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A Quantitative Analysis

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BACHELOR'S THESIS

**The Pre-Flop Game in Online Poker
A Quantitive Analysis**

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1 Introduction

After its foundation in 1998 online poker evolved to a multi-billion dollar industry leading to thousands of games played every day worldwide. At its peak in 2009 the revenue of the online poker industry was estimated to be over 2.4 billion dollars (c.f.[8]).

The obvious incentive to win money usually leads players to choose the best strategy they are capable of in order to maximize profit. This makes players' behaviour an interesting topic to analyse, as a strategy which reduces profits can be considered to be irrational. Furthermore, a great amount of data about online poker games is easy to acquire due to the vast amount of games played every day.

Consequently, a lot of research was conducted about online poker within different fields of science, as it is interesting concerning players' behaviour and statistical analysis is possible due to extremely much data available. Research concerning poker can be divided into three major groups. One: poker is used for computer science to research the topic of artificial intelligence, two: it is examined whether it should be categorized as a game of skill or not and three: the social and psychological aspect, especially focusing on gambling addiction.

The first ever published article about poker was written in 1995 before the foundation of online poker, taking first steps to create a program to solve Texas Hold'em poker using artificial intelligence (c.f.[6]). After this first approach the University of Alberta founded the computer poker research group in which poker is examined for artificial intelligence, first theoretically and afterwards using online poker data. Modelling opponents (c.f.[23]) and dealing with imperfect information (c.f.[27]) was researched broadly, before in 2016 the first superior poker program was created, solving heads up limit Texas Hold'em poker (c.f.[7]). This is considered to be a breakthrough concerning the topic of artificial intelligence and machine learning.

Online poker was restricted in the USA and several other countries on the so called "Black Friday" in 2011 due to legal components of online gambling(c.f.[8]). This rose the question whether poker is a skill game or not, leading to a lot of research and publications, since all legal restrictions only apply to gambling games not to those relying on skill (c.f.[15],[22],[18]). All articles considered poker to rely at least partly on skill. [18] concluded strong evidence that poker is a game of skill within his research. Such publications lead online poker to recover again to some extent because restrictions were less and less enforced.

Further, there is a lot of research conducted about social and psychological aspects of online poker, mainly focussing on pathological behaviour and gambling addiction(c.f.[4],[19],[24]). Results established online poker to be a threat for many people involved. The so called tilting, meaning to loose control over the decision taking process because of emotions, can be observed as a common feature in online poker. The influence of emotions and psychological aspects on strategy and rational behaviour is stressed within of this research.

To the best of our knowledge the development of poker over the past years and the behaviour of poker players when being pressured by an opponent have not been researched yet. These two topics contribute to previous research as an improvement in strategy would suggest the game to rather depend on skill than on chance. Furthermore, the reaction towards pressure highlights psychological aspects of the game which, to some extent, might be generalizable to different fields of human behaviour. The rise of various poker schools like pokerstrategy.com or twoplustwo.com should have increased the level of skill involved in online poker and changed the way poker is played to some extent. The number of members on pokerstrategy.com increased from 1.8 million in 2008 to over 7 million members in 2015. As a consequence, the website became by far the largest poker community (c.f.[3]).

To conduct this research we examine the pre-flop game, hence the first round of betting with each player only holding two cards. This is very suitable as it is simple concerning players choices, but still contains all the interesting features of betting, strategy and pressure.

In this thesis we will conduct statistical analysis with two datasets, one from 2009, the other from 2015 in order to examine differences and improvement of strategy over the years, which might be caused by the rise of poker schools. We will analyse how online pre-flop poker has changed the past six years by first providing a descriptive analysis of the decisions taken and later focus on the reaction under pressure. Pressure is hereby defined as the least amount of money a player is forced to bet (by an opponent) in order to stay in the game. Additionally, we will examine if strategic improvement can be observed over the years, which would contribute a reason for poker to rather be skill game.

