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New Energy Vehicle Industry Investment Risk Analysis and Control: A Comprehensive Decision-Making Framework Combining Prospect Theory and the Analytic Hierarchy Process

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ABSTRACT

In Amid China's pressing energy crisis and excessive investment in the new energy vehicle sector, this study delves into the risks and challenges associated with such investments. By incorporating an analysis of micro-level individual psychology, it designs specific indicators to assess investment risks. Building on existing research and practices in investment risk assessment, the study introduces a novel framework that integrates individual psychological factors. This new system elucidates the interplay between investment risks and investor psychology, aiming to assist individual investors in making informed decisions, optimizing capital allocation, and fostering the sustainable growth of the new energy industry.

KEYWORDS

New energy vehicle; Risk assessment system; Individual investment psychology; Prospect theory; Risk avoidance

1 Introduction

With the rapid development of the economy and the improvement of people's living standards, China's demand for oil has been increasing, and since 1993 China has changed from a net oil exporter to a net importer. Due to the increasing cost pressure and environmental pressure of using oil, renewable and environmentally friendly new energy has been increasingly emphasized by our country in recent years. China's new energy industry, with more than 40 years having passed since the start of reform and opening-up, has been growing in scale of development and construction, and the enthusiasm for investment and financing has been increasing, as of now, China holds the top position globally in the scale of new energy usage, but still faces many difficulties such as overcapacity, insufficient cutting-edge capacity and land constraints and many other difficulties. Venture capital acts as a "catalyst" in advancing the development and application of new technologies, with new energy vehicles serving as a key driver in accelerating innovation across other sectors of the new energy industry, it is highly favored by investors, and in China's capital market, as of the beginning of 2023, the number of individual investors has exceeded 200 million, which is an important part of the market vitality. In China's capital market, as of the beginning of 2023, the number of individual investors has exceeded 200 million, which is an important source of market vitality, but also an important support for the normal play of market function, so how to help individual investors avoid investment risks and make individual investment better for the new energy automobile industry to inject new impetus to promote the industry's innovation, improve the living environment, and improve the social well-being, has an important research value. At present, there are fewer studies that directly combine the behavioral finance theory with the new energy investment risk assessment system, this paper stands in the micro perspective, adds the psychological ideas such as outlook theory on the basis of the existing studies, and enriches the quantitative investment strategy of the current new energy investment risk assessment system in anticipation of providing theoretical and practical guidance to the individual investors in this field.

2 Overview of the current status of domestic and international research

Nie Lei and Zhang Ning (2014)[1] against the backdrop of governments worldwide implementing policies to support the new energy vehicle industry, this study addresses the challenge of enhancing venture capital's role in injecting new vitality into the sector. Utilizing the AHP and Delphi methods, and drawing on research by domestic and international scholars, a comprehensive evaluation index system is established, tailored to the unique characteristics of the new energy automobile industry, which is a better solution to the complex evaluation problems in the process of venture capital investment, and plays a theoretical guidance role in investment practice. It better solves the complex evaluation problems in the process of venture capital and plays a role of theoretical guidance for investment practice. Yao Yuan (2022)[2] analyzes the demand and development of new energy industry and its dilemma in the context of serious environmental crisis and energy crisis at the current stage of China's economic and social development and analyzes the demand and development of new energy industry and its dilemma in the light of the problems of high cost of development of new energy industry, low competitiveness of the market and the rising investment risk caused by blind investment, and obtains the conclusion that "Government policy support and appropriate risk management measures can effectively boost the growth of the new energy industry and refine its risk management systems. The conclusion that such policies and measures enhance the industry's ability to withstand risks has contributed to the study of investment risks in China's new energy sector."

Liu Hao (2020)[5] in China is facing a very serious energy crisis and environmental crisis in the background, To address investment risk issues in the new energy industry, factor analysis and regression methods are employed, fuzzy synthesis method, and other ways, and actively construct an investment risk evaluation system for the new energy industry, as to effectively curb investment risks in the new energy industry and support its ongoing progress, improve the current ecological environment, and to promote economic growth.(2022)[7] In light of nations striving to substitute conventional energy sources with renewable ones and making significant investments in this domain, facing the volatility and stochasticity inherent in renewable energy projects that have created a large amount of uncertainty in the investment activities, utilizing prospect theory and intuitionistic fuzzy sets, an advanced FMEA method effectively resolves expert indecisiveness and cognitive biases, prioritizing renewable energy investment risks. This aids investors in accurately assessing risks and making optimal decisions.

