Baccarat Simulation

Synapsis

"Gambling is a major public policy issue in Australia, affecting the health and wellbeing of individuals and families in a range of ways. Estimates suggest that Australians lost approximately $25 billion on legal forms of gambling in 2018–19, representing the largest per capita losses in the world (Letts 2018; QGSO 2021)."

"The social costs of gambling – including adverse financial impacts, emotional and psychological costs, relationship and family impacts, and productivity loss and work impacts – have been estimated at around $7 billion in Victoria alone (Browne et al. 2017). Gambling-related harms affect not only the people directly involved, but also their families, peers and the wider community (Goodwin et al. 2017)."

- **(https://www.aihw.gov.au/reports/australias-welfare/gambling)**

As opposed to other countries, Australia has one of the highest rate of gambling in the world, going at 80% of its citizens participating in the activity This has led to gambling being a significant public health and financial issue, with around 80,000 to 160,000 (or 0.5 - 1.0%) of Australian adults experiencing significant problems from gambling and a further 250,000 to 350,000 (or 1.4 - 2.1% of adults) experiencing moderate risks that may make them vulnerable to problem gambling.

- **(https://en.wikipedia.org/wiki/Gambling_in_Australia).**

I aim to analyse one of the popular games that's played in typical casinos in Australia to understand what kind of chances we take when we walk into the casino expecting to win, when it may just be the case that the house has already won, gaining yet another customer.

Introduction

In this game analysis, I will be simulating the common casino game called 'baccarat' and derive certain probabilities and outcomes based on different strategies such as player win and bank win. For this simulation, I will be using excel formulas to simulate the game and use data tables with the outcomes of the simulation to analyse results and gain insight on what kind of edge the house has over players in a typical casino.

Simulation

For the simulation, I will be creating a game flow first so that the formula writing process is concise and easy to understand. But first, lets study how the game of baccarat works.

Baccarat

Following the rules of one the most popular casino in NSW – Star Casino, the rule of baccarat is as follows:

Players may place a wager on either the bank or the player. Two hands (one for the bank and one for the player), each consisting of two cards, are dealt.

Later, a third card may be required for either hand. A pre-established set of rules, known as the tableau, determines the draw. The winning hand is the one that totals the closest to 9.

Baccarat is played on either a 7 or 9 playing position table. Baccarat can be played with 3, 4, 6 or 8 decks of cards. All cards from 2 to 9 are counted at face value and an Ace is counted as 1. Picture cards (Jack, Queen and King) and tens are counted as zero. When adding card totals together only the right-hand digit will be counted. For example: 6+5=11, counts as 1 in Baccarat.

The game begins with four cards will dealt: the first and third cards will be the Player's hand and the second and fourth cards will be the Banker's hand. The dealer announces the initial point totals and should either hand add up to 8 or 9, this hand is called a Natural and no further cards are dealt. If neither hand is a Natural, one additional card may be dealt to each hand in accordance with the Table of Play.

Winning bets on the Player's hand are always paid even money (1 to 1). Winning bets on the Banker's hand are paid according to the version of the game being played. Winning bets on a Tie are always paid at odds of 8 to 1.

With the Tableau being as follows:

BANKER

BANKER'S POINT TOTAL:	WHEN PLAYER'S THIRD CARD IS:	WHEN PLAYER'S THIRD CARD IS:
0-1-2	Draws	
3	1-2-3-4-5 6-7-9-0: Draws	8 Stands
4	2-3-4 5-6-7 Draws	0-1-8-9 Stands
5	4-5-6-7: Draws	0-1-2 3-8-9 Stands
6	6-7: Draws	0-1-2-3 4-5-8-9 Stands
7	Stands	
8-9	Has a natural, therefore no more cards to either player or banker	

PLAYER'S HAND THIRD CARD RULE

PLAYER'S FIRST TWO CARDS TOTAL:	PLAYER'S HAND
0-1-2-3-4-5	Draws a card unless the banker has a natural
6-7	Stands
8-9	Natural stands

NB. Banker must stand on 6 and 7 on the initial deal when a Player has 6 or 7 on the initial deal. Banker must draw on 0-5 when a Player stands on 6 or 7 on the initial deal. There are no optional draws.