Possible reasons for a change in poker players' pre-flop behaviour are restrictions to play online poker in the US (c.f.[8]) and the use of tutorials and literature, being now more available(c.f.[1]).

We will examine in more detail how players react when being put under pressure pre-flop and to what extent this leads to irrational behaviour. There will be several explanatory approaches provided, for certain strategical patterns of players if being pressured.

This thesis will show how the pre-flop game has changed the past years by using previous research conducted and statistical analysis of two datasets each from a different year.

2 The Pre-Flop Game - Overview

As mentioned, this thesis will only focus on the first round played in Texas Hold'em poker games, also referred to as the pre-flop game.

There are no common cards dealt yet which would have to be considered for post flop analysis, thus pre-flop analysis is easier to understand and more clearly concerning strategical patterns.

According to the biggest online poker strategy web site the pre-flop game is crucial for any poker player, thus we can expect players to put a lot of thought into their decisions (c.f.[1]).

The pre-flop game starts with the two players sitting behind the player in "button" position. Both have to contribute a mandatory size of money to the pot before seeing their cards - the first player behind the button, the so called small blind, the next one the big blind, usually double the size of the small blind. Afterwards, every player is dealt two cards face down, which the players are allowed to see.

Later, there are several rounds of betting starting with the player sitting behind the big blind and further on moving clockwise, in which every player - depending on the previous actions of their opponents - has the option to check, call, raise or fold.

While checking (staying in the game without contributing any further money) is only possible if the necessary amount of money is already contributed to the pot, which in our case is only possible for the big blind position if no one before him decided to raise, the other three options deal with a difference between the amount of money the player has already committed to the pot and the amount necessary to proceed in the game. Folding means quitting that round while calling means putting the minimum amount of money forward that is necessary in order to stay in the game. To bet even more than the minimum necessary is called raising and puts pressure on any other player still participating in this round of the game, as all the other players have to adjust afterwards to this amount to stay in the game.

The flop is dealt as soon as potential raises are called by at least one other player. The game is won if a raise is not called by any other player, hence the flop does not have to be dealt.

Afterwards, there are several rounds of betting and common cards shown, which is called the post-flop game but this will not be examined within this thesis.

As soon as one player's raise is not called or all common cards are dealt resulting in a showdown, the player holding the best combination of cards wins, the round ends, the button moves one position clockwise, the blinds are put forward and new pocket cards are dealt (c.f.[5]).

Overall, there are three parts of analysis within this thesis, two descriptive ones and one using statistical inference and multi-layer modelling.

First, there is a broad overview provided on pre-flop decisions within the years of 2009 and 2015. Afterwards, the percentage of players reaching the flop separated by year, the number of players at each table, the size of the blind and the positions is demonstrated within a bar chart. These two steps should introduce the reader to the pre-flop decisions and give a general overview of the pre flop game itself.

The following analysis focuses on the influence of pressure on the probability for a player to reach the flop, within the two different years. The pressure is the minimum amount of money a certain player has to contribute to the pot to further proceed in the game. Explanatory approaches of several kinds are delivered afterwards.

3 Sampling Theory and Variables Examined

All the data used is acquired from the online poker tracking site hhsmithy.com. The kind of poker analysed is Texas Hold'em no limit, in which raises are only limited by the size of the players' total amount of money involved in the game, also referred to as the stack. All players are able to bet the entire money they are enrolled with as long as they have not folded already.

This way of playing poker is more risky and popular than Hold'em limited within the online poker community, even though risks are less calculable and severe losses are possible within one hand. Psychologically speaking, this makes the game more exciting hence more popular especially to gambling addicts.

The data only contains games with three to six players at each table, which are also referred to as short-handed tables and are the most common ones.

We chose to analyse games being played at NL100 and NL200, which imply 0.5-1\$ and 1-2\$ blinds for each game and buy ins of 100\$ or 200\$.

These limits are played very frequently. NL100 and NL200 is played mostly by advanced or intermediate players thus only few professional players and beginners are found on such limits.

