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Analysis of Real Texas Holdem Hands
and Discrimination of Skill vs. Luck

A thesis submitted in partial satisfaction
of the requirements for the degree
Master of Applied Statistics and Data Science in Statistic

by

Jingyu Fu

2024

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2024

ABSTRACT OF THE DISSERTATION

Analysis of Real Texas Holdem Hands
and Discrimination of Skill vs. Luck

by

Jingyu Fu

Master of Applied Statistics and Data Science in Statistic

University of California, Los Angeles, 2024

Professor Frederic R. Paik Schoenberg, Chair

This thesis examines the roles of luck and skill in Texas Hold'em poker through theoretical analysis, statistical modeling, and empirical data from millions of hands. The study evaluates their influence across game stages—pre-flop, flop, turn, river, and show-down—highlighting how skill mitigates randomness as the game progresses.

Findings reveal that while luck dominates early stages, skill increasingly impacts outcomes by enabling strategic and psychological decision-making. Quantitative models measure stage-specific contributions of luck and skill, showing that skill drives consistent long-term performance, whereas luck introduces short-term variability. Visual analyses further emphasize their complementary roles.

The research provides actionable insights for optimizing poker strategies, managing risks, and improving long-term performance, while contributing to the debate on whether poker is a game of luck or skill. Future work may explore advanced modeling techniques and broader applications in decision-making under uncertainty.

The dissertation of Jingyu Fu is approved.

Nicolas Christou

Yingnian Wu

Frederic R. Paik Schoenberg, Committee Chair

University of California, Los Angeles

2024

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CHAPTER 1

Introduction

1.1 Background

Texas Hold'em is a poker game that originated in the United States. Since the 20th century, it has gradually become a popular game around the world. This game is not only played in friends and family entertainment, but has also become a part of competitive sports and international events such as the World Series of Poker (WSOP), reflecting its influence in the culture, economy, and entertainment industry.

The appeal of Texas Hold'em lies in its perfect combination of two different elements: luck and skill. The order of dealing cards and the combinations of cards in hand are determined by randomness. Making luck a decisive role in the short term. However, various other factors could play dominant roles in the game, such as the player's strategy, psychological tactics, mathematical calculations, and interpretation of the opponent's behavior. Therefore, Texas Hold'em is considered as a complex decision-making game, which challenges players in both the short and long term.

The debate over whether the Texas Hold'em is determined by luck or skill remains ongoing. Due to the numerous random factors involved in the game, many people believe that it is a gambling activity. However, professional poker players and research studies have shown that skills and strategies can significantly influence the outcome of the game over the long term.

1.2 Research Questions and Goals

This study explores whether the winning and losing results are mainly determined by luck or skill. Specifically, this study has the following goals:

1. Quantitative evaluation: Analyze the role of luck and skill at different stages of Texas Hold'em to clarify their relative contributions.
2. Build a theoretical model: Construct a statistical model to assess the impact of luck and skill on players' long-term benefits.
3. Providing empirical evidence: Gather and analyze a comprehensive historical game dataset to provide objective and scientific evidence for the "luck vs. skill" debate and to offer suggestions for future research and game strategies.

CHAPTER 2

Texas Hold'em Poker Basic Rules and Decision-Making Process

Texas Hold'em requires strategy and psychological tactics. It combines randomness and decision analysis. The basic rules of the game make it a typical game theory model. In Texas Hold'em, each player is dealt two “hole cards”, followed by multiple rounds of betting, and the winner is determined based on the combination of the final five public cards. The game consists of four main stages: Pre-flop, Flop, Turn, and River, each of which has different decision requirements and strategies.

1. Pre-flop:

In the beginning, each player will hold two “hole cards”, which are only visible to themselves. Players need to decide on betting strategies based on the strength of their hands and the behavior of their opponents. Factors to consider include hole card combinations (such as straight flushes, pairs, etc.), seat positions (early or late), and betting dynamics. Players can choose to “fold”, “call” or “raise”.

2. Flop:

The three community cards are turned over. Players can evaluate their hands by combining their two hole cards with the community cards. The amount of information at this stage increases significantly, and players need to re-evaluate the strength of their hands and decide whether to make further bets. Players need to consider the probability of potential “making hands”, such as suits, straights, etc, and adjust their

strategies based on the opponent's possible hands.

3. Turn:

The fourth community card is turned over. At this time, players need to more accurately evaluate the strength of their own hands and the possible strategies of their opponents, and choose whether to make more aggressive bets or defend.

The strategy of the turn stage tests the player's psychological warfare ability and calculation ability. For example, players can choose to "bluff" to confuse their opponents, or set traps to make their opponents misjudge. Every decision at this stage may greatly affect the outcome of the game, so it requires extremely high strategic analysis.

4. River:

The last public card is turned over, and all potential hand combinations have been determined, entering the final betting stage. Players need to make the final decision based on all the known information, whether to choose a large bet to put pressure, or to be conservative and call to avoid too much loss, or to fold and give up the game.

The strategy in the river stage is often closely related to psychological warfare and behavioral analysis. Players need to combine the opponent's behavior pattern and all the information on the table to make the best decision. At this time, psychological tactics are particularly important, such as using the betting range to confuse the opponent or judging the quality of the opponent's hand based on his reaction.

2.1 The Definition of Luck and Skill

In Texas Hold'em, defining luck and skill is inherently challenging. Their concepts are complex and are rarely detailed in books or journal articles on game theory. However, some existing studies have proposed various methods to understand and measure these factors.

1. Luck:

Luck usually refers to the influence of random factors that are beyond the player's control [2]. In Texas Hold'em, this is mainly reflected in the random order and combination of cards dealt during each game. The impact of luck is unpredictable and uncontrollable by a player's strategy, making it a decisive factor in the short-term of the game. For example, a player might win with a strong hand, or lose due to an unfavorable combination of community cards.