With this, the game flow is created:

player hand																	
8-9																	
yes (stand)			no														
p_hand_1 vs b_hand_1			banker hand														
>	<	=	8-9														
player win	banker win	tie	yes (stand)			no											
			p_hand_1 vs b_hand_1			player hand											
			>	<	=	0-5											
			player win	banker win	tie	yes (draw)						no (stand)					
						banker draw (tableu)						banker hand					
						yes (draw)			no (stand)			0-5					
						p_hand_2 vs b_hand_2			p_hand_2 vs b_hand_1			yes (draw)			no (stand)		
						>	<	=	>	<	=	p_hand_1 vs b_hand_2			p_hand_1 vs b_hand_1		
						player win	banker win	tie	player win	banker win	tie	>	<	=	>	<	=
												player win	banker win	tie	player win	banker win	tie

And the tableau rewritten to reference in the simulation:

		banker									
		players third card									
		0	1	2	3	4	5	6	7	8	9
bankers point	0	draw	draw	draw	draw	draw	draw	draw	draw	draw	draw
	1	draw	draw	draw	draw	draw	draw	draw	draw	draw	draw
	2	draw	draw	draw	draw	draw	draw	draw	draw	draw	draw
	3	draw	draw	draw	draw	draw	draw	draw	draw	stand	draw
	4	stand	stand	draw	draw	draw	draw	draw	draw	stand	stand
	5	stand	stand	stand	stand	draw	draw	draw	draw	stand	stand
	6	stand	stand	stand	stand	stand	stand	draw	draw	stand	stand
	7	stand	stand	stand	stand	stand	stand	stand	stand	stand	stand

cards												
1	2	3	4	5	6	7	8	9	0	0	0	0

Now that the setup is done, we simulate the game.

Step 1

First, we simulate 6 hands: 3 cards for the player, and 3 cards for the bank (house). We do this bye selecting one the 13 cards from the deck as the dealer would in baccarat:

=MAKEARRAY(10000,6,LAMBDA(r,c,INDEX('deck & rules'!B33:N33,1,RANDBETWEEN(1,13))))

This creates 10,000 separate rounds of 6 hands. The cards are referenced from the above 'cards' table which yield its value (face card value as 0, and the rest corresponding to its value). Thus, we have the table:

p_1	p_2	p_3	b_1	b_2	b_3
4	7	8	6	5	0
0	2	0	0	0	3
7	7	6	9	3	5
0	0	5	7	0	5
0	8	2	8	0	1
1	7	6	0	0	0
0	0	8	0	9	8
3	0	6	4	0	9
3	6	8	7	5	3
5	1	4	0	2	4
5	0	2	5	1	0
6	0	5	0	3	0
0	0	3	1	8	7
0	0	0	6	0	7
0	0	3	2	3	7
1	5	0	1	3	9
8	4	0	6	1	1
8	2	0	0	3	9
2	2	2	0	0	6
8	0	0	9	0	9
4	2	3	0	6	7
4	3	4	0	1	0
2	2	4	6	7	7
3	8	0	7	3	0
5	0	2	2	0	5
8	8	8	0	2	0
3	9	1	5	3	4
0	2	7	3	9	8

P_1 to p_3 corresponding to the 3 player cards and B_1 to B_3 corresponding to bank hands.

