understanding decision-making behaviour, but also serves as a frame of reference for evaluating and testing other theories. Bernheim and Rangel's research has further deepened the scope of application of EUT. The study explored how insights from behavioural economics can be integrated into EUT to create more sophisticated and accurate hybrid models. These hybrid models not only consider rational choices in traditional EUT, but also incorporate irrational elements of human behaviour found in behavioural economics, such as cognitive biases and emotional influences, thus improving the accuracy of the models in predicting real-world decision-making behaviour. With the development of computational models and advances in data analysis techniques, the application of EUT in dealing with complex decision-making scenarios has been significantly expanded. For example, in climate change policy formulation and financial risk management, EUT provides a powerful tool to help decision makers assess the potential impacts and consequences of different policies or strategies. These application scenarios usually involve large amounts of uncertainty and complex system dynamics, and the application of EUT can help decision makers better understand and manage these complexities.

In conclusion, EUT continues to play a central role in decision-making research as a fundamental and flexible theoretical tool. It not only provides a solid theoretical foundation for understanding human decision-making behaviour, but also demonstrates a strong potential for application in modern decision-making problems through its integration with other disciplines.

4. Critical Analysis

In assessing the literature reviewed, the author noted that the majority of the literature demonstrated high academic quality and significant relevance in exploring the application of expected utility theory to everyday decision-making. Through rigorous empirical studies, case studies, or theoretical explorations, this literature provides rich data support and insights for understanding the practical applications of expected utility theory. However, some of the studies have certain limitations in sample selection, data collection and analysis methods, such as insufficient sample size, single data source or insufficiently refined analysis methods, which may have affected the generalization and accuracy of the findings.

In addition, there is some controversy and disagreement between the views and conclusions of different authors. Some studies have found the expected utility theory to be highly applicable in explaining certain decision-making behaviors, while others have pointed out the limitations of the theory in explaining complex decision-making behaviors. This disagreement reflects the diversity of decision-making behaviors and the limitations of expected utility theory itself and suggests the need for flexibility in applying the theory to specific contexts

5. Future Research Directions

Although the existing literature has extensively explored the application of expected utility theory in daily decision making, there are still some research gaps. First, there are relatively few studies on the applicability of expected utility theory in different cultural contexts, and how the differences in individuals' perceptions of risk and uncertainty in different cultures affect decision-making behaviors is an issue that deserves in-depth investigation. Second, with the development of emerging technologies, such as artificial intelligence and big data, which are increasingly used in decision support systems, how to combine these technologies with expected utility theory to improve the science and efficiency of decision making is also an urgent research topic.

Future research can focus on the following aspects: first, deepening the research on the applicability of expected utility theory in different cultural contexts, revealing the mechanism of the influence of cultural factors on decision-making behaviors; second, exploring the application of emerging technologies in decision support systems, especially how to optimize the process of constructing and solving the expected utility model by using Big Data and Artificial Intelligence technologies; third, carrying out cross-disciplinary research to introduce the research results of psychology, neuroscience and other fields into the study of expected utility theory, in order to more comprehensively understand the intrinsic mechanism of decision-making behavior.

6. Conclusion

In summary, this paper focuses on the theme of "Case Studies on the Application of Expected Utility Theory in Daily Decision Making", and through systematically combing and analyzing the relevant literature, this paper has explored in depth the application of expected utility theory and its effectiveness in different fields and situations. The findings of this paper not only enrich the understanding of expected utility theory but also provide useful references and insights for subsequent studies. Through critical analyses, this paper points out the limitations of existing studies and possible future research directions and emphasize the importance of the need for flexibility in applying expected utility theory in relation to specific contexts. Finally, this paper reiterates the importance of the research question, that is, a deeper understanding of the application of expected utility theory in daily decision-making is important for improving the science and efficiency of decision-making. It is hoped that the findings of this paper can provide valuable references and lessons for researchers and practitioners in related fields.

References

[1] Von Neumann J, Morgenstern O. Theory of Games and Economic Behavior. Princeton University Press, 1944.

[2] Simon H A. A Behavioral Model of Rational Choice. The Quarterly Journal of Economics, 1955, 69(1): 99-118.

[3] Kahneman D, Tversky A. Prospect Theory: An Analysis of Decision under Risk. Econometrica, 1979, 47(2): 263-291.

[4] Gigerenzer G. Gut Feelings: The Intelligence of the Unconscious. Penguin UK, 2007.

[5] Gigerenzer G, Todd P M. Simple Heuristics That Make Us Smart. Oxford University Press, 1999.

[6] Hsee C K, Zhang J. General Evaluability Theory. Perspectives on Psychological Science, 2010, 5(4): 343-355.

[7] Knight F H. Risk, Uncertainty, and Profit. Houghton Mifflin Company, 1921.

[8] Arrow K J. Alternative Approaches to the Theory of Choice in Risk-Taking Situations. Econometrica, 1951, 19(4): 404-437.

[9] Tversky A, Kahneman D. Advances in Prospect Theory: Cumulative Representation of Uncertainty. Journal of Risk and Uncertainty, 1992, 5(4): 297-323.

[10] Allais M. Le comportement de l'homme rationnel devant le risque: Critique des postulats et axiomes de l'école américaine. Econometrica, 1953, 21(4): 503-546.

[11] Bleichrodt H, Wakker P P. Regret theory: A bold alternative to the rational decision-making model. Journal of Economic Theory, 2015, 160: 1-23.

[12] Zeelenberg M, Pieters R. Consequences of regret aversion in real life: The case of the Dutch postcode lottery. Organizational Behavior and Human Decision Processes, 2004, 93(2): 155-168.

[13] Bell D E, Loomes G. Decision regret and time variation in risk preferences. Management Science, 1988, 34(9): 1129-1133.

[14] Bernheim B D, Rangel A. Beyond revealed preference: Choice-theoretic foundations for behavioral welfare economics. The Quarterly Journal of Economics, 2009, 124(1): 51-104.

[15] Bleichrodt H, Pinto J L. A parameter-free elicitation of the utility for health states. Management Science, 2000, 46(10): 1485-1496.

[16] Gul F. A theory of disappointment aversion. Econometrica, 1991, 59(3): 667-686.

[17] Baillon A, et al. The effect of learning on ambiguity attitudes. Management Science, 2018, 64(5): 2181-2198.

[18] Gilboa I, Schmeidler D. Maxmin expected utility with non-unique prior. Journal of Mathematical Economics, 1989, 18(2): 141-153.

[19] Quiggin J. A theory of anticipated utility. Journal of Economic Behavior & Organization, 1982, 3(4): 323-343.

[20] Wakker P P. Prospect Theory: For Risk and Ambiguity. Cambridge University Press, 2010.

[21] Strzalecki T. Axiomatic foundations of multiplier preferences. Econometrica, 2011, 79(1): 47-73.

[22] Gollier C. Portfolio choices and asset prices: The comparative statics of ambiguity aversion. Review of Economic Studies, 2011, 78(4): 1329-1344.

[23] Farhi E, Gabaix X. Optimal taxation with behavioral agents. American Economic Review, 2020, 110(9): 2764-2817.

[24] Lemoine D. Escape from hot water? A simple theory of dynamic climate policy with multiple equilibria. American Economic Journal: Economic Policy, 2019, 11(4): 191-230.

[25] Bleichrodt H, Wakker P P. Regret theory: A bold alternative to the rational decision-making model. Journal of Economic Theory, 2015, 160: 1-23.