2. Skill:

Skill refers to the player's ability to make effective decisions under uncertain conditions. This definition can be quantified and understood in several ways:

- (a) Differences in player performance: Some scholars (e.g., Potter van Loon et al., 2015) suggest that if a game is primarily determined by luck [4], the performance of different players should be relatively similar. However, if the game relies solely on skill, there can be a significant difference in the performance. That is, the skill factor allows high-level players to gain an advantage in the long run, while luck only affects performance in the short term.
- (b) Possibility of learning and improvement: Dedonno and Detterman experimentally demonstrated that Texas Hold'em is a game of skill [1]. They found that participants who received strategic training performed significantly better than those who did not, suggesting that players can improve their game skills through learning and practice. Furthermore, their study revealed that skill involves not only

mastery of mathematical probability, but also the application of psychotactics and strategy analysis.

These definitions provide a theoretical basis for studying the relative role of luck and skill in Texas Hold'em. By analyzing strategies and decisions in real hands in detail, it is possible to more clearly quantify the impact of luck and skill on the outcome at different stages.

CHAPTER 3

Data Overview

3.1 Data Description

This dataset originates from HandHQ.com and comprises millions of authentic online poker hand histories collected from six distinct online poker platforms [3]. To ensure data privacy, all identifying information—such as table names, hand IDs, and player names—has been anonymized. This anonymization process not only safeguards the privacy of individual players but also plays a critical role in enabling unbiased analysis. By removing personal identifiers and context-specific details, the dataset reduces the risk of analytical bias stemming from player-specific trends or preferences. Furthermore, this approach enhances the generalizability of the findings, as the analysis focuses purely on the strategic and probabilistic elements of poker gameplay, making the results applicable across a broader range of scenarios and player demographics. Thus, the dataset maintains both scientific rigor and ethical standards, offering a reliable foundation for meaningful poker research. Despite the anonymization process, the data still retains the necessary strategic and probabilistic elements, providing a solid foundation for in-depth poker analysis.

The hand history is presented in a text format, providing detailed information about various aspects of each poker game, including:

1. Stage Information: Each game is assigned a unique identifier, referred to as the stage number.
2. Table Setup: The table name, game type, and specific details about the betting struc-

ture—such as the big blind, small blind, and ante—are documented. Additionally, the players’ names and the number of chips each player possessed at the beginning of the hand are recorded.

3. Player Action: Each player’s actions throughout the game are tracked, such as paying a blind, folding, raising, or going all-in. The sequence of players’ actions is also captured, starting with the hole cards being dealt and ending with the final showdown.
4. Game Results: The distribution of the pot and the cards revealed during the showdown at the end of each hand are summarized. Any cards that were not shown are also documented.

```

Stage #3017243630: Holdem No Limit $10, $2.50 ante - 2009-07-01 00:00:26 (ET)
Table: CLE0 AVE (Real Money) Seat #2 is the dealer
Seat 2 - XrM1XlN29RxlLx3oZHhG0w ($1,515 in chips)
Seat 3 - X+u4T/E5ANkyZLKm1YjqwQ ($2,067.40 in chips)
Seat 4 - wyXD1026Buq3VWHAij37Jg ($1,987.50 in chips)
Seat 5 - 3wT3m+GDGtVWU1KR2MWJ1Q ($1,171 in chips)
Seat 6 - /P+7Z0P/b7YiK60FW9dRAQ ($1,710.50 in chips)
Seat 1 - eXXdS46B0E4apgZgp7gHFw ($2,000 in chips)
eXXdS46B0E4apgZgp7gHFw - Ante $2.50
XrM1XlN29RxlLx3oZHhG0w - Ante $2.50
X+u4T/E5ANkyZLKm1YjqwQ - Ante $2.50
wyXD1026Buq3VWHAij37Jg - Ante $2.50
3wT3m+GDGtVWU1KR2MWJ1Q - Ante $2.50
/P+7Z0P/b7YiK60FW9dRAQ - Ante $2.50
X+u4T/E5ANkyZLKm1YjqwQ - Posts small blind $5
wyXD1026Buq3VWHAij37Jg - Posts big blind $10
eXXdS46B0E4apgZgp7gHFw - sitout (wait for BB)
eXXdS46B0E4apgZgp7gHFw - Ante returned $2.50
*** POCKET CARDS ***
3wT3m+GDGtVWU1KR2MWJ1Q - Raises $47.50 to $47.50
/P+7Z0P/b7YiK60FW9dRAQ - Folds
XrM1XlN29RxlLx3oZHhG0w - Folds
X+u4T/E5ANkyZLKm1YjqwQ - Folds
wyXD1026Buq3VWHAij37Jg - Folds
3wT3m+GDGtVWU1KR2MWJ1Q - returned ($37.50) : not called
*** SHOW DOWN ***
3wT3m+GDGtVWU1KR2MWJ1Q - Does not show
3wT3m+GDGtVWU1KR2MWJ1Q Collects $37.50 from main pot
*** SUMMARY ***
Total Pot($37.50)
Seat 2: XrM1XlN29RxlLx3oZHhG0w (dealer) Folded on the POCKET CARDS
Seat 3: X+u4T/E5ANkyZLKm1YjqwQ (small blind) Folded on the POCKET CARDS
Seat 4: wyXD1026Buq3VWHAij37Jg (big blind) Folded on the POCKET CARDS
Seat 5: 3wT3m+GDGtVWU1KR2MWJ1Q collected Total ($37.50)
Seat 6: /P+7Z0P/b7YiK60FW9dRAQ Folded on the POCKET CARDS

```

Figure 3.1: Sample of Original Dataset

This dataset enables us to analyze patterns, strategies, and the impact of luck and skill on outcomes in poker games. Containing millions of hands, the data provides a rich empirical basis for exploring the dynamics of Texas Hold'em.

