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UNRAVELING ECONOMIC CHOICES. A HISTORICAL PERSPECTIVE ON THE INTERSECTION OF DECISION SCIENCE AND BEHAVIORAL ECONOMICS

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ABSTRACT

This review looks at the development of decision science and behavioral economics, tracing the chronological progression of these disciplines and their symbiotic fusion in elucidating our comprehension of economic choices. It starts by discussing the limitations of traditional economic theories that assume rational and profit-maximizing behavior, highlighting the need for a more empirically anchored approach. The paper traces the development of decision theory amidst uncertainty, beginning with Blaise Pascal's notion of expected value, progressing to Daniel Bernoulli's expected utility, and later formalized by John von Neumann and Oskar Morgenstern. This journey culminates in the contributions of Daniel Kahneman and Amos Tversky, who introduced the concept of subjective expected utility. The paper acknowledges the inclusion of uncertainty surrounding delayed payoffs and discusses the role of cognitive biases and heuristics—mental shortcuts—in decision-making, showing how they affect our economic choices. The authors also show how these insights have been used in real-world settings, such as nudging, a technique used to subtly guide one's behavior.

KEYWORDS: Behavioral economics, Decision science, Prospect theory, Cognitive biases, Nudge theory

Behavioral economics provides a comprehensive framework for understanding economic decision-making by integrating findings from psychology, neuroscience, and microeconomic theory. It aims to present a more realistic depiction of human behavior compared to traditional economics which assumes flawless rationality and market efficiency.

The roots of behavioral economics can be traced back to Adam Smith, the author of influential work, "The Wealth of Nations" (1776), which assumes that humans are rational beings who prioritize their own interests. It acknowledges the presence of rational preferences and the pursuit of personal satisfaction (Ashraf, Camerer, and Loewenstein, 2005).

However, behavioral economics recognizes that human behavior often deviates from pure rationality due to cognitive biases and employing specific techniques of judgment making. It has gradually developed over several decades and has gained recognition as a distinct field more recently.

Contrary to classical economics, which often adopts a normative, idealistic, and abstract approach, behavioral economics presents a more descriptive, grounded view of real-world behaviors. It harnesses insights from psychology to elucidate the processes driving economic decision-making. By exploring elements such as irrational behavior, cognitive biases, and heuristics, behavioral economics strives to enhance decision-making via methods such as nudges and behavioral interventions. This focus on the mechanisms that underpin human rationality—or the frequent absence thereof—is particularly noteworthy and impactful.

Behavioral economics has grown hand in hand with decision science, a field that underpins its foundational principles. Decision science scrutinizes the decision-making processes of individuals, groups, and organizations, placing particular emphasis on decision-making under uncertainty—a common feature of real-world scenarios where perfect knowledge of outcomes is often beyond reach.

In this essay, we will trace the development of decision science concepts, underscoring their crucial role in comprehending and delineating the central tenets of behavioral economics.

EXPECTED VALUE

The expected value is a crucial concept in decision theory that has undergone gradual upgrades over the centuries. It is also one of the fundamental concepts in probability theory and statistics, used to predict the average outcome of an event over a large number of trials (Feller, 1971, chapter IX). It's the sum of the products of each outcome by its respective probability. For a given decision problem X determined by n possible outcomes x_i, having a probability of p_i, the expected value E(X) is calculated using the following formula [1]:

$$E(X) = \sum_{i=1}^{n} x_i p_i \qquad [1]$$

The concept of expected value emerged during the mid-17th century discussion over the problem known as the "problem of points." This problem aimed to find a fair method of dividing the stakes between two players who had to prematurely end their game. To tackle the problem, Blaise Pascal (1623-1662) engaged in a series of notable correspondence with Pierre de Fermat (1601-1665) (Devlin, 2008). A Dutch mathematician, Christiaan Huygens (1629-1695) presented in his 1657 book *De ratiociniis in ludo aleœ* a solution that was derived from the same principle as the solutions proposed by Pascal and Fermat. His approach is thoroughly discussed (Bernoulli 1713 chapter I section III). It is worth noting that the term "expected value" (and even term "probability") was not used by Pascal, Fermat, or Huygens, and its precise formulation was only presented in the beginning of the following century by Pierre Simon de Laplace (1749 - 1827) (Laplace 1814, chapter IV).

The famous argument known as "Pascal's Wager" (Pascal 1670, section III, 153-156)[1] is often cited as the first application of the concept of expected value in the problem of decision-making in conditions of uncertainty. The argument pertained to the question of the existence of God. Pascal maintained that belief in God is not a matter of rational certainty since it can neither be conclusively proven nor disproven. Nonetheless, he proposed that we confront a decision of profound consequences when it comes to faith. The existence of God either validates the possibility of eternal bliss in heaven or, in the absence of God, might result in no afterlife or potential negative consequences.

Pascal argued that when evaluating this decision, we should consider the expected value of each option. The expected value is calculated according to the formula presented above.

In the case of belief in God, Pascal suggested that we assign values to the potential outcomes based on their infinite nature. He stated that the value of eternal happiness in heaven is infinitely positive, while the value of eternal damnation or oblivion is negative. On the other hand, the value of temporary pleasures or liberties in a godless existence is finite, as it only pertains to our earthly life.

Considering these values, Pascal argued that even if the probability of God's existence is extremely low (but greater than zero) the expected value of believing in God is still infinitely positive. In other words, the potential benefit of gaining eternal happiness outweighs any temporary sacrifices or limitations that may come with belief.

Conversely, if we choose not to believe in God and live as if God doesn't exist, the expected value of this option is finite or neutral. We may enjoy

[1] The page numbers mentioned correspond to the English translation.

temporary pleasures in this life, but we risk missing out on the infinite rewards of a divine existence if God does indeed exist.

Therefore, Pascal's Wager suggests that it is more rational to believe in God because the expected value of belief is infinitely positive, while the expected value of disbelief is finite positive at best. It encourages us to consider the potential consequences of our beliefs and to prioritize the potential infinite rewards over finite earthly gains (Jordan, 2006).

Expected value of a game was used as the fundamental criterion for assessing the relative benefits of different available games. In the case of a given game, any price lower than the expected value is considered a worthwhile investment. The player should be indifferent between participating in the game or receiving an amount equal to its expected value without playing.

