Original Research Article

How Cognitive Biases Interact with Risk Perception to Influence Real Estate Investment Decisions: A Systematic Review and Discrete Choice Experiment

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ABSTRACT

Behavioral biases and risk perception shape real estate investment decisions in ways that extend beyond the assumptions of rational choice theory. Classical Financial valuations may be logical on paper. However, these calculations neglect the fact that finance involves different psychological dimensions of risk perception. For example, individuals tend to underestimate losses but approach gains with overconfidence. This paper addresses that gap by combining a systematic literature review and a high-stakes real estate choice experiment. The findings reveal that individuals exhibit risk aversions stronger than predicted by models. It also revealed that while biases such as Loss Aversion or Herding are significantly consequential, other biases also manifest to a different extent under environmental cues. The choice experiment further demonstrated that intentionally nudged biased scenarios create polarized risk preferences. Overall, the paper highlights the limitations of traditional models such as the Expected Utility Theory (EUH) and the Capital Asset Pricing Model (CAPM) in explaining psychological drivers in finance. By integrating behavioral insights into real estate investment analysis, a more nuanced and interdisciplinary understanding of human behavior in the financial market would be applied, benefiting both investors and policymakers.

Keywords: Behavioral Finance; Risk Perception; Cognitive Bias; Nudge; Real Estate Investment

INTRODUCTION

In past decades, the window of opportunity in the financial industry has swung open [1]. The investigation into contemporary economic trends following the digital revolution in the late twentieth century has become a popular subject among modern monetary theorists [2]. Confidence and participation in equity and debt securities upsurged as investors' means to accumulate capital. The aftermath of the stock market crash led to numerous reflections and speculations among investors regarding their portfolio management and risk perception in this industry [3]. Hence, the nature of alternative investments—the weak correlation with other asset classes—led to considerable attention, particularly one major alternative investment: real estate investment. Although this new preference is increasingly gaining interest, research on alternative investments is limited,

not only because it has gained significance only in recent years.

In the early twentieth century, the assumptions in financial decision-making were all based on the pillars established from hypotheses in efficient markets (4). The emergence of modern finance in the latter twentieth century led to new theories in decision-making. EUH suggests that investors allocate assets by weighing the benefits and risks they pose (5). Behavioral finance questions the idea of rationality examines the 'irrationality' in decision-making and the psychological factors that influence it.

The present study reviews historical studies of behavioral biases in the investment industry to provide a summary, and conducts a choice experiment on biased investment decisions to address the following research questions: (RQ1) What does literature analysis reveal about significant behavioral biases and noteworthy risk environments that arise from the real estate investment industry? (RQ2) How do distinct risk environments impact similar cognitive frames, and vice versa, with different frames? (RQ3) To what extent can data manipulation mitigate existing investment distortions, and how should it be considered ethically?

Risk tolerance is independent of cognitive biases (i.e., biased behaviors are not consistent with different investment scenarios). Failing to consider the influence of cognitive biases and their varying intensities may lead to an incomplete understanding of patterns in the real estate investment industry. That said, many empirical studies have been limited due to data availability. The constraint remains an issue in conducting research. Hence, it has caused less interest in exploring this area of study, particularly the investigation of the interdependence of cognitive biases and risks (6). This paper acknowledges that while quantitative analysis and utility calculations are indispensable in making real estate investment decisions, it suggests a non-conventional interpretation of understanding choices by evaluating behavioral biases and their interaction with diverse risk situations. It also examines the impact of using behavioral interventions and data manipulation in regulating investment dynamics. The paper refers to bias as a psychological deviation from rationality in investment decisions, a predictable and significant pattern that influences investors' response to uncertainty, given that the perceived expected utility is omitted as a factor (7). The significance of this research stems from its attempt to isolate psychological drivers in investment decisions from external and incidental factors that have clouded many prior studies. Lastly, it establishes a framework that can aid future research in behavioral adjustments and designs to address irrational choice-making in uncertain markets.

LITERATURE REVIEW

The purpose of this literature review is to present earlier empirical results in a systematically organized manner. Additionally, a key aspect of this review is to provide a synthesis that uncovers significant patterns and relationships by integrating multiple studies. The following analysis would furnish a detailed examination of the state of the art for the four sections: Classical models in behavioral finance, Key biases in the investment industry, Key risks in the real estate industry, and Constructing hypotheses for behavioral analysis. Due to the scope of literature studies, biases or risks that appear in 50% or more of the investigated literature could be characterized as key.

Classical models in behavioral finance

According to the dictionary definition, the word bias refers to a personal inclination toward a judgment that is not well-reasoned, one that is influenced by emotions or feelings (8). Risk is defined as the possibility of a loss (9). With this understanding, identifying biases and risks is valuable for seeing the investment industry as a whole and can better equip investors to make more logical judgments. Nevertheless, in behavioral finance, the definitions of bias and risk should be understood in a different fashion. Choices in the investment industry cannot be characterized as poor, since no decisions have a guaranteed return on investment (ROI) when risk is involved. An investment under bias can only be made in a misleading or irrational manner. Similarly, risk can be understood as the likelihood that an investment, and or commodity, loses its value or incurs cost. EUH weighs risks when calculating the value of an investment (10). This suggests that, in classical finance, risk is a quantified number and can be represented using metrics. A case in point is the earlier model published by William F. Sharpe, known as the Capital Asset Pricing Model (CAPM). Sharpe recognized the matter of weighing risks when valuing an investment. Subsequently, he represented 'risks' by using the symbol β (beta) as a measure, as follows (11):

$$\text{Expected Return} = R_f \cdot \beta \times (R_m - R_f) \qquad (1)$$

Where R_f is the promised ROI regardless of risks.

And "$R_m - R_f$" is known as the market risk premium, essentially the extra return when an investment is made in the presence of risk. Note here that the market risk premium is multiplied by beta. The assumption is that beta is a number assigned to the 'riskiness' of a decision relative to the market, where $\beta > 1$ means the investment is more volatile than the market, and investments with $\beta < 1$ are less risky than market risk. Despite a defined beta, the CAPM remains misleading under two assumptions: beta only captures systematic risks (i.e., market-related risks, as the asset is only compared to the market), and investors are rational, as they only compare expected returns. Nonetheless, the model still simulates a foundational knowledge, which is that investments with higher risks generate higher returns (demonstrated by adjusting β). Taking this into consideration, a positive linear correlation can be inferred. However, in Portfolio Selection: Efficient Diversification of Investment, American economist Harry Markowitz argued otherwise (12). Markowitz proposed an optimal way of allocating an investment portfolio by balancing assets with different levels of risk. The Modern Portfolio Theory (MPT) considers the expected returns when portfolios are diversified to varying degrees. Figure 1, otherwise known as the Efficient Frontier, is the extrapolated presentation from the MPT (13).