3.2 Processing Methods

The dataset used in this analysis is derived from a larger collection of millions of hand histories from Texas Hold'em poker games. Due to the volume of data, a subset of 146 hands was selected based on specific filtering criteria. First, only hands with five complete community cards available in the "SUMMARY" section were included, ensuring all public cards were revealed. Second, the dataset was restricted to hands where the two players' hole cards were fully shown during the showdown, extracted from the "Shows" action lines. Third, hands were selected where complete betting activity for all four rounds (pre-flop, flop, turn, and river) could be identified and segmented by keywords such as "TURN" and "RIVER." This allowed for a detailed reconstruction of pot sizes at each stage. Lastly, only hands where the betting amounts of the two players who reached the showdown were fully traceable through their seat indices were included. After applying these criteria, 146 hands remained for the analysis, providing a comprehensive yet manageable dataset.

The selected hands represent games played on July 1, 2009, during real-money online poker sessions. Each hand provides detailed records of betting actions, pot sizes, community cards, and player hole cards, offering a comprehensive view of the game's progression and outcomes. By narrowing the focus to this subset, the analysis aims to better understand the dynamics of skill and luck in a controlled and statistically valid manner.

To manage and analyze the data effectively, we utilized the R programming language and its powerful data processing tools. The workflow involved splitting the dataset into manageable pieces and applying filters to ensure it was suitable for statistical analysis. The following are the main steps of the process:

1. Read the text data:

Load the entire text data as a character vector for subsequent segmentation and processing.

2. Split Data:

We need to recognize each game. “Stage #” is used to identify the starting position of each hand, ensuring that each hand is a separate entry after the split. Blank entries or paragraphs that do not contain hand information are filtered out.

3. Extract Player’s Hand and Community Cards:

Extract detailed descriptions of the player’s hand and community cards and convert them into numeric representations, with each card mapped to a unique integer.

4. Calculate the cumulative pot amount:

Retrieve the betting amounts from each stage to calculate the cumulative pot amount, with each betting phase contributing to the total pot amount.

5. Find out the maximum bet:

Extract the maximum bet amount for each stage to analyze the players’ strategies.

6. Build a Result Data Frame:

Organize all the extracted information into a structured data frame, including the player’s hand, community cards, the cumulative pot amount for each betting phase, and the main betting actions for each stage.

7. Handle missing values:

Remove missing values from the dataset to maintain data integrity and ensure accurate analysis.

8. Save structured data:

Save the final processed data frame as an RDS file for efficient loading and use in subsequent analysis.

3.3 Significance of Data Processing

These steps transform raw, unstructured Texas Hold'em hand data into an easy-to-analyze format. This transformation enables the application of statistical and machine learning methods to conduct rigorous and detailed analyses, such as evaluating player's betting strategies, calculating the probability of winning at different stages, studying the impact of luck and skill, etc. In addition, the data frame structure facilitates data visualization and model building, providing support for revealing complex gaming behaviors in Texas Hold'em.

CHAPTER 4

Predictive Models of Luck and Skill

To investigate the roles of luck and skill in Texas Hold'em, we employ the following model to quantify the impact of each factor on player performance. By analyzing the correlation between the player's bets and community cards at various stages, the model illustrates the contributions of luck and skill to the decision-making process.

4.1 Model overview

This model is designed to evaluate the winning rate of Player A (the punter) at each betting stage through simulations and probability calculations, quantifying the benefits associated with luck and skill. Specifically, the model analyzes the hands of Player A and Player B as well as the five community cards to predict the probability of winning at each stage [5].

4.1.1 Defining the Parameters

1. Player Hand and Community Cards:

The model uses c_1 to c_9 to represent Player A and Player B's hands and five community cards:

- (a) c_1 and c_2 : Two cards from Player A's hand.
- (b) c_3 and c_4 : Two cards from Player B's hand.

- (c) c_5 to c_9 : Five community cards, which are revealed in turn as the game progresses.
- (d) Each card is converted into a unique value by a conversion function, `switch`, ranging from 1 to 52, to facilitate subsequent probability calculations.

2. Bet Amount and Pot Amount:

The betting behavior in the game is described by the bet amount and the pot amount: `Abet0` and `Bbet0` represent the amount of bets placed by Player A and Player B respectively before the cards are dealt, and `pot0` represents the total amount of the pot at that time.

c1	c2	c3	c4	c5	c6	c7	c8	c9
39	13	52	26	12	45	29	44	21
23	12	8	51	2	37	25	38	40
3	10	9	30	4	6	45	21	36
33	19	49	35	42	9	36	11	26
3	13	15	26	12	38	39	4	29

Figure 4.1: Samples of Card Information

At each stage of the game, `Abeti` and `Bbeti` represent the bet amount of Player A and Player B, and `poti` represents the accumulated pot amount (i from 1 to 4, representing the flop, turn, river and final showdown, respectively).

Abet0	Bbet0	Abet1	Bbet1	Abet2	Bbet2	Abet3	Bbet3	Abet4	Bbet4
2.50	2.50	40.00	40.00	75.00	75.00	225.00	225.00	803.50	803.50
10.00	0.00	0.00	10.00	30.00	30.00	60.00	60.00	490.00	490.00
5.00	10.00	5.00	0.00	20.00	20.00	45.00	45.00	150.00	150.00
5.00	10.00	45.00	40.00	70.00	70.00	0.00	0.00	0.00	0.00
10.00	5.00	20.00	25.00	45.00	45.00	0.00	0.00	150.00	150.00

Figure 4.2: Samples of Two Players' Bets

pot0	pot1	pot2	pot3	pot4
30.00	150.00	300.00	750.00	2357.00
15.00	35.00	95.00	215.00	1195.00
15.00	20.00	60.00	150.00	450.00
15.00	100.00	240.00	240.00	240.00
15.00	60.00	150.00	150.00	450.00

Figure 4.3: Samples of Pot Information

4.1.2 Calculation steps

The model divides each stage into three phases: win rate, luck gain, and skill gain. Each phase is simulated and computed, as described in the following process:

1. Pre-Deal Win Rate Calculation.

Before the flop, the model calculates Player A's win probability (p_0) by simulating all possible combinations of community cards and evaluating the strength of Player A's hand against Player B's. This involves the following steps:

Step 1: Define Player Hands

Assume Player A holds Ace of Spades, King of Spades, and Player B holds 10 of Hearts, 9 of Hearts. These cards are removed from the deck, leaving 48 remaining cards.