Step 2

Now that we have all the hands necessary for any situation of a round, we calculate the points of each player and banker hand:

=IF(A2+B2>9,A2+B2-10,A2+B2)

This yields the value of the first player hand. According to the rules of baccarat, any total value over 10, the single digit of the number is the total value. E.g. a 9 and 6 equals 15 but the 10 is disregarded therefore the total value is 5. This returns another table:

p_hand_1	b_hand_1	p_hand_2	b_hand_2
1	1	9	1
2	0	2	3
4	2	0	7
0	7	5	2
8	8	0	9
8	0	4	0
0	9	8	7
3	4	9	3
9	2	7	5
6	2	0	6
5	6	7	6
6	3	1	3
0	9	3	6
0	6	0	3
0	5	3	2
6	4	6	3
2	7	2	8
0	3	0	2
4	0	6	6
8	9	8	8
6	6	9	3
7	1	1	1
4	3	8	0
1	0	1	0
5	2	7	7
6	2	4	2

Step 3

Finally, we can simulate each round and return the outcome based on the previously created gameflow:

```
=IF(G2>7,
    IF(G2>H2, 1, IF(G2<H2, 0, 2)),
    IF(     H2>7,
            IF(G2>H2, 1, IF(G2<H2, 0, 2)),
            IF(       G2<6,
                      IF(         XLOOKUP(C2,'deck & rules'!$D$22:$M$22,XLOOKUP(H2,'deck & rules'!$C$23:$C$30,'deck & rules'!$D$23:$M$30))="draw",
                                  IF(I2>J2,1,IF(I2<J2,0,2)),
                                  IF(I2>H2,1,IF(I2<H2,0,2))),
                      IF(H2<7,
                         IF(G2>J2,1,IF(G2<J2,0,2)),
                         IF(G2>H2,1,IF(G2<H2,0,2))
                         )
                )
        )
    )
```

The results will be categorized into 3 different outcomes: 1 for winning, 0 for losing and 2 for a tie.

outcome
1
1
1
0
1
1
1
0
0
1
1
0
2
2
2
2
0
1
1
1
0
1
0
1
2
0
1
0
1
0

Result

Now that we have data, let's analyse how the game has played out. First, let's have a look at the general statistics of the 10000 games such as the player, banker and tie win rate.

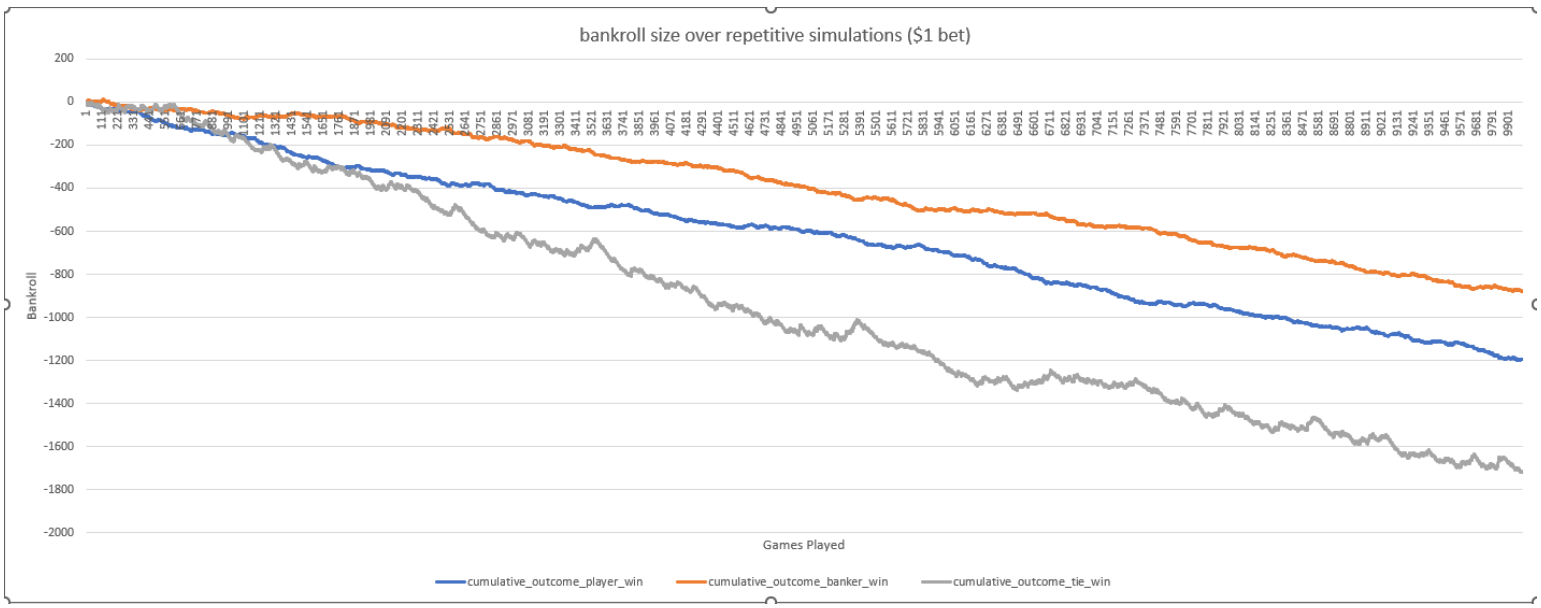
simulations	player_winrat	bank_winrate	tie_rate	max
10000	46.04%	45.27%	8.69%	5