However, this approach proved to be problematic, giving rise to paradoxes, the most well-known being the St. Petersburg paradox (Dutka, 1988; Göttinger, 1972). Formulated in 1713 by Nicolas Bernoulli (1687-1759) in a letter to Pierre Raymond de Montmort, the St. Petersburg paradox presents a thought experiment involving a game with the possibility of an infinite payoff.

Imagine a game where you pay an entry fee to participate, and a fair coin is tossed repeatedly until it lands on tails. The number of tosses determines the payout, which doubles with each toss. For example, if the coin lands on tails on the first toss, you receive $2 (and the game ends). If it lands on tails only on the second toss, you receive $4. If it lands on tails on the third toss, you receive $8, and so on.

The paradox arises when considering the expected value of the game, calculated by multiplying the payoff of each possible outcome by its probability and summing up these values. In this case, since the coin is fair, the probability of getting tails on the k^{th} toss is 1/2^k.

Through the computation of the infinite series and the evaluation of the game's expected value, it becomes evident that the sum diverges to infinity. In accordance with the expected value rule, a rational player would seemingly be inclined to invest any amount of money in order to participate, as it would always result in a positive outcome. However, this theoretical deduction sharply contradicts empirical evidence.

There have been many attempts to solve this paradox (Dutka, 1988), but the one proposed by Daniel Bernoulli is the most significant for us.

THE BERNOULLI THEORY OF EXPECTED UTILITY

Daniel Bernoulli (1700-1782) argued that individuals do not make decisions based solely on expected values objectively expressed in terms of money.

Instead of the expected value, he introduced the concept of expected utility, which accounts for the subjective value or utility an individual assigns to different outcomes (Niels, 1967; Adams, 1960; Göttinger, 1972).

According to Bernoulli, individuals derive utility from wealth or monetary outcomes, and the additional utility gained from each additional dollar diminishes as wealth increases. In other words, the subjective value or satisfaction (utility) gained from each additional dollar decreases.

Considering diminishing marginal utility, Bernoulli proposed that individuals evaluate prospects not in terms of their expected monetary value but rather in terms of their expected utility. He argued that the utility gained from the potential high payoffs in the St. Petersburg paradox game would eventually reach a point of diminishing returns, limiting the individual's willingness to pay a high entry fee. In this context, even though the expected value of the game is infinite, individuals may not be willing to pay any price to enter it due to diminishing marginal utility. Their preferences and decision-making are shaped by the subjective experience of utility rather than the objective expected value.

The process of calculating expected utility is similar to that of expected value. However, instead of solely focusing on the outcomes themselves, we take into account the utility associated with those outcomes. Utility reflects an individual's personal preference or satisfaction with a specific outcome.

Suppose a decision problem X is determined by n possible outcomes x_i each having corresponding utilities $u(x_i)$ and probabilities of p_i, then the expected utility $U(X)$ is given by the formula [2]:

$$U(X) = \sum_{i=1}^{n} u(x_i) p_i \qquad [2]$$

It should be noted that the expected utility theory signifies an advancement over the simple expected value calculation. This evolution recognizes Bernoulli's insight that individuals strive to maximize their utility, or satisfaction, rather than just the nominal payout values.

As Bernoulli noticed (Bernoulli, 1738 p. 24):

> ... it seems clear that all men cannot use the same rule to evaluate the gamble ... the determination of the value of an item must not be based on its price, but rather on the utility it yields. The price of the item is dependent only on the thing itself and is equal for everyone; the utility, however, is dependent on the particular circumstances of the person making the estimate.

The St. Petersburg paradox, as viewed through Bernoulli's lens of expected utility, emphasizes that individuals' choices and willingness to take risks are influenced by their personal utility functions, which capture their subjective values and attitudes toward wealth and potential outcomes.

It was revealed that the principle of diminishing marginal returns leads to expressing utility in the form of a logarithmic function for a given amount of money. In the St. Petersburg paradox, instead of considering monetary amounts directly, we calculate utility by taking the logarithms of these amounts, which results in a finite sum of the series.

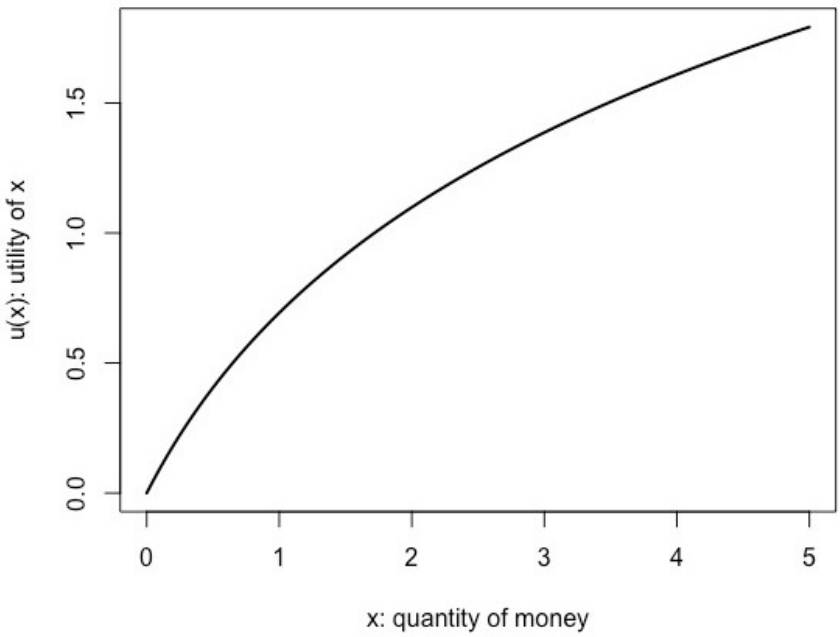

Fig. 1 Concave utility function proposed by Daniel Bernoulli.

Bernoulli's ideas have had their fair share of criticism (Jensen, 1965; Tversky, 1975). The critics pointed out that the logarithmic function doesn't completely solve the St. Petersburg paradox. They argue that even with the logarithmic function, you can still come up with versions of the paradox where the utility turns out to be infinite. Another criticism is that Bernoulli's theory doesn't explain why people willingly engage in games or activities with a negative expected value, like paying for insurance instead of just avoiding it altogether.