Step 2: Enumerate Possible Community Card Combinations

The flop, turn, and river require five community cards. The total number of possible five-card combinations from the remaining 48 cards is:

$$\binom{48}{5} = 1\,712\,304$$

Each of these combinations represents a unique possible board.

Step 3: Simulate Hand Strengths

For each possible combination of five community cards:

- (a) Combine Player A's two cards with the five community cards and evaluate the resulting hand strength.
- (b) Similarly, combine Player B's two cards with the same five community cards and evaluate their hand strength.

Step 4: Compare Hand Strengths

- (a) For each community card combination, compare Player A's hand to Player B's hand.
- (b) For each community card combination, compare Player A's hand to Player B's hand.
- (c) If Player B's hand is stronger, it is counted as a win for Player B.

Step 5: Calculate Win Probability

After simulating all possible community card combinations, calculate Player A's pre-flop win probability (p_0) as:

$$p_0 = \frac{\text{Number of Wins for Player A}}{\text{Total Number of Simulations}}$$

Suppose the simulations show that Player A wins 1,113,000 out of 1,712,304 possible combinations. Then:

$$p_0 = \frac{1,113,000}{1,712,304} \approx 0.65$$

2. Luck Gain Calculation Before Dealing:

Luck buff measures the potential gain that Player A will receive as a result of the random dealing. The formula is:

$$luck_0 = pot_0 * p_0 - Abet_0.$$

Here, $pot_0 * p_0$ represents the expected payoff of Player A, i.e., the pot amount multiplied by the probability of Player A winning. By comparing it to Player A's bet amount at the initial stage, $Abet_0$, it is possible to determine the gain or loss due to the luck factor.

This measures the impact of randomness on Player A's expected profit.

Step 1: Define Variables

(a) Assume the pot size before the flop is $pot_0 = 500$.

(b) Player A has bet $Abet_0 = 200$ in this phase.

Step 2: Calculate Expected Profit

Player A's expected profit from the pot is $pot_0 \times p_0$: Expected Profit = $500 \times 0.65 = 325$

Step 3: Subtract Bet Amount

Subtract Player A's bet from their expected profit to determine the luck gain:

$$luck_0 = 325 - 200 = 125$$

Thus, due to the random dealing of cards, Player A's luck contributed 125 chips to their expected profit.

3. Skill Gain Calculation Before Dealing:

Skill buff measures whether Player A's strategy is effective before the cards are dealt.

The formula is:

$$skill_0 = pot_1 * p_0 - Abet_1 - pot_0 * p_0$$

Here, $pot_1 * p_0$ represents the expected return of Player A after the next round of betting.

Continuing the example, suppose the pot size after the next round increases to $pot_1 = 800$, and Player A bets $Abet_1 = 300$. The skill gain is:

$$skill_0 = 800 \times 0.65 - 300 - 500 \times 0.65 = 520 - 300 - 325 = -105$$

The negative value indicates that Player A's strategy before the flop failed to increase their expected profit effectively.

4. Calculation of the winning percentage on the flop:

In the flop phase, three community cards are revealed. The model recalculates Player A's win probability p_1 by simulating all possible combinations of the turn and river cards to evaluate hand strength.

For example, suppose the flop reveals Queen of Hearts, 10 of Diamonds, 5 of Spades. After simulation, Player A's win probability increases from $p_0 = 0.65$ to $p_1 = 0.75$, reflecting an improvement in Player A's chances of winning.

5. Luck Gain Calculation on the Flop:

Calculate the luck gain on the flop as follows:

$$luck_1 = pot_1 \times p_1 - pot_1 * p_0$$

This calculation reflects the effect of the randomness of the flop on Player A's expected return, i.e. the difference between the expected return after the flop and the expected return before the flop.

Continuing the scenario, suppose the pot size $pot_1 = 1000$, and the flop increases Player A's win probability to $p_1 = 0.75$. The luck gain is:

$$luck_1 = 1000 \times 0.75 - 1000 \times 0.65 = 750 - 650 = 100$$

Thus, the randomness in the flop added 100 chips to Player A's expected profit.

6. Skill Gain Calculation on the Flop:

- (a) The skill buff is updated post-flop and is calculated as: $skill_1 = pot_2 \times p_1 - Abet_2 - pot_1 \times p_1$.
- (b) By evaluating Player A's betting strategy on the flop, the model determines whether his strategy is effective in increasing the expected return on winning.

Suppose the pot size increases to $pot_2 = 1500$, Player A's win probability remains $p_1 = 0.75$, and Player A bets $Abet_2 = 400$. The skill gain is:

$$skill_1 = 1500 \times 0.75 - 400 - 1000 \times 0.75 = 1125 - 400 - 750 = -25$$

A negative value suggests that Player A's strategy during the flop did not significantly enhance their expected profit.