The level of skill naturally rises with the size of the big blind as people who strive to win more money try to play on higher limits. The analysis benefits from the fact that very few beginners or "rookies" are involved in these limits who might provide difficulties because of randomness throughout their strategies (c.f.[26]).

With these limits we can expect players to have a big incentive to win and thus will play most of the time as accurately as they are capable of. Consequently, they provide good data for analysing the development of poker strategy throughout the years.

This separation by blinds offers the opportunity to examine two slightly different groups of poker players, as one group has twice as much money involved than the other.

Overall, there are datasets for two different years used, each containing about 15 million hands played, which are themselves divided into two subsets each of the size of about 7.5 million hands representing the two limits, mentioned above, they are played on.

One set contains data of hands played before the black Friday of poker in July 2009, the other, more recent data, starting in July 2015.

Both datasets are tracked from major poker sites used all around the globe.¹

This leads to a dataset containing about 30 million hands played. Such a great sample is very bias resistant and ensures statistical significance throughout most models, thus enabling generalization to some extent.

There are fewer hands available from tables with less players involved because a lot of players prefer tables with five or six players. Overall, nearly 60% of hands analysed are played at a six players table, 31% at tables with five people leaving fewer hands for the other two. Unfortunately, this makes analysis with data containing fewer players at a table more bias prone.

¹Full Tilt Poker, Party Poker, Poker Stars

In the year of 2009 before "Black Friday" more people played poker online than in 2015, hence the data from the year of 2015 is played during a longer period of time.

For each player there are several variables examined.

The pre-flop decisions are separated in rounds of betting, which always provide the action taken each turn of a certain player. The most turns one player has during the pre-flop game are three, hence there are three variables representing each turn for every player.

Further, there is a variable showing whether the player reaches the flop, so if he folded during one of his turns or not. Winning the round within the pre-flop game is also considered as reaching the flop.

One further binary variable provides the year the game was played in and another one the size of the big blind. Additionally, the number of players at each table is given in form of a variable.

Furthermore, the pressure for any player is provided for each possible round of betting, leading to another three variables. This variable states the minimum amount a player has to contribute to the pot to stay in the game measured in big blinds, thus quantifying to some extent the previous actions taken of their opponents.

The position at the table is also provided within a variable.

There are at most six different positions at a table which are sitting clockwise. The button (BU), the small blind (SB), the big blind (BB), the middle position one (MP1), the middle position two (MP2) and finally the cut-off (CO). If there are fewer than six players the late positions do not exist leading to a table with only button, small and big blind at a table with three players. All these positions imply strategic aspects which will be discussed in chapter four.

Overall, there are ten variables examined and analysed for one player.