As shown, the Efficient Frontier represents the expected return and risk of a diversified portfolio, ranging from allocating *100%* in less risky debt securities to *100%* in risky stocks, and anywhere in between. One thing to keep in mind is that the risk is characterized as σ (i.e., standard deviation) and not by β as with the CAPM.
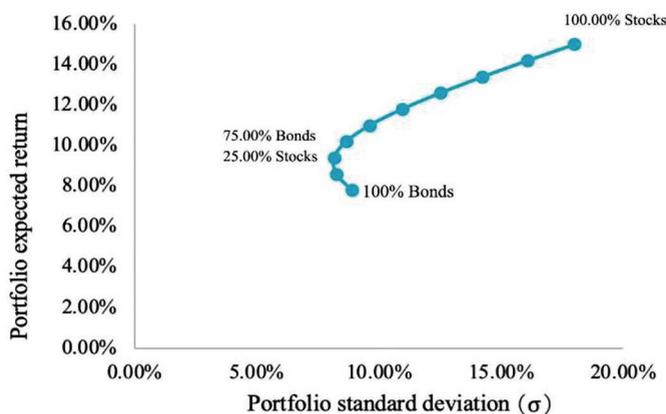
Figure 2 combines multiple indifference curves with the CAL. The position of the indifference curves reflects different investment attitudes. As the curve moves upward and to the right, it represents a demand for higher returns relative to the associated risks. However, the highest indifference curve requires a higher return at the same level of volatility compared to the other two curves. This can be explained by the investor's risk-seeking behavior, where the higher the curve's position, the more risk-averse the investor tends to be. In behavioral finance, psychological tendencies become the missing lens that completes the equation. This brings us to a critical distinction in calculating outcomes. The expected value, used by many classical models, is calculated as:

$$E(X) = \sum p_i \cdot x_i \tag{2}$$

The weighted average of possible outcomes relies solely on the possibilities without capturing the emotional impact of each outcome. By considering psychological variables, the Expected Utility Theory (EUH) inspired the adoption of using expected utility as a calculation, given by:

$$EU = \sum p_i \cdot U(x_i) \tag{3}$$

Where p_i is the probability of the outcome, $U(x_i)$ is the utility; the difference is that the utility isn't explicitly mentioned as the raw outcome. Rather, it incorporates concepts such as risk into the calculation of utility. Both

Figure 1. The Efficient Frontier. Each point on the curve represents the tradeoff between expected returns and risks for different portfolios composed of stocks and bonds.
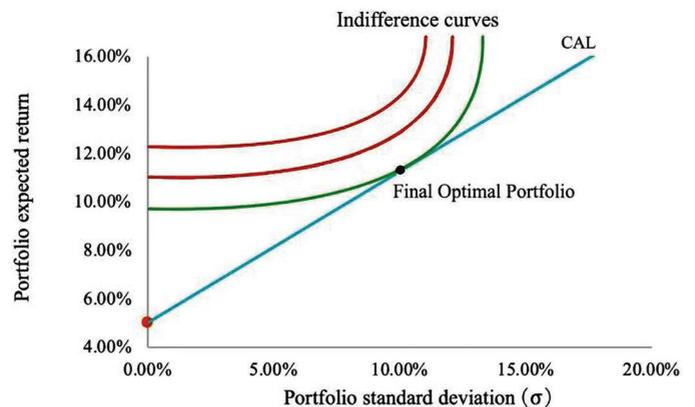

Figure 2. Capital Allocation Line with Indifference Curve. (Blue) Capital Allocation Line. (Green) Compatible Indifference Curve. (Red) Incompatible Indifference Curve. The intersection represents the best tradeoff between risk and returns of a portfolio.

formulas will be compared throughout this paper. This is to show that financial valuation cannot be justified and adopted without considering psychological tendencies.

Key biases in the investment industry
Gain Frame

Biases exist when external information presentation changes decision preferences, similar to the logic behind nudging. Unrealized biases in such scenarios are known as being framed, or they come from the framing effect (14). Gain and loss frames are found to be the most common biases in the real estate investment sector.

Gain Frame is a cognitive bias where investors expecting a profit tend to exhibit more risk-averse behaviors. They prefer accepting a smaller profit over a gamble of a high-risk, high-return option (15). From a quantitative perspective, the gain frame often misleads investors to overestimate the value of the guaranteed profit. As mentioned in the background, the expected utility theory (EUH) inspired many variants in calculating 'utility' to predict the expected value. One specific utility function derived from the EUH is known as the Constant Relative Risk Aversion function (CRRA) (16).

$$EU = \sum p_i \cdot U(x_i) \text{ or specifically}$$

$$U(x) = \begin{cases} \dfrac{x^{1-r}}{1-r}, & r \neq 1 \\ \ln(x), & r = 1 \end{cases} \tag{4}$$

Where the relative risk aversion coefficient is r, it is worth noting that every model typically employs different calculations of risk, such as beta and standard deviation, in common models. Instead of comparing the variations in risk across competing models, it is more important to understand the change in risk within a specific model. For CRRA, $r > 0$ symbolizes risk-averse behaviors. When r increases, the individual in the function possesses a stronger risk-aversion attitude. A special case is when $r = 1$, where the individual has a moderate attitude toward risks. In this case, the calculation becomes the logarithmic utility function. Most calculations in this paper utilize the logarithmic utility function, as only moderate risk scenarios are investigated. With this in mind, the CRRA simulates an expected value differently from using the expected value formula.

Around the 1960s, Nobel Prize-winning economist Robert C. Merton developed the Merton Optimal Allocation Formula, inspired by MPT, which provides a more direct measure of portfolio allocation for risk-averse individuals (17). A comparative study of different portfolio management strategies based on variations in risk aversion can better visualize investment behaviors under the gain frame. The Merton Optimal Allocation Formula is shown below:

$$\pi^* = \frac{\mu - r_f}{\gamma \cdot \sigma^2} \tag{5}$$

Where π^* symbolizes the optimal proportion of wealth to invest in a risky asset, μ is the expected return of the risky asset, r_f is the return of a risk-free asset, γ is the relative risk aversion coefficient, and σ^2 is the variance of the risky asset's return. The Merton Optimal Portfolio Theory assumes that it only works when a risk premium exists. In other words, when both the risky and safe options have the same expected return, there's no extra reward for taking the risk. Therefore, to simulate the Merton Optimal Portfolio effectively, the previous scenario would be adjusted by increasing the expected utility of the risky option slightly, while adjusting the possibility of doubling the reward to 60% and the possibility of no return to 40%. Merton's theory could then simulate the 10% risk premium:

$$\pi^* \approx 0.42 = \frac{0.60 - 0.50}{1 \cdot 0.24}$$

The 0.24 variance in risky assets is a standard unit and is adopted from the variances of other average risky assets. Nonetheless, with a moderately risk-averse behavior, 41.7% of the portfolio was suggested to be invested in risky assets. Consider the risk-averse coefficient to increase to 2:

$$\pi^* \approx 0.21 = \frac{0.60 - 0.50}{2 \cdot 0.24}$$

The recommended portfolio adoption of 41.7% in risky assets dropped to 20.8%. When all else is equal, risk aversion and risky allocation move in a proportionate negative direction. It also quantitatively demonstrates that, under the gain frame, individuals with a risk-seeking mentality tend to seek riskier investments.