However, it is important to acknowledge the significant contributions of

Bernoulli's theory. It brought about a major shift in the field of economics by introducing the concept of expected utility and providing insights into diminishing marginal utility and risk aversion. While it is true that Bernoulli's theory is not without its imperfections, it served as a crucial foundation for further advancements in economic theories.

JEREMY BENTHAM: PHILOSOPHICAL ANALYSIS OF UTILITY

Jeremy Bentham (1748-1832) emphasized the importance of utility, which he defined as the measure of pleasure or happiness derived from an action or outcome. The philosopher argued that the fundamental goal of ethical and economic decision-making should be to maximize overall societal utility. He proposed a quantitative approach to utility, advocating for its measurement (Bentham, 1781; Read, 2007).

Bentham's philosophical lens often falls within the realm of hedonistic utilitarianism, an intellectual tradition where the notion of utility is deeply entwined with the pursuit of pleasure and the evasion of pain.

To provide a method of assessing this utility, Bentham introduced a concept known as the "felicific calculus."

This calculus is an attempt to quantify happiness by assessing several variables:

- Intensity – gauges the power of the pleasure or pain at hand.
- Duration – captures the span of time for which the pleasure or pain persists.
- Certainty or uncertainty – considers the likelihood that the anticipated pleasure or pain will indeed come to pass.
- Propinquity or remoteness – estimates the temporal proximity of the impending pleasure or pain.
- Fecundity – evaluates the probability of recurrence for sensations identical to the initial experience.
- Purity – measures the chance that the original sensation won't be succeeded by its opposite.
- Extent – assesses the scope of the action's impact – the number of individuals likely to be affected by it.

By scrutinizing these variables, Bentham sought to transform the inherently subjective experience of happiness and suffering into an objective calculus, thereby providing a framework for maximizing overall happiness in society.

JOHN VON NEUMANN AND OSKAR MORGENSTERN: RATIONAL DECISION-MAKING

Following Daniel Bernoulli's initiation of expected utility theory, the concept underwent significant evolution and refinement. While Bentham was concerned with societal well-being, other theorists typically focused on individual decision-makers. It's crucial to note that Bernoulli's notion of utility does not hinge on any presupposed hypotheses regarding human behavior or the principle of rational decision-making. His introduction of the logarithmic function was not inherently tied to the concept of probability or hypotheses about human responses under risky conditions. This void was filled by John von Neumann (1903-1957) and Oskar Morgenstern (1902-1977), who established the basis for a novel concept of utility grounded on axioms delineating how a rational individual should react when confronted with risky decisions.

In 1944, they published their groundbreaking work, "Theory of Games and Economic Behavior" (von Neumann and Morgenstern, 1944), which introduced the concept of expected utility and presented a rigorous mathematical framework for analyzing decision-making under uncertainty. The authors posited that individuals strive to maximize expected utility when confronted with decisions that involve uncertain outcomes.

The proposed axioms can be summarized as follows:

Completeness: It is possible to compare any two outcomes. This means that for any two choices, one can determine whether they prefer one to the other or are indifferent to them.

Transitivity: Preferences remain consistent across different choices. If one prefers Outcome A to Outcome B and prefers Outcome B to Outcome C, then they should also prefer Outcome A to Outcome C.

Continuity: If an individual has a preference for Outcome A over Outcome B, then there exists a specific probability p such that they are indifferent between a lottery that offers A with probability p and B with probability (1-p), and getting B for certain. Essentially, there's a certain mix of A and B that is just as preferable as B alone.

Independence (or substitution): If a person prefers A to B, then they should prefer lottery with outcomes A and C to lottery with outcomes B and C whenever the chance of winning A is in both lotteries equal to the chance of winning B.

As von Neumann and Morgenstern demonstrated, based on the preferences of an individual satisfying these axioms, a utility function characterizing that individual can be derived. This function assigns numerical values in such a way that whenever the decision-maker prefers option *s* over option *t*, the number assigned to *s* is greater than the number assigned to *t*. The utility function is dependent on the probabilities of different possibilities.

Indeed, the theory faces a significant challenge as numerous experiments have consistently revealed discrepancies between people's choices and behaviors and the predictions of expected utility theory. In light of these findings, the upcoming discussion will delve into paradoxes that highlight specific situations where an individuals' decision-making deviates from the expected utility theory's forecasts, consequently raising questions about the assumption of rationality.

THE ALLAIS PARADOX

The paradox, proposed by Maurice Allais in 1953, presents a thought-provoking challenge to the principles of expected utility theory. This paradox exposes inconsistencies in decision-making that contradict the assumptions and predictions of expected utility theory. The Allais Paradox presents individuals with choices involving two sets of lotteries, designed to test their risk preferences.

Imagine you're asked to choose between the following two options, each representing a lottery:

The lottery nr 1
Option A:
A guaranteed win of $1 million.
Option B:
A 10% chance to win $5 million,
An 89% chance to win $1 million,
A 1% chance to win nothing.

The majority of individuals tend to opt for option A, even though option B has a higher expected utility (which refers to the average payout over multiple instances). This behavior can be attributed to the perception that the assurance of winning something in option A holds greater value compared to the slightly higher average payout but accompanied by higher risk in option B. This decision aligns with expected utility theory and is not the paradoxical part.

Now, we have
The lottery nr 2
Option C:
An 11% chance to win $1 million,
An 89% chance to win nothing.
Option D:

A 10% chance to win $5 million,
A 90% chance to win nothing.

In the Allais paradox, individuals tend to choose D over C, which contradicts the principle of expected utility theory if they had previously chosen A over B.

Empirical research conducted by Allais has provided compelling evidence that individuals who previously preferred A over B are unwilling to select option D over option C.

But in both lotteries the player receives a fixed amount with a probability of 89%: $1 million in lottery 1 and nothing in lottery 2. According to expected utility theory, such a fixed amount should not affect the choice between lotteries. After excluding this amount, the remaining 11% in both experiments represents the same lottery, in which one can win $5 million with a probability of 10% and nothing with a probability of 1%. Therefore, according to the independence axiom of von Neumann and Morgenstern's expected utility theory, if an individual favors option A over option B, they should also favor option C over option D. This is because both pairs involve a similar trade-off: a certain gain versus a risky yet potentially larger gain. Consequently, the research demonstrates a violation of this axiom, as individuals' preferences shift when an irrelevant alternative (option C) is introduced, resulting in inconsistent decision-making.