4 Pre-Flop Actions - A Decision Tree

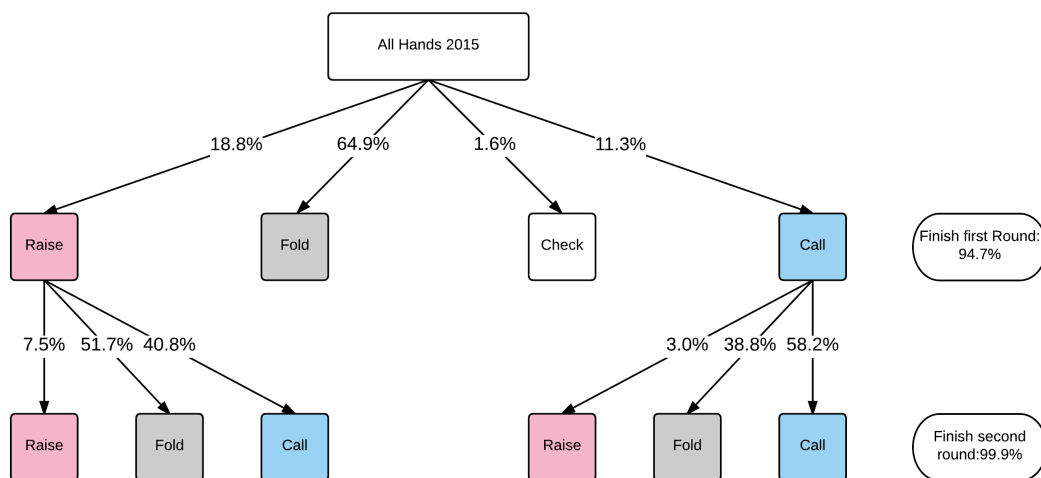
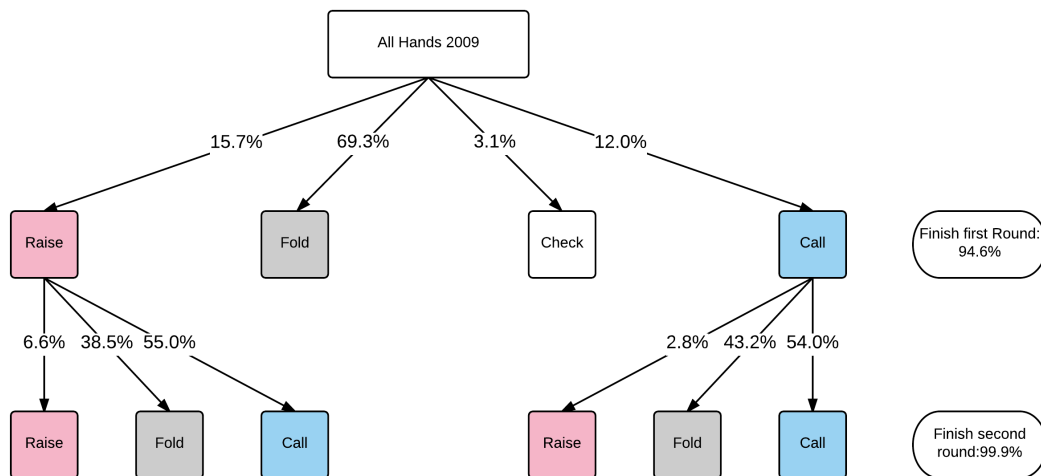


Figure 1: Decision Tree

A general overview of pre-flop decisions, decision-combinations and their frequencies is provided within this chapter. The decision tree provides a visualisation of players' decision in every round of betting depending on their previous choices.

A tree is shown for the years of 2009 and 2015.

As soon as all raises are called or the game is won, the pre-flop game is finished in that particular round and there is no need for another round of betting.

The probabilities inside the decision tree refer to the rounded percentage with which one player takes the given option. All probabilities add up to 100%.

In either year, the first level of the tree is the most important one, as nearly all pre-flop games are decided within this first round of betting. For the year of 2009 94.6% of the games did not have a second round of pre-flop betting while in 2015 94.7% did not.

Within the second round of betting over 99.9% of the pre-flop games are decided in both years, making observation of the third round of betting not necessary due to the size of the data affected.

If checked or folded during the first round there is no need for a second round of betting for this particular player. As only the big blind position can check if all the previous players either folded or called, he automatically reaches the flop by calling. By definition, folding ends the game for the player.

For a second round of betting there has to be at least one call challenged with a raise or one re-raise. Subsequently, for a third round of betting there has to be at least one further re-raise, which is very rare and, most of the time, leads to all-in pushes. (c.f.[5]).

Overall, the percentage of each pre-flop choice is a good indicator to see whether strategy has changed within the years, thus directly refers to the thesis about improvement over the years.

According to [24] a more aggressive style of play improves chances for a positive payout. Thus we could expect players from 2015 to pressurize opponents more frequently and severely. Concerning poker strategy, counter intuitively folding is considered to be more aggressive than calling, because weak calls are usually not practicable to be played aggressively.

The most common and recommended strategy seen on online tutoring sites is the tight-aggressive style, which implies only to play few starting hands, but those aggressively(c.f.[1]). In consequence of this strategy, one would expect to see more raising and folding and less calling for the year of 2015 compared to 2009 in the decision tree provided.