7. Turn and River Phase Calculation:

- (a) During the turn and river phases, the model continues to simulate all possible community card combinations and calculates the win rate p_2 and p_3 in turn.
- (b) Similarly, calculate the luck buff and skill buff separately for each stage. The luck buff on the turn is $luck_2 = pot_2 \times p_2 - pot_2 \times p_1$ and the skill bonus is $skill_2 = pot_3 \times p_2 - Abet_3 - pot_2 \times p_2$. The luck and skill bonuses on the river are calculated based on the final win percentage.

Suppose the turn increases Player A's win probability to $p_2 = 0.85$, the pot size reaches $pot_3 = 2000$, and Player A bets $Abet_3 = 500$. The calculations are:

$$luck_2 = 1500 \times 0.85 - 1500 \times 0.75 = 1275 - 1125 = 150$$

$$skill_2 = 2000 \times 0.85 - 500 - 1500 \times 0.85 = 1700 - 500 - 1275 = -75$$

This shows both the impact of randomness and strategy in the turn phase.

8. Total Luck Buff and Skill Buff:

- (a) The model adds up the luck gain and skill gain in each stage, calculates the total luck gain of Player A (*lucktotal*) and the total skill gain (*skilltotal*), and compares them in absolute terms.
- (b) This accumulation process shows the total impact of luck and skill over the course of the game, providing a clear quantitative metric for analyzing the outcome of the game.

Continuing the example above, the cumulative totals are:

$$lucktotal = |125 + 100 + 150 + 200| = 575$$

$$skilltotal = |-105 - 25 - 75 + 300| = 495$$

4.1.3 Application and Significance

This model provides a systematic approach to analyzing luck and skill in Texas Hold'em. By simulating the decision-making process and changes in win rate at different stages, the model is able to reveal when a Player Benefits from luck or when a player gains an advantage through strategy. This quantitative analysis helps to verify the debate of “is Texas Hold'em a game of luck or a game of skill”, and provides a scientific basis for theoretical research and practical application.

CHAPTER 5

Data visualization and analysis

Through a series of visualizations, we analyze the distribution of gains or losses at each stage of Texas Hold'em and examine the correlation between stages in detail. These visual analyses provide insights into how luck and skill influence player performance across different stages of the game. Specifically, for each stage, scatter plots will be used to illustrate the trends of Luck (blue points) and Skill (red points) across multiple games. These plots enable a clear comparison of Luck and Skill in terms of their contribution to gains or losses, offering a deeper understanding of their impact at each phase of the game.

5.1 Pre Flop

In the pre-flop phase, luck has a greater impact, as the hole cards in the player's hand are entirely random. Players have no control over the quality of the hole cards dealt, making the range of gains or losses dependent on the volatility of the Luck. As demonstrated in the graph, luck has a smaller range of volatility, but the role of skill is also limited, and it is only reflected in a small number of betting strategies (e.g., folding, raising) with the aim of reducing potential losses or winning the pot by applying pressure.

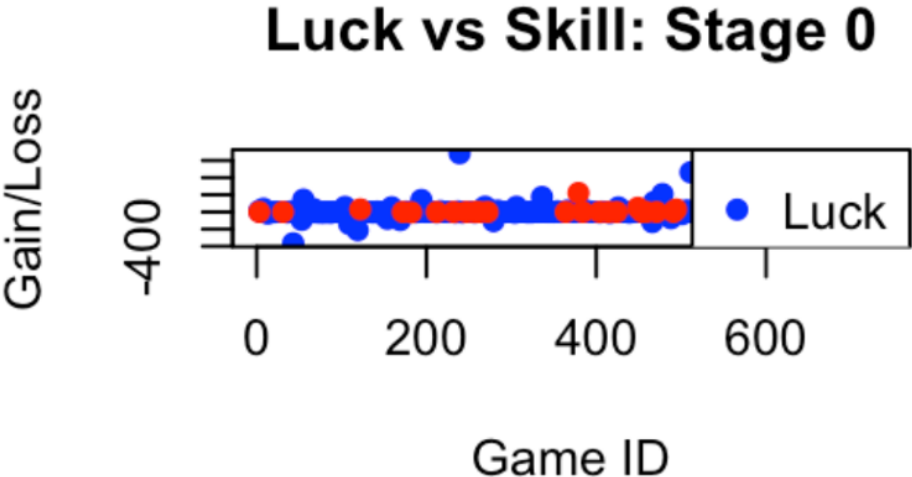


Figure 5.1: Luck vs. Skill in the Pre-Flop Stage: Trends Across Games

5.2 Flop

On the flop, both luck and skill come into play. The effect of luck comes from the three community cards that are flipped, which can dramatically alter the value of a player's hand. Skill becomes increasingly important as players analyze post-flop hand combinations and interpret opponents' betting behavior. As depicted in the graph, luck remains fluctuating, but skill shows signs of stabilizing, indicating that the player's skill is gradually taking a more important position in adjusting bets and decisions, therefore influencing the outcomes.