Loss Aversion

While individuals under the gain frame tend to prefer safer investments over riskier ones, can common wisdom also be applied to individuals when facing a loss? As both the theoretical model and empirical data suggest, the effect tends to be interestingly the opposite. In the late twentieth century, the renowned behavioral finance researchers Daniel Kahneman and Amos Tversky

developed the most widely adopted theory of utility: Prospect Theory (18). The trend of the Prospect Theory can be visualized in Figure 3 (19):
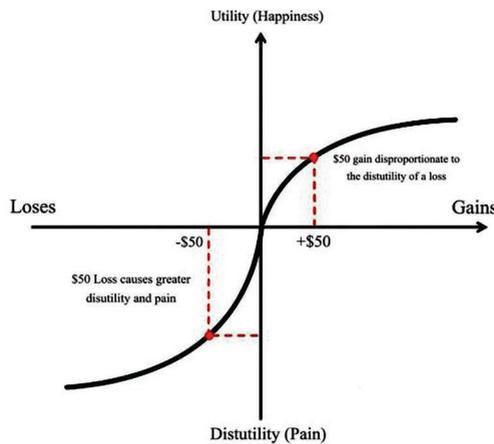

Figure 3. Prospect Theory Function. Pain from loss increases more exponentially than increases in happiness from identical gain.

Both gain and loss increase or decrease at an exponential rate, and the objective gains and losses will eventually achieve a steady state (Figure 4). The reason behind this is the marginal utility theory, which posits that the satisfaction of a gain or the pain of a loss diminishes with increasing quantity. However, the increase in utility in gains would disproportionately correspond to the same disutility of the loss. This can be seen from the steeper curve on the loss side. Through continuous model tuning, Kahneman and Tversky suggested that a loss hurts about twice as much as an equivalent gain.

In a quantitative representation, consider the scenario where an investor faces a definite loss of $50,000 but has the option to choose a riskier alternative, which involves a 50% chance of losing $100,000 and a 50% chance of losing nothing. The expected value suggests:

Option 1 (Definite Loss): E(–$50,000) = 1 · –$50,000

Option 2 (Risky Loss): E(–$50,000) = 0.50 · –$100,000 + 0.50 · $0

Again, both scenarios propose equal value. The dilemma can then be explained through Prospect Theory, mathematically calibrated and separated by Kahneman and Tversky:

$$PTV = \Sigma v(x) \cdot \pi(p) \tag{6}$$

or specifically

$$v(x) = -\lambda \cdot (-x)^\beta \text{ and } \pi(p) = \frac{p^\gamma}{[(p^\gamma + (1 - p)^\gamma]^{1/\gamma}} \tag{7}$$

The former formula, the Value Function, calculates the loss amount by considering diminishing sensitivity, where x is the outcome relative to the origin (e.g., -x represents a loss), and β represents the curvature parameter, which represents the diminishing sensitivity of losses. β is kept as 0.88 in the original Prospect Theory. And γ is the loss aversion coefficient, or how much more heavily losses are weighted than gains. The loss aversion coefficient is set by default to 2.25. The latter function, the Probability Weighting Function, measures the subjective value calculated by the value function. Kahneman and Tversky stress that not only is the expected value evaluated irrationally, but also probabilities are perceived irrationally. Investors typically overweight lottery chances but underweight likely possibilities. In the Probability Weighting Function, *p* is the objective probability of an outcome γ is symbolized as the probability distortion parameter (i.e., if $\gamma < 1$, small probabilities are overweighted.) And $\pi(p)$ is the subjective probability that irrational investors perceive. Consider using Prospect Theory on the previous scenario, the Value Function is given by:

Option 1 (Definite Loss):
$v(x) = -2.25 \cdot (50,000)^{0.88} \approx -2974.07$

Option 2 (Risky Loss, Loss Outcome):
$v(x) = -2.25 \cdot (100,000)^{0.88} \approx -5918.10$

Option 2 (Risky Loss, No Loss Outcome):
$v(x) = -2.25 \cdot (0)^{0.88} \approx 0$

And the probability weighting calculations of both options are:

Option 2 (Risky Loss, Loss Outcome):
$$\pi(x) = \frac{0.5^{0.61}}{(0.5^{0.61} + (1 - 0.50)^{0.61})^{1/0.61}} \approx 0.42$$

Option 2 (Risky Loss, No Loss Outcome):
$\pi(x) = 1 - 0.42 = 0.58$

Option 1 is unnecessary to consider probability weighting because it is a definite loss. Now, apply all

calculations in the complete prospect theory shown below:

Option 1 (Definite Loss): $PTV_A = -2974.07$

Option 2 (Risky Loss):
$PTV_B = 0.42 \cdot (-5918.10) + 0.58 \cdot (0) \approx -2485.60$

Both options signify losses, and although option 2 is riskier and has a worse possible loss than option 1, Prospect Theory predicts that investors will prefer it over the first option ($-2485.60 > -2974.07$). This demonstrates that, in the loss frame, investors are typically more risk-seeking, contradicting the classical expected value and CRRA in the gain frame.

Herding

In a scenario where you are participating in a beauty contest game. Among subjects, you can win by picking the person that most other participants believe is the prettiest, not necessarily your favorite. This is John Maynard Keynes's beauty contest analogy (20).

Herding is a common irrational behavior that exists across various investment regimes. Investors would follow the other majorities, leading to mass trading in one direction. Ultimately, the market would become unstable. Many investors, when considering various options, always look for popular choices. The sense of security made the herding behavior so prevalent in the industry. However, though making a decision based on what other people do feels reassuring, it also blinds investors' cognitive thinking. When real estate equity grows positively, investors shift their focus from inquiring about the market itself to predicting what others interpret from its growth.

Investors, due to their tendency to exhibit herding behavior, are often very short-sighted. In fact, experienced investors who historically undergo performance-pressure markets exhibit less herding and are more orthodox in their decision-making (21).

Overconfidence

Investors often overestimate their abilities, believing they are more capable than they are, which leads to thoughtless decisions and misjudged transactions (22). Overconfident investors tend to underestimate risks and overestimate returns, often based on incomplete or outdated information. Investors often assume they have more control over insider information, market timing, and future prediction (23). However, many investments, especially those in alternative investment markets, are opaque, and not all information is readily available. Confidence arises from considering only accessible information to make judgments that are obviously false. However, overconfidence is difficult to evaluate because people tend to weigh risks differently (24). For example, one might underestimate the effect of environmental impact on the real estate industry based on available information. Therefore, they would leverage their investment in places with a severe environment because they're confident that nothing will happen, while someone else might be susceptible to the climate. In this case, understanding the interaction between biases and risks is imperative. For this study, overconfidence is considered based on participants' reported confidence in chosen options and risk attitude.