For the first round of betting 15.7% of players in 2009 and 18.8% of players in 2015 decided to raise. The difference of 3.1% might not seem tremendous, but it is both significant according to significance tests (P-value beneath computer accuracy within chi-square and exact binomial test) and has a severe impact on the pre-flop game itself. In other words, the amount of raises the first round of betting has such a great impact on any player, that even slight changes severely affect the game.

Furthermore, twice as many people checked in 2009 (3.1%) than in 2015, suggesting that more players in big blind position were not pressured at all in 2009. Hence the aggression level should be beneath the one in 2015.

Overall, fewer players folded in 2015 with 64.9% than in 2009 with 69.3%.

This does not hold with the theory of the game improving over the years, as litera-

ture suggests to fold frequently(c.f.[24]).

The ratio of players calling is relatively equal within the years, with 12.0% in 2009 and 11.3% in 2015.

According to an exact binomial test, examining if the differences between the two years are significant, all the differences for each decision taken the first round are significant with P-values beneath computer accuracy. Hence the values are significantly different beyond any doubt. This can be traced back to the big number of observations, in which even 12.0% to 11.3% is significantly different.

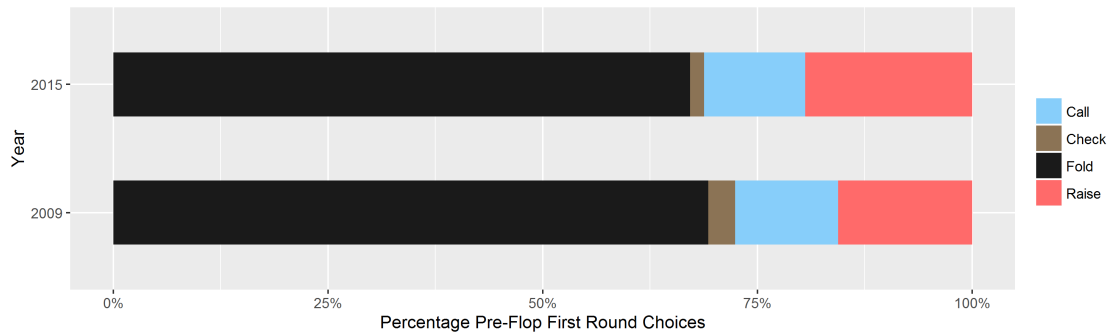


Figure 2: Bar Chart - First Round of Betting

Figure 2 visualizes the differences of the first round of betting pre-flop, showing how the strength of cards with which a certain option is taken differs in the years. We can conclude from more raises made in 2015 that they have to be made with on average weaker hands than in 2009, because raises are made with on average stronger hands than calls, which themselves are usually made with stronger hands than folds. We can further conclude that players called with worse hands the first round in 2015, due to more folding in 2009. This leads to the strength of the pocket cards with which was called in 2015 ranging from the 72.5 to 84.4 % of starting hands arranged according to their strength and from 64.3 to 80.5 % in 2009. All in all, the first most important round of betting suggests a major difference between the years.

These numbers only live partly up to the expectations. We can conclude that actions have become more aggressive as people decided to raise with weaker hands. (If raised more weaker hands have to be involved.) On the other hand fewer people folded in the year of 2015, leading to calls with weaker hands than in 2009. The difference between the years is quite high, the first round of betting suggesting a change of strategy over the years.

The second round of betting is, as explained above, only possible for a players who has called or raised the first round and whose hand is questioned by another raise.

This was the case for 5.4% of players in 2009 and 5.3% of the players in 2015. Although only few player reach the second round due to those reasons, it is very

interesting to examine, as the second round delivers insights into strategic aspects and the players' reaction towards pressure. Players reaching the second round of betting have already contributed money to the pot, increasing the overall probability to stay in the game, as they want to protect their investment.

Starting with the options after a call first round 43.2% of players in 2009 decided to fold, facing the second round while in 2015 only 38.8% did. Consequently, in 2009 more people did not consider their hand to be strong enough as they were challenged to continue in the game.