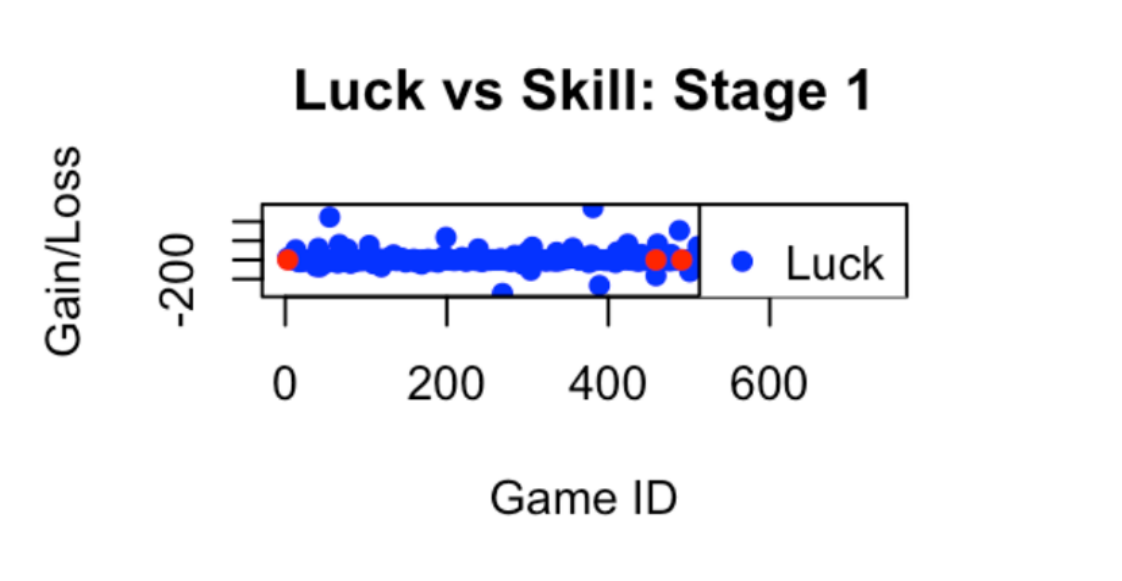


Figure 5.2: Luck vs. Skill in the Flop Stage: Trends Across Games

5.3 Turn

Luck volatility increases significantly on the turn, as the addition of a fourth community card can change the situation of the entire hand, such as making a strong hand or making the hand edge weaker. At the same time, the fluctuations in skill narrows and the performance becomes more concentrated indicating that players rely more on technical analysis at this stage (e.g. evaluating the expected value of a bet, speculating on the likely strength of the opponent's hand). The chart shows that Luck's high volatility can create substantial short-term impact, but skill starts to play a bigger role in reducing losses and amplifying advantages especially for experienced players.

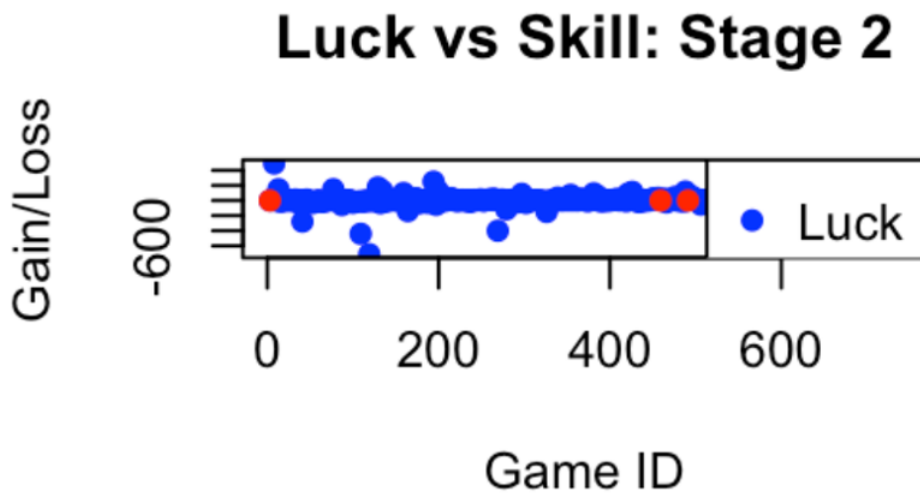


Figure 5.3: Luck vs. Skill in the Turn Stage: Trends Across Games

5.4 River

On the river, the distribution of luck and skill begins to stabilize. Luck is primarily determined by revealing the fifth and last community card. The final hand strength combination also becomes clearly visible, which removes the uncertainty from luck in earlier phases. The role of skill is further enhanced by the use of technical strategies to influence an opponent's decision-making, such as leading an opponent to raise or fold incorrectly. The chart displays that the fluctuation range of luck decreased, whereas skill is more concentrated, implying that the technique has more weight in the final decision.

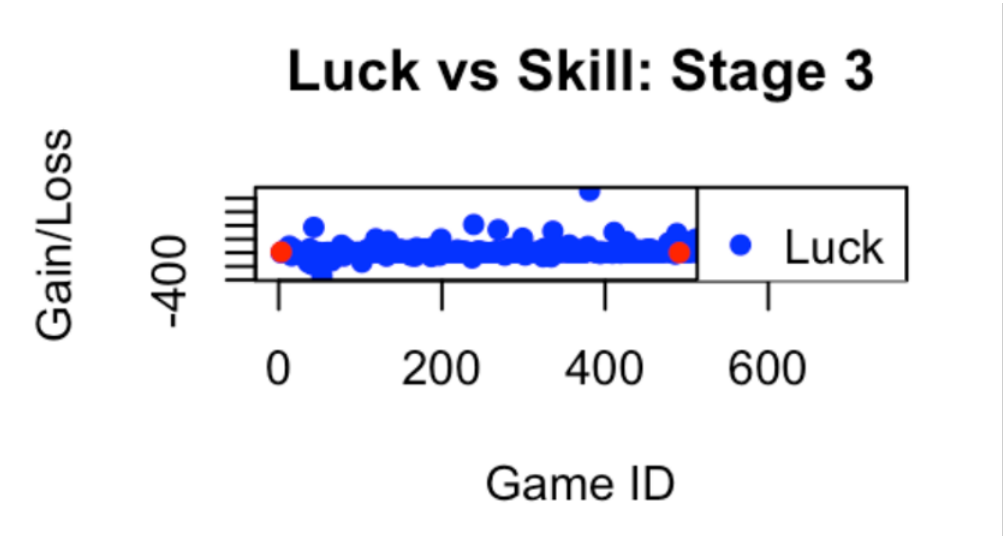


Figure 5.4: Luck vs. Skill in the River Stage: Trends Across Games

5.5 Showdown

Luck is completely dominant in the showdown phase, as the outcome solely depends on the final hand combination, and the player has no more intervention over the results. However, skill is reflected in the cumulative decisions of all previous phases, such as inducing an opponent to fold before the showdown or extracting maximum value through precise betting. As shown from the chart, the gain or loss fluctuation range of luck is more dispersed, emphasizing its unpredictable and uncontrollable nature in determining the final result. Meanwhile, the direct impact of skill appears weaker, as its role is primarily realized through prior strategic choices.