Ambiguity Aversion

Ambiguity bias refers to an investor's preference for known possibilities over unknown ones. Most investors are ambiguity-averse; they typically avoid unknown risks and favor transparent risks (25). In the context of herding behavior, investors have conventionally thought that the option most people choose would signify less risk and therefore copy them. That said, this study considers ambiguity aversion when investors have an evident pattern in choosing the option of transparent risks over incalculable risks, while other frames are set the same.

Key risks in the real estate industry

In 2001, the attack on the World Trade Center prompted corporate real estate to concede to the unpredictability of risks (26). Corporate managers are increasingly recognizing the importance of mitigating the risks associated with natural disasters. Real estate investment is subject to a variety of risks, and properties can have concentrated and idiosyncratic risk. In the real estate investment industry, the most common risks identified in the literature study are discussed in order: Environmental Risk, Operational Risk, and External Risk.

Environmental risk

Environmental risk has become a growing concern in the real estate industry. Many studies, particularly in coastal areas, suggest that the risk of flooding and hurricanes is reaching its peak in the recent decade. The value in assets and investors' attitude toward the real estate market are becoming more tentative. Properties in

high flood areas are selling at discounted prices (27).

Environmental risk is particularly ambiguous. While forecast and historical data can provide investors with data availability, environmental risks are still comparatively less transparent than macro trends and economic risks. A relatively new peripheral concern, the environmental risk, has caused many real estate firms to reevaluate the assets in their physical real estate portfolios, and many of them are facing devaluation (28).

In recent years, companies have begun to incorporate climate change risks into their portfolio valuations and have developed analytical capabilities to recognize both physical and transitional risks in direct and indirect ways. Physical risks are the direct impact that environmental risks have on buildings. With the quickening pace of technological development, assessing the potential damage an environmental risk can cause is becoming easier. Transitional risks are indirect risks, such as investors' attitudes toward climate risk or the regulation of the real estate industry in environmental protection (29). Both physical and transitional risks can impact the future trend of the real estate investment industry. For instance, carbon-intensive infrastructures would face regulatory costs and, in the long term, heavy transitional risks.

Transitional risks are suggested to have an uneven effect across different assets. When assessing portfolios, many companies found that the transition and regulation of environmental risks actually benefit the asset, while others devalue it. Physical risks can also indirectly affect the valuation of an asset (30). In 2020, the McKinsey Institute claimed Bristol, England, experienced increasing flooding. Although the assets themselves are not affected, transportation around them is. Ergo, the assets were also reluctantly viewed (31).

Many companies, due to environmental risks, are reallocating their asset portfolios. This will alter the market structure and may also introduce other operational risks. Nonetheless, environmental risk should not be underestimated when valuing an investment.

Operational risk

Operational risk refers to the potential losses that can arise from a property's maintenance or operations (32). Operational risks typically appear as an explicit cost in the cash flow statement. Companies are now acknowledging that real estate properties aren't only generating income, but also incurring such costs. Aging assets usually have higher maintenance costs.

Development risks are also part of the operation. Development risks refer to those associated with the development or renovation of real estate assets (33). For example, the tender for an infrastructure project was unsuccessful. Operational risks have been rising in recent years, but the attitude toward such risks ultimately depends on the investor's attitude.

External risk

The real estate industry is highly sensitive to interest rates and to economic volatility. In 2019, the pandemic caused a historically steep downward trend in real estate prices since the 2008 financial crisis. Events such as the pandemic on a macro level dragged income down, lowering demand and market efficiency in the real estate industry (34). External risks are beyond the investor's control. Geopolitical events are among the determining factors of market shocks, alongside interest rates, inflation, government policies, and federal regulations, among others (35). External risks, such as environmental risks, vary between locations. Domestic investors have unique attitudes regarding their local government. However, external risks usually have a larger impact than any other specific risks: they are systematic. In other words, they influence the entire market at once. It is said that investors often underestimate low-probability macro risks such as the 2008 financial crisis. Despite the ambiguity in assessing the extent of an external risk, many investors opt to diversify their portfolios by selecting assets with negative correlations to mitigate the impact of external risks. This points out that a single external risk can have asymmetric effects on different properties. This paper analyzes people's attitudes toward this risk.

Constructing hypotheses for behavioral analysis

Based on primitive theories, apart from the quantitative calculation in delivering a risk-adjusted portfolio curve, individual risk tolerance should also be considered when determining the optimal portfolio (36). In addition, this paper will verify the following hypothesis from an empirical trial: (H1) Investors exposed to identical expected utilities display skewed preferences. (H2) Investors under different risk environments display dissimilar risk tolerance. (H3) Investors subject to different biases display dissimilar risk tolerance. By examining these hypotheses, this research not only answers the interactions between risk perceptions and cognitive biases but also shows the role classical models play in these interactions.

METHODS AND MATERIALS

Systematic literature review

To provide a thorough understanding of behavioral finance, the paper conducted a systematic literature review of articles published on behavioral biases and risk perceptions in the real estate investment industry. It is also essential to understand the real estate industry, alternative investment vehicles, and classical financial models to grasp how investing works and compare new findings with conventional theories. The role of this literature review is to first identify the universal biases and risk environments in the real estate investment industry. Second, to understand classical finance and how it differs from behavioral finance. Third, to interpret prior experiments on psychological choices and decision making.

The degree of risk perception is undoubtedly related to the self-possessed biases. This paper intentionally stresses a hierarchical framework of risk perception biases, from biases caused by external framing to internally distorted judgments. The order should present the ascending complexity of distorted judgments cohesively in the lens of the real estate investment industry. In addition, biases in each class would be juxtaposed to capture the opposing psychological forces (e.g., loss vs. gain frame in external framing possess contrasting preferences).

Studies in behavioral finance date back to the mid-1900s and gained popularity in recent decades (37). Therefore, studies in the review would be included solely if they were conducted from 1950 to the present. Papers in this literature review are mostly drawn from two databases: Google Scholar and JSTOR. The keywords used when using advanced filter were captured from prior reading of this topic: *(Field: Title, Abstract, Keywords: "Behavioral Finance" OR "Behavioral Bias" OR "Cognitive Bias" OR "Psychological Bias" OR "Emotional Bias" OR "Risk Perception" OR "Investment Risks" OR "Climate Risks" OR "Risks" OR "Mental Distortion" OR "Real Estate" OR "Investment" OR "Nudging").*

Discrete choice experiment

To demonstrate the applicability of behavioral finance and diversification of risk attitudes, a discrete choice experiment is considered the best fit for analyzing and juxtaposing different bias frames. For this purpose, a discrete choice experiment is designed and divided into three independent surveys, each serving as a treatment group. One of the key challenges in the context of the recreation behavioral choice experiment is selecting participants. The difficulty lies in the selectivity of respondents, which inherently contains certain biases. It is challenging to recognize and employ people with the corresponding behavioral biases in experimentation. Therefore, the experiment is designed to create scenarios from the already biased perspective associated with the treatment group. In other words, the participant, regardless of whether they have inherent biases or not, would view investment scenarios from a biased perspective, nudging decision-makers to make distorted decisions.