The Allais paradox epitomizes this inconsistency, highlighting that people's choices can be influenced by how options are presented, and that the expected utility theory does not consistently predict individuals' behavior. This paradox underscores the limitations of the theory and emphasizes the significance of considering framing effects in decision-making processes.

The Allais Paradox suggests that individuals may exhibit risk aversion in some contexts but violate this preference in others when faced with different framing or presentation of the options. It demonstrates that decision-making is influenced not only by the objective probabilities and outcomes but also by subjective factors, such as how the options are framed or the context in which they are presented. The paradox challenges the principle of independence of irrelevant alternatives, one of expected utility theory axioms. According to this principle, the addition of a third, irrelevant option should not impact individuals' choices between two other options. However, individuals' preference reversal in the Allais paradox contradicts this assumption (Allais and Hagen, 2013).

THE ELLSBERG PARADOX

The paradox, proposed by Daniel Ellsberg (1961), illustrated how people behave when they are faced with uncertainty versus known risks.

You're presented with two urns. Urn A contains 30 red balls and 60 balls that are either black or yellow, in an unknown proportion. Urn B contains 90 balls: red, black, or yellow, also in an unknown proportion.

You're given two choices for betting:
Bet 1: Choosing a red ball vs. a black ball from Urn A
Bet 2: Choosing a red or black ball vs. a yellow ball from Urn B

The paradox is that when asked to choose, most people prefer betting on red from Urn A (where the odds of drawing a red are known to be 1/3), rather than black (where the odds are uncertain). However, when presented with Bet 2, people often choose yellow from Urn B (where the odds are uncertain), rather than red or black (where the odds are known to be 2/3).

The Ellsberg paradox challenges the completeness axiom. The completeness axiom posits that for any two gambles an individual can always specify a preference for one over the other, or express indifference. But in the Ellsberg paradox, individuals exhibit ambiguity aversion, preferring known risks to unknown ones, showing that they are not indifferent even though, according to the expected utility theory, they should be. This suggests that the Completeness axiom doesn't always hold when ambiguity is present. Your decisions should be consistent; that is, if you believe there's a higher chance of drawing a red ball from Urn A than Urn B, you should also believe there's a higher chance of drawing a black ball from Urn B than Urn A. However, most people prefer to draw from Urn B for both bets.

The reason for this preference is that Urn B's distribution is known, while Urn A's distribution is ambiguous. This is what we call "ambiguity aversion". Despite the probabilities being objectively the same, the lack of knowledge or ambiguity in Urn A causes people to behave irrationally, according to classical economic theory (Ellsberg, 1961).

In decision-making theories influenced by von Neumann and Morgenstern, it is assumed that decision-makers exhibit rational behavior. Upon the revelation of the Allais and Ellsberg paradoxes, the theory posited by von Neumann and Morgenstern appeared incomplete, or even potentially misrepresenting the actual process of decision-making (Gilboa, 2009). In this context, Herbert Simon's concept of bounded rationality gained prominence.

HERBERT SIMON'S BOUNDED RATIONALITY

Herbert Simon (1982) introduced the concept of bounded rationality as a contrasting perspective to the notion of *homo economicus*. Simon argued that individuals face cognitive limitations and employ information processing methods that deviate from absolute rationality. He emphasized that decision-makers are constrained by factors such as time limitations, limited cognitive capacity, and the complexity of the decision-making context. Rather than aiming for optimal solutions, individuals tend to satisfice, which means they choose alternatives that are "good enough" to meet their goals within the given constraints. Decision-making is driven by satisficing rather than optimizing. Due to limitations in time and information, individuals engage in a limited search process, considering a subset of all available options. This bounded search helps manage cognitive load and facilitates decision-making. Bounded rationality is about understanding that people use quick strategies, like mental shortcuts or "rules of thumb," to make decisions. Simon recognizes that we do not exhaustively analyze every single option in intricate detail. Instead, we employ strategies that allow us to make reasonably good choices efficiently.

In the upcoming chapters, we will explore the research conducted by Daniel Kahneman and Amos Tversky. Initially, Kahneman and Tversky brought attention to the significant role of mental shortcuts, or heuristics, in our decision-making processes. These heuristics serve to simplify complex decisions, but they can also lead to systematic errors, particularly when faced with uncertainty. Furthermore, Kahneman and Tversky observed that the structure or presentation of a decision problem, known as framing effects, can exert a significant influence on the choices individuals make. Lastly, they introduced the prospect theory, which provides a descriptive framework for understanding decision-making under conditions of risk. This theory highlights how our choices are shaped by our current circumstances and reference points.

HEURISTICS

Kahneman and Tversky examined the mechanics of information processing in humans, shining a spotlight on the identification of heuristics and biases.

Heuristics are mental shortcuts or "rules of thumb" that simplify complex decision-making processes. They allow individuals to make decisions quickly and efficiently, which can be especially useful in complex or time-sensitive situations. However, while heuristics can facilitate decision-making, they can also lead to systematic errors because they involve simplification. Heuristics come into play when individuals solve problems by relying on cues that have only indirect connection to the problem at hand. These cues enable a quick resolution of the problem with a minimal cognitive effort. As a consequence, the resulting solution is fast and effortless yet often imperfect.

Heuristics may lead individuals to make irrational decisions, form incorrect judgments.

Biases can be divided into five categories.
(1) The illusion of validity and overconfidence.
(2) WYSIATI (What You See Is All There Is).
(3) The misperception of randomness.
(4) The misperception of probability.
(5) The influence of context.

(1) The illusion of validity occurs when people believe that their judgments and predictions are more accurate and reliable than they actually are (Fischhoff et al., 1977). This bias arises because humans have a natural inclination to create coherent and meaningful narratives based on available information, even when the information is sparse or ambiguous. The illusion of validity is related to other cognitive biases, such as an overconfidence bias and a confirmation bias. The overconfidence bias refers to the tendency to overestimate one's own knowledge or skills, while the confirmation bias refers to the inclination to seek and interpret information that confirms preexisting beliefs or expectations. Overconfidence can result in taking on unnecessary risks, underestimating the likelihood of negative outcomes, and dismissing contradictory information or feedback. Confirmation bias refers to the cognitive tendency to seek out information that coheres with one's preexisting beliefs or hypotheses. It operates akin to a selective filter, potentially disregarding alternative evidence and viewpoints.