Even though the hands with which was called in 2015 were as established before weaker, more players decided to keep on playing their hands when being raised. This suggests that players tend to play their hands more aggressively as soon as they decide to stay in the game first round in 2015, leading to higher risks. It is dubious if such a strategy is better.

There are 3.0% of re-raises in 2015 and 2.8% in 2009, signalling a very strong hand or attempt to bully a raise out of the game. Thus again, there was more aggression in 2015. The scenario of a re-raise after a first round call rarely occurs, as calling first round does usually not suggest a very strong hand. Even though players in 2015 used wore cards for calling first round, there were slightly more re-raises within the second round than in 2009.

The method of re-raising when the first round call is challenged seems very odd. If the cards were not strong enough for a first round raise, they are usually not strong enough for a very risky second round re-raise. The strategy would only make sense if a player is holding one of the best possible hands and is willing to wait for the flop, to get paid more compared to a situation in which everyone else folds to a pre-flop raise. This strategy is very risky and usually not recommended. The re-raise would further make sense if a player is certain another player wants to bluff him out of the pot.

Consequently, there were fewer calls in 2009 (54.0%) than in 2015 (58.2%), again proposing a more aggressive style of strategy in 2015.

The options after a first round **raise** differ from the ones after a first round **call**, as a first round raise usually already suggests a very strong hand.

More players decided to(re-re)raise with 7.5% in 2015 and 6.6% in 2009. Once again, the more aggressive choice was more common in 2015 than in 2009. Note that a re-raise is more probable in 2015 although the average hand with which was initially raised is on average weaker. This is no sign of irrational behaviour as the 7.5% of the re-raised will most likely be those that are very strong indeed.

The major difference between the years can be seen within the other two options.

In 2009, only 38.5% folded while in 2015 51.7% did. A player would only fold against a re-raise if he considers his opponent's cards to be stronger than his own. This huge difference suggests that people in 2015 raise with weaker hands in the first round comparing the year of 2015 and 2009, making the game more aggressive.

There are several reasons which could explain this huge difference between the years, one of which is the in [11] researched strategy of pre-flop blind stealing. Using this strategy a player pressures the big and small blind, often in late position in order

to bluff them out of the game and thus collecting the blinds. But if a player faces a strong hand in small or big blind position he might get re-raised hence is forced to fold.

The ratio of calls is consequently lower in 2015 (40.8%) than in 2009 (55.0%).

All the analysis of pre-flop decisions emphasises the differences between the two years and even though there are mixed results concerning improvement over the years, poker strategy has certainly changed over the years.

5 Probability to Reach the Flop - A Bar Chart

This second overview provides the probability of reaching the flop for any player regarding several preconditions. The preconditions, hence variables the data is separated by are the size of the big blind, the year the game was played in, the number of players at each table and finally the position of each player.

Figure 4 takes the first step to analyse the players' decision making process, but is only regarding the categorical variables mentioned above. The chance to reach the flop for one certain player is the most important variable for the rest of the analysis, because with this variable a huge variety of interesting features of the pre-flop game can be seen. After all, a player cannot win, if he does not reach the flop. It has to be mentioned that the target variable is binary and thus chances are calculated by the mean of the variable over all players affected. Such procedures are originally bias prone, but the extreme high number of observations makes individual variance nearly irrelevant. This approach holds the basic information about pre-flop decisions considering all categorical variables used.

The main subject of this chart is to provide some insight into important pre-flop conditions and to show the probabilities themselves. The overview also helps to understand more thorough analysis in chapter 6 and makes comparison of the two years and the interaction of the year with all other variables possible. All the influences of these variables will be interpreted in depth. Further, the years influence on all the other variables will later be examined. Thus, we will see more precisely how big the influence of the variable year is.

The chart provides all interactions between the variables but only the interaction of the year with the other ones is interpreted. It has to be mentioned that the number of observations differs severely between the categories observed. The table provided beneath the chart shows how many observations the analysis was conducted with in every category.