L., Yulong, L., & Lilin, P. (2014) [10] Against the backdrop of China's renewable energy power generation industry reaching a world-leading level following rapid growth, and addressing issues such as funding shortages and haphazard investment in the sector, the study examines China's renewable energy investment and financing landscape from five angles. It summarizes the financing models and characteristics while proposing practical recommendations for improvement.

Existing literature has made a large number of studies on the investment risk and assessment approaches of new energy and its subsectors using methods and function formulas such as AHP, ELECTRE III , FMEA, Z number, DEA analysis, etc., but only a small number of studies have incorporated behavioral finance theories in the establishment of the assessment system.

3 Correlation Analysis Between Investor Psychology and Market Investment

There exists a close correlation between investor psychology and market investment. The irrational psychology of investors not only influences their decision-making process but also directly affects market valuation and investment risk through various market indicators. For instance, in the new energy vehicle sector, investors may blindly follow trends due to industry hotspots or favorable policies, creating a "herd effect" that drives up stock prices through excessive speculation. Alternatively, overly optimistic projections of industry prospects or neglect of industry risks can lead to valuation bubbles. In the new energy vehicle industry, fluctuations in investor psychology can be amplified by policy changes, technological breakthroughs, or uncertainties in market demand, resulting in significant volatility in industry valuation and investment risk.

In 2010, Mo consolidated multiple indicators to create an Investor Sentiment Index, examining its influence on market valuation. His findings revealed a strong positive relationship between the index and market valuation.[12] When investor sentiment is high, market trading volume increases, the turnover rate rises, stock prices are pushed up, and market valuation levels improve accordingly. Conversely, when investor sentiment is low, market trading volume decreases, the turnover rate drops, stock prices fall, and valuation levels decline.

In summary, there is a significant interactive relationship between investor psychology and market investment. To better control risks in the new energy vehicle industry, investors and managers should fully recognize the impact of psychological factors on market investment. By strengthening investment education, optimizing decision-making models, and other measures, they can mitigate the negative effects of irrational behavior on market investment.

4 Introduction to Research Methods

4.1 Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP), introduced by American operations researcher Satty, is a decision-making approach that breaks down decision-related elements into hierarchical levels such as objectives, criteria, and alternatives, followed by quantitative analysis. This method decomposes the problem into different constituent factors, and aggregates and combines the factors at different levels according to their interrelationships, influences, and membership relationships, forming a multi-level analytical structure model. Ultimately, the problem is reduced to the determination of the relative importance weight of the lowest level (decision-making solutions, measures, etc.) relative to the highest level (overall goal) or the arrangement of the relative superiority and inferiority order. It can mathematize and systematize people's thinking process, making it easy for people to accept. Currently, it has been widely used in various fields.

4.2 Prospect Theory

Prospect theory, introduced by psychologists Daniel Kahneman and Amos Tversky, explains decision-making behavior under risk and uncertainty. The theory outlines four key principles: (1) the reflection effect, where individuals tend to be risk-averse when facing gains; (2) the reflex effect, where individuals become risk-seeking when facing losses; (3) loss aversion, where people are more sensitive to losses than to gains; and (4) reference dependence, where judgments about gains and losses are influenced by reference points. This theory highlights that individuals are generally risk-averse with gains, risk-seeking with losses, and more affected by losses than gains. When evaluating potential gains and losses, people do not simply pursue maximizing expected utility, but are influenced by a reference point (usually the current state or a specific level), exhibiting characteristics such as loss aversion, probability weighting, and nonlinear utility. Based on the long-standing assumption of rational individuals, Prospect Theory, rooted in empirical studies, highlights the irrational psychological factors affecting decision-making by analyzing human psychological traits and behavioral tendencies.

5 Incorporating the concept of prospect theory

Combining the characteristics of prospect theory, the author constructs a relatively simple utility function combination to model how investors make decisions when encountering potential gains and losses.