(2) WYSIATI (What You See Is All There Is) is a term coined by Daniel Kahneman in his book "Thinking, Fast and Slow". It describes a cognitive bias of making judgments based only on the information readily available to them, without considering the larger context. Humans have a tendency to rely on the information that is most easily accessible or salient in their minds. Our thinking is often influenced by what is immediately present and noticeable, rather than seeking out a more comprehensive and accurate understanding of a situation (Kahneman, 2011). Customers tend to make purchasing decisions based on immediate, visible factors such as product aesthetics and celebrity endorsements, rather than delving into less apparent details like technical specifications or product performance. This behavior underscores their reliance on readily available information over potentially more signifi-

cant, but less obvious, factors.

(3) The misperception of randomness refers to a difficulty of accepting the truly random nature of events. Instead, people tend to see patterns, order, or meaning in random or unpredictable sequences, attributing significance or causality where none exists. Our brains are wired to detect and make sense of patterns, which can sometimes lead us to perceive order or intention where none actually exists. The misperception of randomness can manifest in various ways. For example, individuals may see meaningful coincidences or attribute cause and effect relationships to random events (Kahneman and Tversky, 1971). The misperception of randomness refers also to people's tendency to expect random sequences to look "more random" than they actually are.

(4) Humans are poor at accurately perceiving risks and neglect probability when making decisions under uncertainty. This is often exhibited in how people overestimate the likelihood of sensational, memorable events (like plane crashes or shark attacks) while underestimating more common, mundane risks (like car accidents) (Kahneman and Tversky, 1971).

(5) Our judgments, decisions, or perceptions are influenced by the context in which they occur. The anchoring bias occurs when individuals rely heavily on the initial piece of information presented to them when making judgments or estimates. The context of the anchor can influence subsequent decisions, as people tend to adjust their judgments based on the initial reference point. In one of classic experiments, participants were asked to estimate a value (like the percentage of African nations in the United Nations), but only after being shown a random number between 0 and 100. Despite the random number having no relation to the question, participants' estimates were heavily influenced by it, showing the power of an anchor (Kahneman and Tversky, 1974).

The very way information is presented can significantly impact our decisions. People may respond differently to the same information depending on whether it is presented positively or negatively, as gains or losses. The effect is called framing.

FRAMING

The phenomenon of framing pertains to how the presentation of choices can influence decision-making and behavior (Tversky and Kahneman, 1981). It explores how the same information, when presented in different ways, can yield diverse preferences and judgments.

Framing influences both perception and subsequent decision-making. It encompasses various aspects such as the wording, context, emphasis, order or reference points used in presenting choices.

We recognize three distinct variations of the framing effect (Levin et al., 1998):

a) Gain-loss framing. The prospect theory, to be explored further, examines how individuals' risk preferences can be influenced by the possibility of gains or losses. The way choices are presented can significantly impact people's attitudes towards risk. When decisions involve potential gains, individuals tend to favor safer options and avoid risks. On the other hand, when the same decisions are framed in terms of potential losses, people become more inclined to take a gamble.

b) Attribute framing. Emphasizing specific features or dimensions, can influence individuals' preferences. Highlighting positive attributes can make options more appealing, while emphasizing negative attributes can lead to aversion or rejection of choices.

c) Goal framing. Specific goals can influence individuals' motivation, effort, and willingness to take action. The goal framing involves presenting the positive consequences of task completion or the negative outcomes resulting from its omission.

Kahneman and Tversky proceeded to consolidate various research findings to create a theory known as "prospect theory." This theory describes how people make decisions when faced with uncertainty and emphasizes the impact of the status quo and reference points on preferences.

THE PROSPECT THEORY

So far, the argument has been revolving around two distinct but interconnected concepts. The first concept examines the nature of utility, and the second concept delves into the theme of rationality, looking at its limitations and the aspects that shape the decision-making process.

Daniel Kahneman and Amos Tversky integrated these concepts within the framework of prospect theory. Unlike traditional normative economic theories that prescribe how people should ideally behave, prospect theory takes a descriptive approach, aiming to explain how people actually behave when faced with uncertainty (Kahneman and Tversky, 1979).

Similar to the notions of expected value and expected utility, prospect theory encompasses the shape of the utility function and individuals' perception of probability. Kahneman and Tversky demonstrated that the utility function follows an S-shaped pattern.

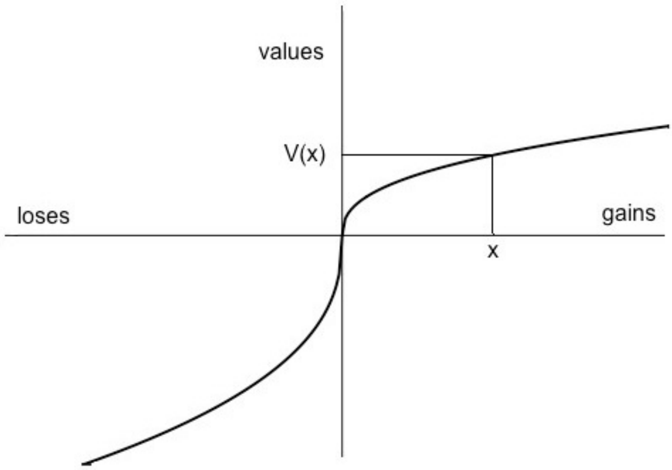

Fig. 2 S-shaped value function proposed by Daniel Kahneman and Amos Tversky (1979).

The steepest ascent of the S-shaped curve, found in the negative range, indicates that the distress caused by losses generally outweighs the satisfaction derived from equivalent gains. For instance, the disappointment experienced from losing $100 is typically more intense than the pleasure gained from acquiring the same amount. This aspect of the utility function explains why individuals are often more motivated to avoid losses rather than pursue gains of equal value.

The S-shaped curve incorporates a reference point, often aligned with one's current state. This implies that people assess potential gains and losses in relation to this reference point, rather than in absolute terms. The shape of the function transitions from concave for gains to convex for losses at this reference point, capturing the shift in risk preferences for potential gains (displaying risk aversion) and losses (demonstrating risk-seeking behavior).