The term 'nudging' is depicted as a way of influencing decision-making by adjusting how choices are illustrated (38). A graphic example of nudging is visualized in Figure 4:

Figure 3. Example of effect of context on accessibility (26). The middle symbol in Numbers, Symbols, and Letters group can be misleading due to the presentation setting.

In Figure 3, the "Numbers" group, it is seen as the number "13". But in the 'Letters' group, it is interpreted as the letter "B", although both symbols are fundamentally same. This visualization is an example of judging differently under the same appearance but with a distinct context. Hence, nudging can be seen as an effective way to apply a biased perspective on participants without creating ambiguity.

Leaning on the typical structure of choice experiments in behavioral biases, the first section of the survey began with an introduction to the experiment. In the second section, a profitable asset is presented alongside two alternative financial options. In the third section, an investment at a loss was offered with two financial choices. The final section concentrated on socio-demographic questions. The three surveys focus on Gain Frame and Loss Frame vs. Expected Value, Gain Frame and Loss Frame under Unfamiliarity Bias, Gain Frame and Loss Frame under different Risk Conditions respectively (Appendix A).

Survey is randomly assigned to participants with ages ranging from 16 to 60+. Respondents were asked to complete the survey through social media and in

person. All respondents were not required to provide their names, identification, nor any private information in the survey to ensure confidentiality. Furthermore, each survey requires at least 30 responses. Therefore, the sample is normally distributed and the conditions for inference are met.

To organize the data, the Scientific Platform Serving for Statistical Professionals (SPSSPRO) was used to create pivot tables, cross-analysis, and statistical testing. Furthermore, each survey's total response would be assigned a calculated Cronbach's α coefficient, a measure of reliability and consistency, based on the variance of the respondents (39). The following number scale in Table 1 represents the threshold of Cronbach's α.

The data from the experiment is tested through several statistical tests. The chi-square goodness-of-fit test was used to test whether the distribution of a choice differs from a predefined theoretical expectation (41). To test for differences in a paired nominal group (e.g., gain and loss frame in treatment 1), and to see if the responses were changed across two related conditions, the 'McNemar's test' was used (42). Lastly, when analyzing association across independent treatments (e.g., treatment 1 to treatment 2), the chi-square test of independence was used (43). Note that a 5% significance level (α) was adopted for all statistical tests to evaluate the results with a standard level of confidence. Table 2 is provided below as a reference.

Ethics and considerations

The choice experiment conducted in this paper was evaluated by the Institutional Review Board (IRB) and granted by the Board. All participants received a consent form prior to the experiment and acknowledge that names or any other private information were not required. However, choice experiments should still be scrutinized with potential psychological risks involving human participants. This choice experiment is relatively undemanding and does not involve any incentives.

Table 1. Cronbach's Alpha benchmark (40). The coefficient signifies the reliability of respondent's data in the surveys used experiments.

Cronbach's Alpha	Reliability
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptance

Table 2. Overview of the experimental design, listing each comparison unit, associated statistical test, and null/alternative hypotheses applied to evaluate framing and risk-related decision patterns.

Analysis	Experimental Unit 1	Experimental Unit 2	Applied Testing	Hypotheses
Gain frame vs. EV	T1's gain frame	Expected gain frame	Chi-Square goodness-of-fit test	H_0: n(T1 Q1 'option 1') = n(T1 Q1 'option 2') H_a: n(T1 Q1 'option 1') ≠ n(T1 Q1 'option 2')
Loss Frame vs. EV	T1's loss frame	Expected loss frame	Chi-Square goodness-of-fit test	H_0: n(T1 Q2 'option 1') = n(T1 Q2 'option 2') H_a: n(T1 Q2 'option 1') ≠ n(T1 Q2 'option 2')
Gain Frame vs. Loss Frame	T1's gain frame	T1's loss frame	McNemar's Test	H_0: n(T1 Q1 'B') = n(T1 Q2 'C') H_a: n(T1 Q1 'B') ≠ n(T1 Q2 'C')
Gain Frame vs. Loss Frame under unfamiliarity	T2's gain frame	T2's loss frame	McNemar's Test	H_0: n(T2 Q1 'B') = n(T2 Q2 'C') H_a: n(T2 Q1 'B') ≠ n(T2 Q2 'C')
Gain Frame vs. Loss Frame under risks	T3's gain frame	T3's loss frame	McNemar's Test	H_0: n(T3 Q1 'B') = n(T3 Q2 'C') H_a: n(T3 Q1 'B') ≠ n(T3 Q2 'C')
Gain Frame vs. Game Frame with unfamiliarity	T1's gain frame	T2's gain frame	Chi-Square test of independence	H_0: %(T1 Q1 'option 1') = %(T2 Q1 'option 1') H_a: n(T1 Q1 'option 1') ≠ n(T2 Q1 'option 2')
Loss Frame vs. Loss Frame with unfamiliarity	T1's loss frame	T2's loss frame	Chi-Square test of independence	H_0: %(T1 Q2 'option 1') = %(T2 Q2 'option 1') H_a: n(T1 Q2 'option 1') ≠ n(T2 Q2 'option 2')

RESULTS

Social Demographic data

The choice experiment consisted of 107 participants. Overall, it demonstrated a nearly even distribution of male and female participants. Participants consist of students receiving education from universities or high schools, working professionals, and retired workers. A large portion of respondents are mainland Chinese citizens, while many other countries are also represented. A more detailed social demographic chart is presented below (Table 3):

Table 3. Sociodemographic profile of the study sample (N = 107), including gender, age distribution, and country of origin.

Social-demographic overview of the sample	(N=107)
Gender	**Percentage**
Male	49.50%
Female	43.90%
Non-Binary	2.80%
Prefer not to say	3.70%
Age	
16-25	54.20%
26-40	13.10%
41-60	30.80%
60+	1.90%
Country of origin	
China	58.90%
USA	23.40%
Hongkong	3.70%
Singapore	2.80%
Russia	0.90%
Prefer not to say	9.30%

Other data

A Cronbach's is given to each survey; the calculation considers the average time spent on each survey, the variation within each respondent, and the completion rate (Table 1, Section 5.1. "Statistical testing and application"). It should be noted, however, that the time spent on survey three was neglected, and therefore, the coefficient could not be calculated. Nonetheless, the data is given below (Table 4):

Table 4. Reliability assessment of the three surveys using Cronbach's alpha, reflecting consistency of responses across gain and loss frame conditions.

Survey Number	Cronbach's Alpha
1	0.89
2	0.80
3	N/A

Additionally, the mean confidence level of participants in the gain frame questions from surveys one to three, on a scale of 1 to 5, is 3.81. While the mean confidence level of subjects in the loss frame questions from surveys one to three, on a scale of one to five, is 3.58, indicating relatively even confidence.