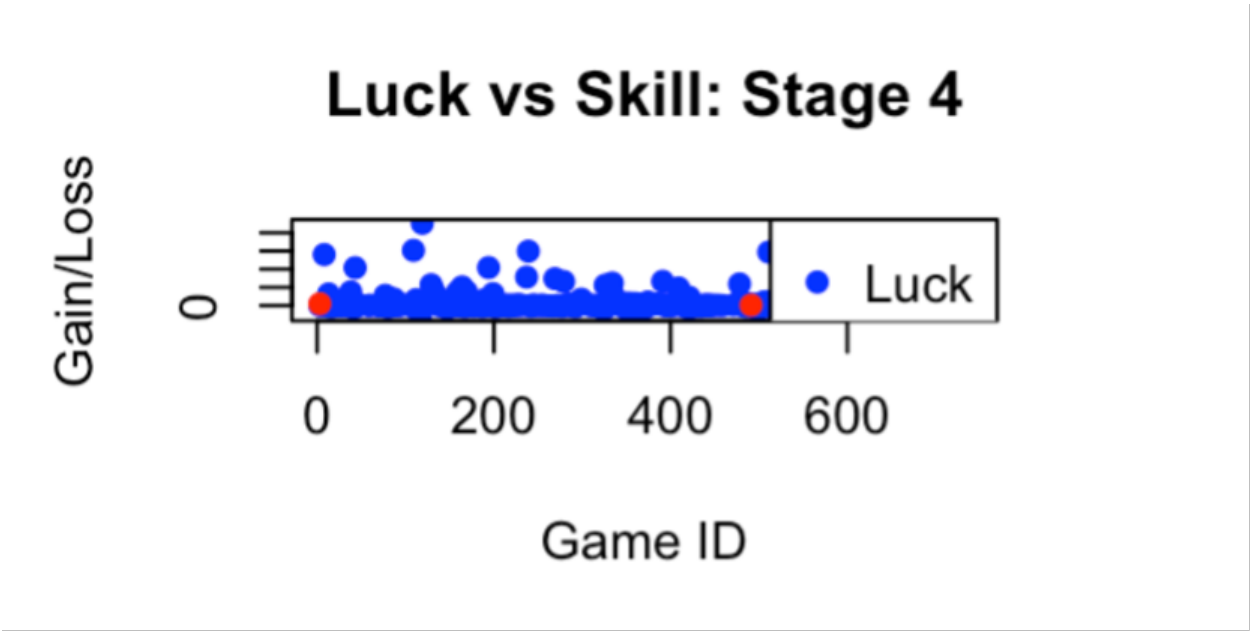


Figure 5.5: Luck vs. Skill in the Showdown Stage: Trends Across Games

5.6 Overall

This plot illustrates the variation of luck and skill across multiple games of Texas Hold'em poker. Same as above, the blue points represent the luck values, while the red points indicate the skill values for each game.

The chart reveals that luck exhibits significantly higher variability compared to skill. Luck has several extreme values, with gains or losses exceeding ± 300 , indicating that random factors, such as the distribution of cards, can heavily influence the outcomes of certain games. In contrast, skill values are more stable and concentrated, showing consistent performance across most games.

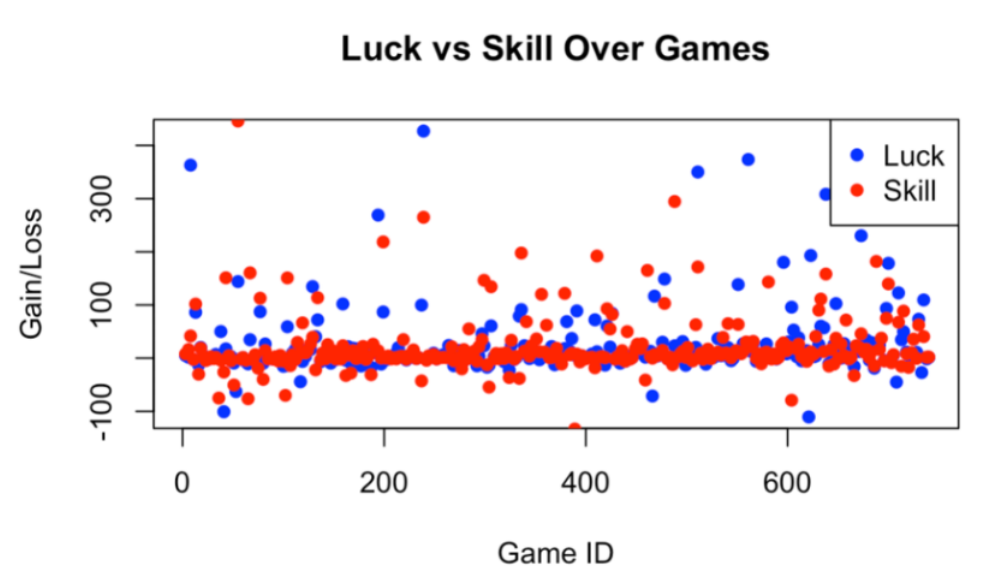


Figure 5.6: Luck vs. Skill: Overall Trends Across Games

The pie chart illustrates the proportional contributions of luck and skill to the overall outcomes in Texas Hold'em poker. Luck accounts for 55.91% of the total gains or losses, while skill contributes 44.09%. This distribution highlights the significant role that randomness plays in the short-term results of the game, emphasizing the impact of card distribution and uncontrollable factors. However, the substantial contribution of skill demonstrates its critical influence, particularly in strategic decision-making, probability calculations, and psychological tactics.