Observing the above results after refreshing the simulations, both player and banker win rates vary around the 45-46 percent range, with the tie win rate ranging from 8 to 9 percent.

Let's analyse the lifespan of a gamblers bankroll when they play baccarat: their choices are to bet on either the player, banker, a tie, or a mix of all three. We will calculate the win rate, house edge, expected value, their peak balance, and the balance by the end of the 10000 games. But before that lets go over some definitions:

- **House Edge**: The House Edge is a term used to describe the mathematical advantage that the gambling game, and therefore the commercial gambling venue, has over you as you play over time. It can be understood that if the house edge is 10%, then for every game you play, the house, or the casino, earns 10% of your wager for that game.
- **Expected Value**: The expected value (EV) is an anticipated average value for an investment at some point in the future. The EV in a gambling or betting context, is the opposite of the house edge – e.g., if the EV is 10%, the player is statistically expected to earn an average of 10% of their wager over time.
- **Peak balance**: the peak balance in this report will be the highest amount of money reached over the span of 10000 rounds/games.

strategy									
player_win					bank_win				
winrate	house edge	EV	max	min	winrate	house edge	EV	max	min
44.03%	11.94%	-11.94%	-1	-1199	46.77%	8.80%	-8.80%	12.45	-880.75
tie_win									
winrate	house edge	EV	max	min					
9.20%	17.20%	-17.20%	0	-1721					



Upon quick glance, for any strategy, the house always has an edge, with betting on player win being fairly similar to betting on the bank win (as bank wins have a payout of 19/20 of the wager or a 5% 'tip'). Betting on solely the game resulting in a tie yield the worst win rate and expected value although the bankroll being more volatile as tie wins have a payout of 8 to 1. By the end of the runs, it is guaranteed that the bankroll will have dropped far into the negatives every time. This is a demonstration of the Law of Large Numbers.

Law of Large Numbers

"In probability theory, the law of large numbers (LLN) is a theorem that describes the result of performing the same experiment a large number of times. According to the law, the average of the results obtained from a large number of trials should be close to the expected value and tends to become closer to the expected value as more trials are performed.[1]

The LLN is important because it guarantees stable long-term results for the averages of some random events."

- https://en.wikipedia.org/wiki/Law_of_large_numbers

According to this theorem, we can calculate that with an expected value of -10% over 10,000 games, we win $(wager)*(Expected Value) *(Number of Games) = 1*-0.1*10,000 = -$1000 dollars betting $1 each game for 10,000 games, which is accurate with the results of the simulation.

Insight / conclusion

With simulation, we can prove that every game in the casino is a losing game in the long run and realise that the casino, although lose to the players sometimes, are winners at the end of the day. It is with almost complete certainty that it is impossible to beat the casino according to law of large numbers, and we understand how the casino stays in business when it seems that it is an establishment which gives customers a chance to multiply their money.

Gambling, as well as betting, given one must participate in it, should be enjoyed lightly like an arcade game, and never as a means to earn money, especially in the long run.