Results from statistical testing

In this section, various statistical tests will be applied in both independent surveys and cross-sectional surveys (Table 2, Section 5.1, "Statistical Testing and Application").

Gain Frame vs. Expected Value

This analysis compares the distribution of respondents in the gain frame question (Q1) (Appendix 1, T1) with the expected distribution previously calculated with the EUH. Table 5 below shows the data:

Table 5. Distribution of respondent choices (safe vs. risky gain) for the gain-frame scenario in Survey 1.

SUM of Count	*Preference in spending the $100,000 investment*		
Survey Number	Option 1 (Safe Gain)	Option 2 (Risky Gain)	Grand Total
1	31	8	39
Grand Total	31	8	39

By using the Chi-Square Goodness-of-fit test with all conditions for inference met, the results are shown:

$$x^2 = \sum \frac{(O_i - E_i)^2}{E_i} \quad df = 1 \qquad (8)$$

$$x^2 = 13.5641, \; p \approx 0.0002$$

The calculated P-value from the Chi-square value with a degree of freedom of one is less than a 5% significance level (0.0002 < 0.0500). With the Odds Ratio of 15.0200, participants were fifteenth times more likely to choose safe gain than risky gain.

Loss Frame vs. Expected Value

This analysis compares the distribution of respondents in the loss frame question (Q4) of the first survey with the expected distribution calculated using the EUH. The data is provided below (Table 6):

Table 6. Distribution of respondent choices (definite vs. risky loss) for the loss-frame scenario in Survey 1.

SUM of Count	Preference in handling the $50,000 maintenance cost		
Survey Number	Option 1 (definite loss)	Option 2 (risky loss)	Grand Total
1	13	26	39
Grand Total	**13**	**26**	**39**

Using the Chi-Square Goodness-of-fit test with the degree of freedom of 1, the results are the following:

$$x^2 = 4.33, \; p \approx 0.04$$

At the 5% significance level, the P-value is statistically significant (0.04 < 0.05). The Odds Ratio of 4.00 indicates that participants were four times likely to choose the risky option than accepting a definite loss.

Gain Frame vs. Loss Frame

This analysis will compare the paired data within survey 1 (Q1 and Q4) to see whether there is a pattern in which most respondents choose to be safe in the gain frame and risk in the loss frame. The contingency chart SPSSPRO created is illustrated (Table 7):

Table 7. Contingency table comparing individual shifts in choice between the gain-frame and loss-frame scenarios within Survey 1.

Sum of Count

Survey 1	Option 1 (Safe gain)	Option 2 (Risky gain)
Option 1 (Safe loss)	8	5 (c)
Option 2 (Risky loss)	23 (b)	3
		(N=39)

The McNemar's test would be applied to the paired nominal data. The null hypothesis is that the number of people who choose safe investment in the gain frame and risky investment in the loss frame (b) is equal to the number of people who choose the direct opposite (c). The formula of the McNemar calculation is presented below:

$$x^2 = \frac{(\,|\,b - c\,|\, - 1)^2}{b + c} \tag{9}$$

$$x^2 \approx 10.320, \; p \approx 0.001$$

The P-value from the Chi-square value with a degree of freedom of 1 is smaller than a 5% significance level (0.001 < 0.050). The Odds Ratio of 4.600 suggests that respondents were 4.6 times more likely to switch from safe option in gain frame to risky gain in loss frame than the opposite.

Gain Frame vs. Loss Frame under unfamiliarity

This analysis will compare the paired data within Survey 1 (Q1 and Q4) to determine whether there is a pattern where participants choose to invest safely in the gain frame and take on risk in the loss frame, but with uncertainty regarding the possibility of the risk. The contingency table is provided (Table 8):

Table 8. Contingency table showing respondent choice patterns across gain- and loss-frame scenarios with ambiguous probabilities in Survey 2.

SUM of Count

Survey 2	Option 1 (Safe gain)	Option 2 (Risky gain)
Option 1 (Safe loss)	19	5 (c)
Option 2 (Risky loss)	8 (b)	5
		(N=37)

The result of the McNemar's test is given:

$$x^2 \approx 0.31, \; p \approx 0.58$$

The calculated P-value with a Chi-square of degree of freedom of 1 is larger than a 5% significance level (0.58 > 0.05). The Odds Ratio of 1.60 reveals people were 1.6 times more likely to switch from safe option in gain frame to risky option in loss frame but is not statistically reliable.

Gain Frame vs. Loss Frame under risks

This analysis compares the paired data within survey 3 (Q1 and Q4) to see whether there is a significant pattern in people choosing different options under two different risks (environmental and external). The contingency table is offered below (Table 9):

Table 9. Contingency table illustrating response patterns across environmental-risk and external-risk scenarios in Survey 3.

External Risk	SUM of Count	Environmental Risk	
	Survey 3	Option 1 (Safe gain)	Option 2 (Risky gain)
Option 1 (Safe loss)		5	5 (c)
Option 2 (Risky loss)		10 (b)	11
			(N=31)

The calculation is represented below:

$$x^2 \approx 1.07, \, p \approx 0.30$$

The P-value is lower than the 5% significance level (0.30 > 0.05). Therefore, no strong framing effect between gain and loss for survey 3 is supported.

Gain Frame vs. Gain Frame with unfamiliarity

This test uses a cross-survey comparison to investigate the difference between the distribution of responses in survey 1 (Q1) of the gain frame and responses in survey 2 (Q1) of the gain frame, but with unfamiliarity in the likelihood of risks. The chart of two independent groups is given (Table 10):

Table 10. Frequency comparison of respondent choices under the gain frame between Survey 1 (known probabilities) and Survey 2 (ambiguous probabilities).

SUM of Count			
Survey Number	Safe Gain	Risky Gain	Grand Total
50-50	31	8	39
Unfamiliarity	27	10	37
Grand Total	**58**	**18**	**76**

For testing two independent groups, the Chi-square test of independence is used. The results of the calculation are provided:

$$\text{Expected} = \frac{(\text{row}) \cdot (\text{column})}{N} = \begin{bmatrix} 29.76 & 9.24 \\ 28.24 & 8.76 \end{bmatrix} \quad (10)$$

$$x^2 \approx 0.16, \, p \approx 0.69$$

The P-value from the Chi-square value of a degree of freedom of 1 is larger than a 5% significance level (0.69 > 0.05). The shares choosing safe and risky do not differ significantly between survey one and survey two. In addition, there are 6.50% more respondents that chose the risky option in survey 2.

Loss Frame vs. Loss Frame with unfamiliarity

This test also uses the Chi-square test of independence to compare the distribution of responses in survey 1 (Q4) of the loss frame and responses in survey 2 (Q4) of the loss frame, but with uncertainty in the possibility of the risk. The data is furnished below (Table 11):

Table 11. Frequency comparison of respondent choices under the loss frame between Survey 1 (known probabilities) and Survey 2 (ambiguous probabilities).