Unlike previous studies on decision-making under uncertainty, Kahneman and Tversky noticed that individuals demonstrate biases not only when evaluating pay-offs but also when assessing probabilities. When making decisions, individuals tend to assign greater weight to small probabilities than their objective probabilities suggest. This means that people perceive small probabilities to be larger than they actually are. For example, they may overestimate the likelihood of winning a lottery or the probability of rare events occurring. Conversely, people tend to assign lower weights to large probabilities compared to their objective probabilities. This means that individuals perceive large probabilities to be smaller or less significant than they actually are. For example, people may underestimate the effectiveness of medical interventions (Wakker, 2010).

Suppose a decision problem X has possible n outcomes x_i with value function $V(x_i)$ and respective probabilities of p_i, then the expected subjective expected utility is given by the formula [3]:

$$SEU(X) = \sum_{i=1}^{n} V(x_i)w(p_i) \qquad [3]$$

The above formula represents another fundamental modification of the formula initially proposed by Pascal as expected value.

MENTAL ACCOUNTING

Interestingly, individuals don't perceive all money as being equivalent. There are specific cognitive mechanisms that people use to categorize, assess, and monitor their financial transactions and behaviors. Mental accounting, a concept introduced by Richard Thaler (1985, 2015) highlighted how individuals categorize and allocate their financial resources. According to Thaler, people create separate mental accounts for different aspects of their financial lives, such as savings, expenses, investments, and leisure activities. Each mental account is treated as a separate entity, and individuals tend to evaluate their financial decisions and outcomes within the context of these accounts. This cognitive process do not align with traditional economic theory that assumes people behave rationally and are seeking to maximize utility. Mental accounting may manifest in situations where people make irrational financial decisions. For example, people are able to keep significant savings in a low-interest bank account while simultaneously taking out a high-interest loan, as long as the savings are intended for a different purpose than the funds from the loan.

THE DUAL SYSTEMS OF INFORMATION PROCESSING

At a certain point, the division between rational and irrational judgments and choices took on a new form. The notion of dual cognitive systems, termed as System 1 and System 2, emerged and was widely disseminated through Daniel Kahneman's 2011 book, *Thinking, Fast and Slow* (Kahneman, 2011). System 1 refers to the rapid and instinctive mode of information processing. It functions effortlessly and automatically, without demanding significant conscious control or effort. System 1 relies on heuristics, associative memory, and pattern recognition to swiftly generate responses or judgments. On the other hand, System 2 involves slower and deliberate information processing. It requires conscious attention and mental resources to engage in complex problem-solving, logical reasoning, and conscious decision-making. System 2 is characterized by effortful thinking and is often employed when encountering novel or challenging situations.

The origins of this theory can be traced back to earlier research. The concept of dual cognitive systems can be traced back to ancient philosophical traditions, such as Plato's division of the soul into rational and irrational parts. The seeds of these ideas can be traced back to William James, who hinted at different modes of thinking (James, 1890). However, it was in the 20th century that systematic investigations into the dual nature of human cognition began. The theory was expanded by the works of Jonathan Evans and Keith Stanovich, who emphasized that the intuitive system (System 1) is heuristics-based and often leads to biases, while the reflective system (System 2) is rule-based and associated with rational thinking (Evans and Stanovich, 2013).

TIME DISCOUNTING

The preceding discussion in this article has been founded on the underlying assumption that payoffs are realized immediately following the decision-maker's choice. In the real world, payoffs are almost always delayed relative to the decision being made. The process of discounting delayed payoffs has posed a significant challenge for economists from both the classical and behavioral schools.

Exponential discounting is the traditional model of discounting, first formalized by Samuelson (1937). It proposes a constant discount rate over time, meaning that the perceived value of a future reward decreases at a steady rate as the delay to that reward increases. This model has the appealing property of time consistency, meaning that the relative valuation of two future rewards does not change over time. For example, if you prefer a reward one year from now to a reward two years from now, you'll also prefer a reward five years from now to a reward six years from now. The unique property of exponential discounting, which generates time-consistent preferences, has been consistently proven incorrect. Individuals generally have a preference for immediate gratification, seeking immediate pleasure and postponing unpleasant experiences as much as possible (Rabin, 2002).

System 1 operates in an automatic manner, displaying a propensity to prioritize immediate rewards. Our intuitive thinking prompts us to favor instant gratification, leading us to select immediate rewards instead of delayed ones.

In contrast, System 2 engages in more deliberate cognitive processes. By employing System 2, we augment our capacity to make decisions that prioritize long-term benefits over immediate rewards. Frequently, a conflict arises between these two systems. While System 1 may urge us to opt for the smaller, immediate reward (such as indulging in a tempting dessert), System 2 recognizes that exercising patience for a larger, delayed reward would be more advantageous in the long run (such as adhering to a healthy diet for the sake of future well-being) (Loewenstein and O'Donoghue, 2004).

Hyperbolic discounting was developed as a response to empirical evidence suggesting that the exponential model didn't fully capture human behavior. People tend to display a decreasing discount rate over time, which is a phenomenon known as temporal discounting. This was empirically observed by a psychophysicist Richard Herrnstein in the 1960s and later developed by others in the late 1980s and 1990s. In a hyperbolic discounting model, people value future rewards much less compared to immediate rewards, but the perceived value of future rewards decreases more slowly as the delay increases. This leads to time inconsistency, where the relative value of two future rewards changes over time. For example, you might prefer $100 today over $110 tomorrow (a high discount rate), but also prefer $110 in 31 days over $100 in 30 days (a lower discount rate). Hyperbolic discounting has been used to model various economic behaviors, such as why people procrastinate or why they tend to save less than they plan to. It's also been used to explain addiction and other impulsive behaviors (O'Donoghue and Rabin, 1999).

NUDGE

In recent years, the "nudge" concept has emerged as the most commonly applied practical usage of behavioral economics. This term pertains to the deployment of gentle, non-imposing strategies to sway people's actions and aid them in making superior decisions. Nudges aim to exploit the predictable tendencies that typically guide human decision-making. With minor modifications to how options are laid out, or by sharing relevant information at the right moment, the goal of nudges is to subtly direct individuals towards choices that serve their best interest. Nudges function by engaging System 1 processing, making the preferred choice effortless and intuitive. By enhancing the immediacy of the long-term advantages of a decision or emphasizing the potential risk, individuals can be nudged towards choices that offer better outcomes in the long term. The "Save More Tomorrow" initiative provides an illustrative example, as it motivates individuals to pledge to escalate their savings rate in the future (upon receiving a salary increase), thereby harnessing present bias for future benefits.