First, we start with the number of players at each table which, according to pokerstrategy.com ([1]), completely changes the pre-flop game. Concerning tactics, strong hands will try to eliminate weak hands within the pre-flop game (to avoid to lose to a lucky hit on the flop)(c.f.[2]). Thus, more people sitting at a table should decrease the chance to reach the flop for the individual. Further, a table with fewer players has a higher percentage of players contributing a blind, which players would like to protect by at least calling.

Categories of Players: Chance to Reach the Flop

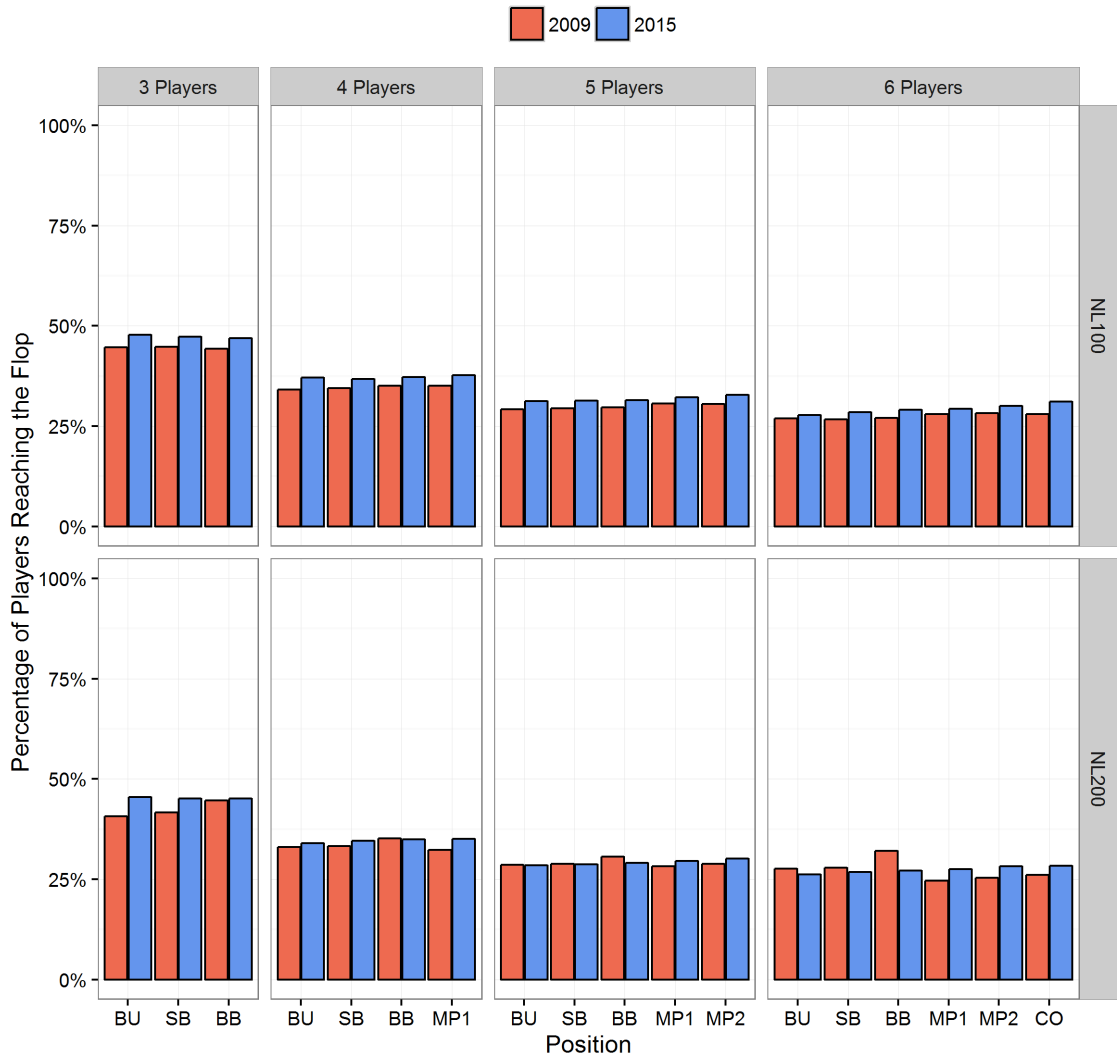


Figure 3: Bar Chart - Overview of the Influence of all Categorical Variables

Table 1: Number of Observations for each Segment

Number of Players	Limit	Observations
3	100	345902
3	200	253012
4	100	896461
4	200	963188
5	100	3438103
5	200	4484078
6	100	8601132
6	200	7874239

Results within the data and bar chart meet the expectations. The probability to reach the flop decreases from 45.9% at a table with three players to 27.8% at a table with six players.

This influence, even though its huge impact, is not interesting for our strategical analysis, as it could be argued that a different number of players at a table changes the game completely and thus different numbers of players at a table would have to be examined separately.

Secondly, we take a look at the influence of the blind's size. According to various research the increase of the blind evokes a skill-increase of the players involved (c.f.[24][14]).

This is also used as an argument to stress the importance of skill in the game(c.f.[16]). As it can be argued, if the increase of a blind increases the skill level as well, skill overall plays a very important role in the game and even might be quantifiable. If poker was a pure game of luck there should be no difference.

Looking at the data the probability to reach the flop declines from 30.1% to 28.7% with an increase of the blind.

There is no generalizable opinion about the percentage which a player should reach the flop with, because sources differ on this aspect by promoting different styles of poker strategy such as loose aggressive (reaching the flop frequently) or tight-aggressive. Thus, skill related conclusions can not be drawn easily.

One could argue that slightly less people reaching the flop hints towards more aggressive play, but whether the level of skill actually improved can not be concluded without doubt.