SUM of Count			
Survey Number	Definite Loss	Risky Loss	Grand Total
50-50	13	26	39
Unfamiliarity	24	13	37
Grand Total	**37**	**39**	**76**

The expected counts and statistical testing are offered below:

$$\begin{bmatrix} 18.99 & 20.01 \\ 18.01 & 18.99 \end{bmatrix}$$

$$x^2 \approx 6.35, \, p \approx 0.01$$

The P-value with a Chi-square value of degree of freedom of 1 is smaller than the 5% significance level (0.01 < 0.05). There is a difference in the pattern of choosing safe and risky options under the loss frame in survey one and survey two. There are 31.60% few respondents that chose to take risks when facing unfamiliarity.

DISCUSSION

The statistical analyses yielded mixed outcomes, with

certain tests producing statistically significant rejections of the null hypothesis, while others failed to yield associations. This section provides an interpretation of the seven tests done in the preceding section.

Comparing the investment decisions under the gain frame in survey one presents the risk-aversion bias people present when already gaining. The result aligns with the CRRA's prediction, despite deviations from the expected counts of the EUH.

Survey 1's loss frame investment decisions found the similar skewed preference already established by the Prospect Theory calculated previously. It shows that people tend to be biased when considering investment options, especially when already facing a loss; in most cases, they become less risk-averse and are more likely to gamble. Together, the results of the first two statistical tests validate Hypothesis 1: investors exposed to identical expected value do display skewed preferences.

The crosstab analysis of the gain and loss frame in survey one confirmed that the responses significantly influenced people under different frames to choose investment options differently. Only a select few exhibited the inverse pattern. This test further verifies the findings of Analyses A and B and validates the paper's hypothesis three: investors subject to different biases do display dissimilar risk tolerance.

Survey two's gain and loss frame question demonstrated ambiguity suppresses framing effect, parallel to the Ellsberg paradox, where people tend to favor certain risks over unfamiliar ones. Similarly, analysis E also does not show any significant framing effect between the people's options in the gain frame compared to the loss frame.

Survey three's contingency analysis of the gain and loss frame similarly showed no significant framing effect. However, because it did not show statistical significance, there is no established correlation between people's change in attitude when facing different risks. Therefore, this paper's third hypothesis couldn't be answered: Investors under different risk environments do not necessarily display distinct risk tolerance.

From the Gain frame investment decisions in surveys one and two, there isn't a significant difference between the two groups when choosing the safe option, and the possible explanation is due to the unfamiliarity effect. Analysis between surveys one and two's distribution of responses in the loss frame should, in theory, show significant differences between survey one's percentage in choosing the safe option under the loss frame and survey two's percentage. Indeed, the null hypothesis is

statistically significant to be rejected (Table 11). This is because in the survey one, most people's preferences under the loss frame should skew toward the riskier option. However, under survey two's unfamiliarity, participants became more cautious and hesitant to engage in gambling. These findings confirm Hypothesis 3 and highlight the moderating effect of ambiguity on framing-induced behavior.

The study demonstrates that investment decisions are shaped by how outcomes are framed and by the degree of uncertainty applied to those probabilities. In practice, these findings suggest that investors should consider both the framing information and the clarity of risk probability to manipulate risk attitudes. However, it also highlights the limitations of contextualizing different risks, as the test suggested no obvious impact. It should be emphasized that while irrationality in the real estate investment industry can be explained through behavioral biases and different risk perceptions, this pattern is not a one-size-fits-all explanation, and certainly requires future empirical measurements.

While biases can lead to distorted investment decisions, as demonstrated in this paper, there are key implications that investors should consider minimizing irrational cognitive thinking when engaging in the financial market. One idea is the presence of myopic loss aversion (44). This is the tendency of investors to overreact to short-term fluctuations and become illogically risk averse. These often distort cognitive thinking and drive premature liquidation; instead, investors should consider long-term outcomes (45).

This paper also supported the impact of data manipulation and information framing. Selective disclosure and omission of probability can influence cognitive biases. Practices that involve intentional framing, such as nudging, can inadvertently influence investor sentiment. That said, despite extra attention to avoiding responses that focus on short-term outcomes, being overconfident and avoiding liquidation can also lead to opportunity cost accumulations and systemic inefficiencies. Such duality emphasizes the need to counteract cognitive distortions in the early stages and identify a threshold. Nonetheless, investors should be aware that they can learn about financial trends through historical evidence, rather than relying on future predictions or the behavior of other investors. By understanding a real estate asset's historical record, an investor can then understand how it is impacted by similar short-term losses or risks.

From a practical standpoint, a portfolio manager

should integrate behavioral safeguards in investment procedures. This includes: first, counteracting myopic loss aversion by adding annual reviews or long-term horizons rather than evaluating the real estate market using monthly intervals; second, Most effort is enhancing transparency and probability in investment reports based on historical records; third, using not only simple utility calculation but also considering risk attitudes to locate the optimal asset diversification. That said, work ethics should be acknowledged before any information manipulation and data exploitation.

Investment professionals should also adhere to consumer protection regulations. Regulators should seek to protect consumers from manipulative practices, such as intentionally creating market opacity. Regulators should also protect and prevent investment firms from selling high-risk investments to individuals lacking sufficient knowledge and information. Or presenting information through deliberate cognitive distortions. Without proper ethical management, the economy would undergo small-scale inefficiency or, at a larger scale, systematic failure (46). Therefore, individual firms should object to the following rules regarding psychological behaviors: disclosure rules, operational rules, and sales practice rules. Disclosure rules enable investors to access information about the company, its financial instruments, and the assets being invested in. Operational rules prevent a company from imposing unstable leverage and minimize risks (47). Sales practice rules ensure advertisements are not misleading and are not psychologically deceptive.

CONCLUSION

The real estate investment industry has gained significant momentum in the recent decade. While on an operational level, understanding investment decisions based on quantitative analysis is indispensable, knowledge of behavioral finance also provides insight from a different perspective. This study examined how cognitive framing, behavioral biases, and risk environments influence investment decision making. The findings demonstrate that relying on expected values to predict investment decisions can yield markedly different results from real-world scenarios, confirming that investment decisions can also be made irrationally.

While this study offers both historical records on fundamentals of biases and risks and empirical support, further research is essential to obtain a more accurate figure. To inform a future research agenda, further investigation should expand sample diversity, better contextualize risk environments, and utilize longitudinal data to verify how biases evolve from short-term decision-making to a longer time horizon. To the best of this paper's knowledge, the results underscore that investment behavior could not be fully predicted through rational models. Addressing these biases and their interconnections with different risk environments is not only a peripheral simulation in investor psychology but a structural necessity. Behavioral finance is crucial to long-term portfolio resilience and market regulation, the recipe for a more comprehensive understanding of how investment decisions are made.

This study contributes to the behavioral finance literature by linking bias typologies to specific frames and risks in the context of real estate. By empirical evidence and theoretical models, it offers a future comparison and reference to improve investment modeling and strategies.