The concept of a "nudge," introduced and popularized by Richard H. Thaler and Cass R. Sunstein (2009), does not constitute a new theory but rather a proposal for the practical application of existing tools and principles of behavioral economics in social practice.

The authors highlight methods for non-intrusive, subtle influence on people's behavior and decisions. Nudges are interventions that gently steer individuals towards making certain choices without removing their freedom of choice. These interventions often rely on behavioral insights and take advantage of cognitive biases, heuristics and social influences to guide decision-making in a particular direction. Nudges operate through the manipulation of choice architecture, the design of the decision-making environment. Altering the way options are presented, the default choice or the information provided can significantly influence individuals' choices. Nudges aim to make desirable behaviors more salient, accessible and easier to adopt while maintaining individuals' freedom of choice.

One prominent nudge technique is altering default options. The default option refers to the pre-selected choice or course of action that individuals are automatically enrolled in or assigned to if they do not actively make a different choice. The default option is designed to influence behavior by leveraging the human tendency to stick with the default or defaulting to the path of least resistance. Research by Johnson and Goldstein (2003) demonstrated that changing the default organ donation policy from opt-in to opt-out significantly increased organ donation rates. Social norms have also been effectively employed as nudges. Cialdini et al. (2006) found that providing individuals with information about the energy-saving behaviors of their neighbors resulted in greater energy conservation efforts. Feedback and information provision have been successful nudges too. Providing individuals with real-time energy consumption data, as shown in studies by Darby (2006) and Farrow et al. (2018), led to heightened awareness and reductions in energy usage.

While nudges are intended to improve decision-making and promote positive behaviors, ethical considerations arise. Critics argue that nudges may be manipulative, infringe on individuals' autonomy or be used to promote the interests of a selected few. It is crucial to apply nudges responsibly, transparently, and with respect for individuals' freedom of choice.

Even if nudges partially infringe on the freedom of choice, they do so to a lesser extent than other methods.

DISCUSSION

We emphasize that the evolution of decision theory, culminating in the emergence of behavioral economics, can be seen as a journey. It begins with expected value theory, moves through expected utility theory and ultimately arrives at the concept of expected subjective utility. Expected value paved the way for quantitative decision-making under uncertainty. It estimates the potential worth of an uncertain outcome by multiplying each possible result by its likelihood and aggregating these. Predominantly based on objective probabilities, this method presumes that decision-making is driven solely by the maximization of monetary outcomes. Although straightforward, expected value computations are still prevalent in areas like gambling and risk assessment. However, the St. Petersburg paradox brought to light that individuals might lean on a different decision-making formula. This insight gave rise to the concept of expected utility, which posits that decisions are influenced more by individual subjective utility functions than by monetary values alone. In this context, 'utility' signifies the satisfaction or value that an individual ascribes to varying outcomes. Therefore, expected utility theory suggests that decision-making revolves around maximizing expected utility rather than merely monetary value. Yet, experiments by Allais and subsequently by Ellsberg, revealed that even expected utility theory fell short in fully explaining decision-making under risk. As a result, the subjective expected utility concept came into play. It advances expected utility theory by incorporating personal beliefs and systematic probability distortions, represented by a probability weighting function.

The intersection of decision science and behavioral economics has significantly contributed to our present understanding of economic choices. Decision science has provided robust methodological tools and theoretical frameworks to help decipher the patterns of decision-making. On the other hand, behavioral economics has offered empirical evidence challenging traditional economic models of rational choice, instead emphasizing the role of cognitive biases and heuristics in decision-making.

Behavioral insights have influenced policy designs through the concept of a 'nudge,' suggesting subtle changes to the decision-making environment can significantly alter choices.

Looking forward, the intersection of decision science and behavioral economics is set to be significantly influenced by the rise of artificial intelligence and its associated technologies.

AI's ability to process large amounts of personal data could enable more personalized economic interventions. For instance, 'nudge' strategies could be tailored to individual decision-making patterns, thus improving their effectiveness.

However, the integration of AI poses new challenges. If AI systems are trained on biased data, they could potentially perpetuate or exacerbate these biases in economic predictions. Therefore, a critical area of future research would be to ensure fairness and bias mitigation in AI-driven economic modeling.

BIBLIOGRAPHY

Adams, E.W. 1960. "Survey of Bernoullian Utility Theory." In *Mathematical Thinking in the Measurement of Behavior*. Solomon, H. (ed.) 1960. Glencoe: 153—268.

Allais, M. 1953. "Le comportement de l'homme rationnel devant le risque: critique des postulats et axiomes de l'école américaine." *Econometrica: Journal of the Econometric Society*: 503-546.

Allais, M. and Hagen, G.M. (eds.) 2013. *Expected utility hypotheses and the Allais paradox: Contemporary discussions of the decisions under uncertainty with Allais' rejoinder* (Vol. 21). Springer Science & Business Media.

Ashraf, N., Camerer C.F., and George L. 2005. "Adam Smith, Behavioral Economist." *Journal of Economic Perspectives,* 19 (3): 131-145.

Bell, D. E., Raiffa, H., and Tversky, A. (eds.) 1988. *Decision making: Descriptive, normative, and prescriptive interactions*. Cambridge: Cambridge University Press.

Bentham, J. 1781. *An Introduction to the Principles of Morals and Legislation*. Online: https://historyofeconomicthought.mcmaster.ca/bentham/morals.pdf

Bernoulli, D. 1738. *Speciemen theoriae novae de mensura sortis. Commentarié academiae scientiarum imperialis Petropolitanae, 5*. English translation 1954, "Exposition of a New Theory on the Measurement of Risk" *Econometrica*, 22(1): 23–36.

Bernoulli, J.. 1713. *Ars conjectandi Jacobi Bernoulli ... Ars conjectandi : opus posthumum : accedit Tractatus de seriebus infinitis, et Epistola Gallicè scripta de ludo pilae reticularis*. Basileae: Impensis Thurnisiorum, fratrum. English translation by E.D. Sylla 2004. *The Art of Conjecturing.* The John Hopkins University Press.