5.1 Value Function

The value function is typically used to represent an investor's utility assessment of gains and losses. In prospect theory, the value function is an asymmetric function relative to a reference point, where the loss portion is steeper than the gain portion, reflecting loss aversion.

$$V(x)=\begin{cases} x^{\alpha} & \text{if } x \geq 0 \\ -\lambda(-x)^{\beta} & \text{if } x < 0 \end{cases}$$

x is defined relative to the reference point as gains or losses.

$\alpha$and $\beta$are shape parameters, where $\alpha<\beta$ indicates that the utility decline for losses is steeper than for gains, representing loss aversion.

λ is the loss aversion coefficient, where $\lambda>1$ indicates that the utility decline for losses is λ times faster than for gains.

5.2 Probability Weighting Function

The probability weighting function is used to represent an investor's subjective perception of events with different probabilities. In prospect theory, low-probability events are assigned higher weights, while high-probability events are assigned relatively lower weights.

$$w(p)=\frac{p^{\gamma}}{(p^{\gamma}+(1-p)^{\gamma})^{1/\gamma}}$$

$p$is the objective probability,γ is a tuning parameter that reflects the degree of nonlinearity in probability weighting.

5.3 Prospect Theory Utility Function

By linking the value function to the probability weighting function, a complete prospect theory utility function can be constructed to evaluate the expected utility of an investment portfolio.

$$U(W)=\sum_{i=1}^{n} w(p_i)V(x_i)$$

$W$is the initial wealth of the portfolio.

n is the number of possible outcomes.

p_i is the probability of the "i-th" outcome occurring.

x_i is the gain or loss of the "i-th" outcome relative to the reference point.

Example:

Suppose an investor is considering two investment options, each with two possible outcomes:

Option A: 50% probability of gaining 100 units, and 50% probability of losing 50 units.

Option B: 20% probability of gaining 200 units, and 80% probability of losing 100 units.

Using the utility function described above, we can calculate the expected utility for each option:

For Option A:U(A)=ω(0.5)V(100)+ω(0.5)V(−50)

For Option B:U(B)=ω(0.2)V(200)+ω(0.8)V(−100)

The specific parameter values must be tailored according to the context of the new energy vehicle industry. the investor's risk preferences, behavioral characteristics, and market conditions. In practical applications, empirical analysis combining market data and investor behavior is required to determine the most appropriate parameter values, as they may vary depending on individual, cultural, and market environmental factors. Finally, the expected utility of the project can be used as a quantitative metric for project evaluation to guide investment decisions and policy formulation.

6 The Design of an Investor Psychological Sentiment Indicator System

6.1 Design Description

When evaluating the risks associated with the new energy vehicle (NEV) industry, it is essential to consider not only the general characteristics common to high-risk enterprises but also the unique risks specific to this sector. Drawing on the research findings of scholars both domestically and internationally, this study references the risk investment project evaluation indicator system for the NEV industry proposed by Nie Lei et al. (2014). Furthermore, by integrating prospect theory, adjustments will be made to the weighting of certain parameters. The specific modifications are as follows:

Adjustment for Loss Aversion: [13]Kahneman, D., et al. (1991) extensively explored the phenomenon of loss aversion, highlighting that investors are typically twice as sensitive to losses as they are to gains (i.e., the loss aversion coefficient $\lambda\approx$ 2.25). To account for risk factors that may lead to losses, this study incorporates the loss aversion coefficient (λ= 2.25) from prospect theory, amplifying the relevant weights. For example, the initial weight for "substitutability" in technological risk was 0.031, which, after adjustment, becomes $0.0316 \times 2.25 = 0.0711$.

Probability Weighting Adjustment: Prospect theory suggests that investors tend to overestimate the likelihood of low-probability events and underestimate the likelihood of high-probability events. Based on this, this study refers to the general probability weighting function proposed by [14]Prelec, D. (1998) to adjust objective probabilities. This adjustment aims to better capture investors' tendency to overestimate low-probability events. The formula for the probability weighting function is as follows:

$$w(p)=\frac{p^{\gamma}}{(p^{\gamma}+(1-p)^{\gamma})^{1/\gamma}}$$

In the formula, $p$represents the objective probability, and γ=0.65 is the adjustment parameter.