Proportion of Game: Luck vs Skill

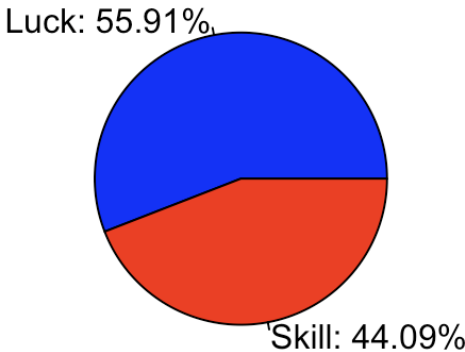


Figure 5.7: Luck vs. Skill: Contribution to Texas Hold'em Outcomes

Additionally, in the majority of games, the difference between luck and skill is relatively small, suggesting a balanced contribution from both factors. However, there are instances where luck strongly dominates, highlighting its potential to override skill in individual games. Over the long term, the consistent nature of skill suggests that it may have a more predictable and reliable impact on results, whereas luck introduces short-term volatility.

This visualization underscores the complementary roles of luck and skill, where luck

dictates immediate swings and skill provides steadiness and resilience over time, creating a dynamic balance that defines the complexity and strategic depth of Texas Hold'em poker.

CHAPTER 6

Discussion and Future Study

With an in-depth visual analysis of gains or losses at each stage of Texas Hold'em, it is clear to see the complex interplay of luck and skill over the course of the game. The performance of the different stages reveals the relative role of luck and skill in the game, and how players should adjust their strategies in each stage to maximize gains or minimize risks.

1. Strategy Adjustment and Optimization:

Players should adjust their strategy according to the characteristics of different stages. In the pre-deal and flop phases, a more conservative or probability-driven strategy can be employed due to the greater luck factor. On the turn and river, skill is more important and can rely more on opponent analysis and psychological tactics to make bold raises or bluffs.

2. Long-term strategic planning:

Texas Hold'em is a game of skill, especially in multi-hand games, where the advantages of high-level players will gradually become apparent. Therefore, players should focus on the optimization of long-term strategies and reduce emotional fluctuations caused by short-term fluctuations. Focusing on learning and improving one's decision-making skills can significantly improve long-term performance.

3. Risk Management:

Looking at the dispersion of gains or losses through boxplots and density plots allows for a better understanding of the risk structure in the game. Players should develop

a risk management strategy to avoid over-betting during the more fortunate phases, and invest more when the skill advantage is clear to balance the risk with the reward.

This study provides a preliminary quantitative analysis of the impact of luck and skill in Texas Hold'em, but there are still many unsolved mysteries. For example, how different types of players adapt to changes in the game, or what advanced strategies should be employed in a particular hand to optimize performance. In addition, in the future, machine learning and more complex probabilistic models can be combined to further explore optimal decision-making at different stages.

Taken together, this analysis not only reveals the central role of luck and skill in Texas Hold'em, but also provides valuable insights for players to improve their strategies. With scientific analysis and data support, players can continue to improve in this challenging and strategic game, and ultimately achieve more stable long-term returns.

CHAPTER 7

Conclusion

In this thesis, we explored the intricate dynamics of luck and skill in Texas Hold'em, using a systematic approach that combined theoretical analysis, statistical modeling, and empirical data from millions of poker hands. By examining the distinct roles of luck and skill across different stages of the game, we provided valuable insights into how these factors influence decision-making and outcomes.

Key Findings

1. Luck vs. Skill Dynamics:

- (a) Luck dominates the early stages of the game, especially during the pre-flop phase, where players have limited information, and outcomes rely heavily on the random distribution of hole cards and community cards.
- (b) As the game progresses, skill becomes increasingly significant. On the turn and river stages, players leverage their analytical and psychological skills to make informed decisions, mitigating the impact of randomness.
- (c) At the showdown, luck has the final say, determining the outcome based on hand combinations. However, skill plays an indirect yet critical role in shaping prior decisions that influence the eventual result.

2. Quantitative Insights:

- (a) The predictive models demonstrated that the contributions of luck and skill can be quantified at each stage of the game. Cumulative calculations of luck and

skill gains highlighted how skill offers a consistent advantage over the long term, whereas luck introduces short-term volatility.

- (b) Visual analyses underscored the complementary relationship between luck and skill. While luck creates opportunities or challenges in individual hands, skill ensures steadiness and resilience in a player’s long-term performance.

3. Practical Implications:

- (a) Players should adopt stage-specific strategies: managing risk and leveraging probabilities during luck-dominated phases while employing psychological and mathematical tactics during skill-driven phases.
- (b) The results highlight the importance of long-term strategic planning and emotional discipline in poker, emphasizing that short-term fluctuations should not deter players from focusing on consistent skill improvement.

This research contributes to the ongoing debate about whether poker is a game of luck or skill by providing empirical evidence and quantitative measures. The findings have broader applications beyond poker, as they reflect decision-making under uncertainty—a key challenge in many fields, such as finance, sports, and strategic business planning.

While this study offers a robust framework for understanding luck and skill in Texas Hold’em, several avenues for future research remain:

1. Expanding the analysis to include variations of poker and other games of strategy.
2. Incorporating machine learning techniques to simulate and optimize decision-making strategies.
3. Investigating the role of player types, psychological traits, and adaptive behaviors in dynamic environments.

In conclusion, Texas Hold'em exemplifies the complex interplay of randomness and strategy. This thesis not only sheds light on the mechanisms of this interaction but also provides actionable insights for players aiming to refine their approaches. Ultimately, the balance of luck and skill is what makes poker a unique and enduringly fascinating game.

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