Cialdini, R. B., Reno, R. R., and Kallgren, C. A. 2006. "A focus theory of normative conduct: Recycling the concept of norms to reduce littering in public places." *Journal of Personality and Social Psychology*, 58(6): 1015-1026.

Darby, S. 2006. "The effectiveness of feedback on energy consumption: A review for DEFRA of the literature on metering, billing, and direct displays." Environmental Change Institute, University of Oxford.

Devlin, K. 2008. *The Unfinished Game.* New York: Basic Books.

Dutka, J. 1988. "On the St. Petersburg paradox." *Archive for History of Exact Sciences*, 39(1): 13–39.

Ellsberg, D. 1961. "Risk, ambiguity, and the Savage axioms." *The Quarterly Journal of Economics*, 75(4): 643-669.

Evans, J. St. B. T. and Stanovich, K. E. 2013. "Dual-process theories of higher cognition: Advancing the debate." *Perspectives on Psychological Science*, 8(3): 223-241.

Farrow, K., Grolleau, G., Ibanez, L., and Le Coent, P. 2018. "Social norms and pro-environmental behavior: A review of the evidence." *Ecological Economics*, 140: 1-13.

Feller, W. 1971. *An introduction to probability theory and its applications.* New York: Willey.

Fishburn, P. C. 1968. "Utility Theory." *Management Science*, 14 (5): 335–378.

Fischhoff, B., Slovic, P., and Lichtenstein, S. 1977. Knowing with certainty: The appropriateness of extreme confidence. *Journal of Experimental Psychology: Human perception and performance*, 3(4): 552.

Gilboa, I. 2009. *Theory of Decision under Uncertainty* (Econometric Society Monographs). Cambridge: Cambridge University Press.

Göttinger, H-W. 1972. "Bernoulli's Utility Theory and Historical Ramifications". *Jahrbücher für Nationalökonomie und Statistik,* 186 (6): 481-497.

James, W. 1890. *The Principles of Psychology*. New York: Henry Holt and Company.

Jensen, N.E. 1967. "An Introduction to Bernoullian Utility Theory: I. Utility Functions" *The Swedish Journal of Economics*, 69, 3: 163-183.

Johnson, E. J. and Goldstein, D. 2003. "Do defaults save lives?" *Science*, 302(5649): 1338-1339.

Jordan, J. 2006. *Pascal's wager: pragmatic arguments and belief in God*. Oxford University Press on Demand.

Kahneman, D. 2011. *Thinking, fast and slow*. Farrar, Straus and Giroux.

Kahneman, D. and Tversky, A. 1971. "Belief in the Law of Small Numbers." *Psychological Bulletin*, 76(2): 105-110.

Kahneman, D. and Tversky, A. 1973. "On the psychology of prediction." *Psychological Review*, 80(4): 237-251.

Kahneman, D. and Tversky, A. 1974. "Judgment under uncertainty: Heuristics and biases." *Science*, 185(4157): 1124-1131. In Kahneman, D., Slovic, P., and Tversky, A. (eds.) 1974. *Judgment under Uncertainty: Heuristics and Biases.* Cambridge University Press.

Kahneman, D. and Tversky, A. 1979. "Prospect Theory: An Analysis of Decision under Risk." *Econometrica*, 47 (2): 263–291.

Kahneman, D. and Tversky, A. 1984. "Choices, values, and frames." *American Psychologist*, 39(4): 341-350.

Kahneman, D., Slovic, P., and Tversky, A. (eds.) 1982. *Judgment under uncertainty: Heuristics and biases.* Cambridge University Press.

Laplace, P.S. 1814. *Essai philosophique sur les probabilités.* Paris: Gauthier-Villars. English translation by E.T. Bell, 1951. *A Philosophical Essay on Probabilities*. New York: Dover.

Levin, I. P., Schneider, S. L., and Gaeth, G. J. 1998. "All frames are not created equal: A typology and critical analysis of framing effects." *Organizational Behavior and Human Decision Processes*, 76(2): 149-188.

Loewenstein, G. and O'Donoghue, T., 2004. *Animal spirits: Affective and deliberative processes in economic behavior*. Available at SSRN 539843.

von Neumann J. and Morgenstern O. 1944. *Theory of Games and Economic Behavior*. Princeton: Princeton University Press.

Niels E. J. 1967. "An introduction to Bernoullian utility theory." *The Swedish Journal of Economics*, 69(3): 163-183.

O'Donoghue, T. and Rabin, M., 1999. Doing it now or later. American Economic Review, 89(1):103-124.

Pascal, B. 1670. *Pensées de M. Pascal sur la religion et sur quelques autres sujets, qui ont esté trouvées après sa mort parmy ses papiers.* Guillaume Desprez: Paris.

English translation in Honor Levi (ed.) *Pensees and Other Writing* Oxford: University Press 1995: 153-156.

Rabin, M. 2002. "A perspective on psychology and economics." *European economic review*, 46(4-5): 657-685.

Read, D. 2007. "Experienced utility: Utility theory from Jeremy Bentham to Daniel Kahneman." *Thinking & Reasoning*, 13,1: 45-61.

Samuelson, P. A. 1937. "A note on measurement of utility." *The review of economic studies*, 4(2): 155-161.

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

Simon, H. A. 1982. *Models of Bounded Rationality*. MIT Press.

Simon, H. A. 2000. "Bounded rationality in social science: Today and tomorrow." *Mind & Society*, 1, 25-39.

Thaler, R. 1985. "Mental accounting and consumer choice." *Marketing Science*, 4(3):199-214.

Thaler, R. H. 2015. *Misbehaving: The Making of Behavioral Economics*. W. W. Norton & Company.

Thaler, R. H. and Sunstein, C. R. 2009. *Nudge: Improving decisions about health, wealth, and happiness.* Penguin.

Tversky, A. 1975. "A Critique of Expected Utility Theory: Descriptive and Normative Considerations." *Erkenntnis* Vol. 9, No. 2: 163-173.

Tversky, A. and Kahneman, D. 1979. "Prospect theory: An analysis of decision under risk." *Econometrica*, 47(2): 263-291.

Tversky, A. and Kahneman, D. 1981. "The framing of decisions and the psychology of choice." *Science*, 211(4481): 453-458.

Wakker, P.P., 2010. *Prospect theory: For risk and ambiguity*. Cambridge University Press.