The value of γ=0.65 is derived from extensive empirical research and experiments. [15]Kahneman and Tversky (1979) found through experiments that the parameter γ in the probability weighting function typically ranges between 0.6 and 0.8, the shape parameter for the gain domain is $\alpha\approx 0.88$, and the shape parameter for the loss domain is $\beta\approx 0.88$, depending on the experimental design and the behavioral characteristics of the participants. [16]Prelec (1998) proposed a general form of the probability weighting function and, through fitting experimental data, determined that the typical value of γ is approximately 0.65. These studies indicate that γ =0.65 is a median value that effectively reflects people's perception of probabilities.

Reference Point Dependence: [15]Kahneman, D., & Tversky, A. (1979) provided a detailed description of investors' irrational behaviors when faced with gains and losses, particularly loss aversion and reference point dependence. Therefore, when calculating gains and losses, this study also establishes a psychological reference point for investors (such as their current asset level) and adjusts the value function for gains and losses based on this reference point.

Through the aforementioned adjustments, the risk assessment framework in this study not only takes into account objective risk factors but also fully reflects the psychological biases of investors when facing uncertainty. This approach provides individual investors with more comprehensive decision-making support.

6.2 Design Results

Table 1* shows specific adjustments applying prospect theory to the Risk Investment Evaluation Index System for the NEV Industry，Table 2* is the original version.

By incorporating the value function, probability weighting function, and prospect theory utility function, we have comprehensively adjusted the weights, focusing primarily on risk factors that may lead to losses (e.g., technological risks, market risks, and macroeconomic risks).

No adjustments were made to profitability γindicators and corporate strength indicators, as these primarily involve gains and are not influenced by loss aversion or probability weighting.

Table 1 NEV Industry Project Evaluation Index System and Weight Integrated with Prospect Theory

Level 1 indicators	weight	Secondary indicators	weight	Portfolio weights	Level 3 indicators	weight	Portfolio weights
Risk	0.625 0	Technical Risks	0.145 2	0.090 8	Fungibility reliability Imitation	0.348 4 0.582 1 0.069 5	0.015 9 0.041 1 0.003 2
		Product Risks	0.102 1	0.063 8	Car safety Energy efficiency rate Innovation Cruising range	0.472 9 0.284 4 0.169 9 0.072 8	0.030 2 0.018 1 0.010 8 0.004 6
		Market Risk	0.051 9	0.032 4	Market demand for NEV Potential Competition	0.833 3 0.166 7	0.013 6 0.002 7
		Manage risk	0.416 6	0.260 4	Moral hazard for managers Managerial management experience Strategic planning capabilities	0.571 5 0.285 7 0.142 8	0.148 8 0.074 4 0.037 2
		Financial risk	0.033 8	0.021 1	Financing capacity Rate of capital accumulation	0.250 0 0.750 0	0.005 3 0.015 8
		Exit risk	0.024 1	0.015 1	How easy it is to exit How to opt out	0.166 7 0.833 3	0.002 5 0.012 6
		Macro environment	0.226 3	0.141 4	NEV subsidy policy risk Financial market risk Macroeconomic situation Supporting facilities	0.573 3 0.115 7 0.052 4 0.258 6	0.040 8 0.008 2 0.007 4 0.036 5
Profitability	0.238 5	Profitability	0.750 0	0.178 9	The scale of the project investment Profit margin of NEV Speed of project recycling	0.104 7 0.637 0 0.258 3	0.018 7 0.114 0 0.046 2
		Ability to sell	0.2500	0.059 6	Marketing channels and personnel Corporate marketing budget	0.833 3 0.166 7	0.049 7 0.009 9
Enterprise strength	0.136 5	Technical capabilities	0.333 3	0.045 5	Core intellectual property rights R&D strength of the enterprise	0.250 0 0.750 0	0.011 4 0.034 1
		Brand strength	0.666 7	0.091 0	Brand competitiveness Brand-building capabilities	0.200 0 0.800 0	0.018 2 0.072 8