CONFLICT OF INTEREST

The author declares that there are no conflicts of interest regarding the publication of this article.

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APPENDIX A

T1: instructions

Welcome, and thank you for participating in this choice experiment. The experiment will take about 6 minutes to complete!

The Choice Experiment

Scenario: You are considering investing $100,000 in a residential apartment building located in downtown New York City, known for strong rental demand and urban appreciation.

This investment yields a return in five years.

How do you prefer to spend the $100,000 investment? Please choose only one choice between the following:

Option 1 (Safe gain): You are guaranteed to earn $50,000 *(total $150,000 with initial investment)* within five years of investment, regardless of risks.

Option 2 (Moderate Risk): After the investment, there is a 50% chance that you will earn $100,000 (total $200,000 with initial investment) or a 50% chance of earning no profit at all (the initial investment of $100,000 will not change at all after 5 years)

The Questionnaire

Based on your choice, how confident are you in the investment option you chose (Scale: 1=Not confident at all, 5=Extremely confident)

In general, how would you describe your attitude toward this scenario?

A. I prefer safe, certain outcomes when facing gains

B. I sometimes take risks for higher rewards when facing gains

Scenario: You have already invested $100,000 in an urban apartment building in New York City. Unfortunately, due to rising property management fees, your investment is expected to incur a one-time maintenance cost of $50,000 in five years.

How do you prefer to handle the maintenance cost? Please choose only one choice between the following:

Option 1 (Definite loss): You will pay the cost, meaning you will lose 100% of $50,000 (Your investment gain is -$50,000) as part of the maintenance cost.

Option 2 (Risky loss): File an inspection report (no cost), which means you might have a 50% chance of losing $100,000 (investment gain of -$100,000), but a 50% chance of losing nothing (you saved the initial

investment without paying any cost)

The Questionnaire

Based on your choice, how confident are you in the decision you chose (Scale: 1=Not confident at all, 5=Extremely confident)

In general, how would you describe your attitude toward this scenario?

A. I prefer safe, certain outcomes when facing loss

B. I sometimes take risks for higher rewards when facing loss

T2: instructions

Thank you for participating in the choice experiment. The experiment will take about 4 minutes to complete.

The Choice Experiment

Scenario: You are considering investing $100,000 in a residential apartment building located in downtown New York City, known for strong rental demand and urban appreciation.

This investment yields a return in five years.

How do you prefer to spend the $100,000 investment? Please choose only one choice between the following:

Option 1 (Safe gain): You are guaranteed to earn $50,000 (total $150,000 with initial investment) within five years of investment, regardless of risks.

Option 2 (Moderate Risk): After investment, there is a chance that you will earn $100,000 (total $200,000 with initial investment) or a chance of earning no profit at all (the initial investment of $100,000 will not change at all after 5 years) Only these two possibilities can happen; however, the likelihood of both chances is unknown.

The Questionnaire

Based on your choice, how confident are you in the investment option you chose (Scale: 1=Not confident at all, 5=Extremely confident)

In general, how would you describe your attitude toward risk?

A. I prefer safe, certain outcomes when facing gains

B. I sometimes take risks for higher rewards when facing gains

The Choice Experiment (Operational Risk)

Scenario: You have already invested $100,000 in an urban apartment building in New York City. Unfortunately, due to rising property management fees, your investment is expected to incur a one-time

maintenance cost of $50,000 in five years.

How do you prefer to handle the maintenance cost? Please choose only one choice between the following:

Option 1 (Definite loss): You will pay the cost, meaning you will lose 100% of $50,000 (Your investment gain is -$50,000) as part of the maintenance cost.

Option 2 (Risky loss): File an inspection report (no cost), which you might have a chance of losing $100,000 (investment gain of -$100,000), but also a chance of losing nothing (you saved the initial investment without paying any cost). Only these two possibilities can happen; however, the likelihood of both chances is unknown.

The Questionnaire

Based on your choice, how confident are you in the decision you chose (Scale: 1=Not confident at all, 5=Extremely confident)

In general, how would you describe your attitude toward risk?

A. I prefer safe, certain outcomes when facing loss

B. I sometimes take risks for higher rewards when facing loss

T3: instructions

Welcome, and thank you for participating in this choice experiment. The experiment will take about 6 minutes to complete!

The Choice Experiment

Scenario: You are considering investing $100,000 in a residential apartment building located in downtown New York City, known for strong rental demand and urban appreciation. Unfortunately, recently, climate change has gained significance, and the city is seen to have increasing storms and heat waves. Your investment consultancy suggested two options.

This investment yields a return in five years.

How do you prefer to spend the $100,000 investment? Please choose only one choice between the following:

Option 1 (Safe gain): You are guaranteed to earn $50,000 *(total $150,000 with initial investment)* within five years of investment, regardless of risks.

Option 2 (Moderate Risk): After the investment, there is a chance that you will earn $100,000 (total $200,000 with initial investment) if there aren't significant environmental impacts or a chance of earning no profit at all (the initial investment of $100,000 will not change at all after 5 years) if severe environmental damage struck.

Only these two possibilities can happen; however, the likelihood of both chances is unknown.

(For example, a flash flood in a storm season could sink your asset's basement, making your investment gain nothing, or nothing may happen at all, and you don't pay anything and gain even more.)

The Questionnaire

Based on your choice, how confident are you in the investment option you chose (Scale: 1=Not confident at all, 5=Extremely confident)

In general, how would you describe your attitude toward this scenario?

A. I prefer safe, certain outcomes when facing environmental risks

B. I sometimes take risks for higher rewards when facing environmental risks

The Choice Experiment (External Risk)

Scenario: You have already invested $100,000 in a residential apartment building in China. Unfortunately, recently, economic volatility has gained significance, and the city is seen to have unpredictable inflation, recession, and fluctuating tax rates. Therefore, a regulatory cost is imposed by the government.

How do you prefer to handle the regulatory cost? Please choose only one choice between the two choices provided:

Option 1 (Definite loss): You will pay the cost, meaning you will lose 100% of $50,000 (Your investment gain is -$50,000) as part of the regulatory cost.

Option 2 (Risky loss): Submit a turndown request (no cost but no regulatory protection), which you might have a chance of losing $100,000 (investment gain of -$100,000) if economic downfall, but also a chance of losing nothing (you saved the initial investment without paying any cost) if the economy is stable. Only these two possibilities can happen; however, the likelihood of both chances is unknown.

(For example, a severe economic downfall could force the government to add $100,000 as additional costs without the regulatory protection, forcing you to pay $100,000, or the economy is stable, and nothing may happen at all.)

The Questionnaire

Based on your choice, how confident are you in the decision you chose (Scale: 1=Not confident at all, 5=Extremely confident)

In general, how would you describe your attitude toward risk?

A. I prefer safe, certain outcomes when facing economic risks

B. I sometimes take risks for higher rewards when facing economic risks

APPENDIX B

Data Availability

The datasets and surveys in this paper are available on the OSF: https://osf.io/f38km/.

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