Example: "Fungibility":

$$\because \ \gamma=0.65;p=0.1$$

$$\therefore w(0.1)=\frac{0.1^{0.65}}{(0.1^{0.65}+0.9^{0.65})^{1/0.65}}=\frac{0.224}{(0.224+0.774)^{1/0.65}}\approx 0.224$$

$$U=\sum_{i=1}^{n} w(p_i)\cdot V(x_i)=0.224\times(-2.25)\approx -0.504$$

$$|U|=0.504$$

Adjusted Weight = Initial Weight $\times|U|$=0.0316×0.504≈0.0159

Table 2 NEV Industry Project Evaluation Index System and Weight

Level 1 indicators	weight	Secondary indicators	weight	Portfolio weights	Level 3 indicators	weight	Portfolio weights
Risk	0.625 0	Technical Risks	0.145 2	0.090 8	Fungibility reliability Imitation	0.348 4 0.582 1 0.069 5	0.031 6 0.052 9 0.006 3
		Product Risks	0.102 1	0.063 8	Car safety Energy efficiency rate Innovation Cruising range	0.472 9 0.284 4 0.169 9 0.072 8	0.030 2 0.018 1 0.010 8 0.004 6
		Market Risk	0.051 9	0.032 4	Market demand for NEV Potential Competition	0.833 3 0.166 7	0.027 0 0.005 4
		Manage risk	0.416 6	0.260 4	Moral hazard for managers Managerial management experience Strategic planning capabilities	0.571 5 0.285 7 0.142 8	0.148 8 0.074 4 0.037 2
		Financial risk	0.033 8	0.021 1	Financing capacity Rate of capital accumulation	0.250 0 0.750 0	0.005 3 0.015 8
		Exit risk	0.024 1	0.015 1	How easy it is to exit How to opt out	0.166 7 0.833 3	0.002 5 0.012 6
		Macro environment	0.226 3	0.141 4	NEV subsidy policy risk Financial market risk Macroeconomic situation Supporting facilities	0.573 3 0.115 7 0.052 4 0.258 6	0.081 1 0.016 4 0.007 4 0.036 5
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		Ability to sell	0.2500	0.059 6	Marketing channels and personnel Corporate marketing budget	0.833 3 0.166 7	0.049 7 0.009 9
Enterprise strength	0.136 5	Technical capabilities	0.333 3	0.045 5	Core intellectual property rights R&D strength of the enterprise	0.250 0 0.750 0	0.011 4 0.034 1
		Brand strength	0.666 7	0.091 0	Brand competitiveness Brand-building capabilities	0.200 0 0.800 0	0.018 2 0.072 8

6.3 NEV Investment Evaluation Model Based on AHP Method

Once the indicator system has been set up, the next step is to assign the evaluation weights for each indicator, taking into account the specific characteristics of the industry. Given that the evaluation of NEV startup companies requires both qualitative and quantitative analysis, the Analytic Hierarchy Process (AHP) can be employed to calculate the weight of each factor. Using the Delphi technique, a panel of 5-10 experts is invited to provide scores according to *Table 3, and the average scores are then calculated to construct the judgment matrix.

The consistency of the judgment matrix is then checked using the formula$CR=\frac{CI}{RI}$ and $CI=\frac{\lambda_{\max}-n}{n-1}$. If the consistency ratio is acceptable, the weights derived from the judgment matrix are considered valid. The product of the weights at each level represents the comprehensive weight of the tertiary indicators. The final score of each indicator, multiplied by its corresponding comprehensive weight, is summed to obtain the overall evaluation score of the project. Projects with higher scores are more suitable as investment targets.

Table 3 Judgment Matrix Scoring Criteria

Scale	1	3	5	7	9
Meaning	Bi is equally important as Bj	Bi is slightly more important than Bj	Bi is significantly more important than Bj	Bi is strongly more important than Bj	Bi is absolutely more important than Bj

7 Conclusion

This study introduces prospect theory, offering a fresh perspective on assessing investment risks in the new energy vehicle sector, and assisting investors in navigating uncertainties more effectively. Future studies could delve deeper into the relationship between market dynamics and investor psychology, aiming to refine the risk assessment model and offer more precise support for the sustainable growth of the industry.

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