The at most six different positions at a short handed poker table all have different tactical implications. General opinion promoted within strategical websites is that positions improve the later it is their turn to move the first round, with the exception of the two blinds, as they already have to commit money to the pot before seeing their cards (c.f.[1]). One reason for the improvement of later positions is that those positions already gained information about their opponents, whose turn it was before them and thus have lower risks to be raised by a strong hand sitting behind them.

The percentage of players reaching the flop in the two positions posting a blind provides information about the aggression of the players before them, as already mentioned in chapter 4. Because the more aggressive the game gets the more pressure lies upon those two late positions, thus increasing their probability to fold.

The data does not confirm this assumption as expected.

As easily recognizable due to the order of positions within the bar chart, the earlier positions are not always less likely to reach the flop.

Furthermore, there are generally just a few differences between the values (for six players it ranges from 28.5% of the BB to 27.5% of the MP1 and even only 27.1% of the BU).

Consequently, the influence of the position is not considered by the players of both

years to be as important as literature suggests. Different positions do not influence the probability to reach the flop as expected. Either players do not act according to the strategy suggested by literature, or reaching the flop is just not very dependent on the position but rather on other variables.

Now for the years there is some difference expected. As this thesis examines whether the game has changed over the years we should expect difference. According to the information provided in chapter 4 one might expect the number of players reaching the flop to be smaller in the year of 2015 due to the more aggressive style of the game.

Looking at the chart the opposite is the case. In 2015, 30.3% of all players reached the flop while in 2009 only 28.5% did.

Even though this result was not expected it does not automatically conclude anything about the skill of the players involved. Because as mentioned, it is not clear whether a high percentage of players reaching the flop means a decline in skill.

The difference between the years is overall quite high. The combination of more raises while more people reach the flop does not seem to make any sense but there are some possible explanations. It hints towards a difference between the approach of dealing with pressure within the years, because even though more players are pressurized within the dataset of 2015 more players reach the flop.

Further, we will take a look at the interactions between the year and the other three variables. We might expect the influences of the other three variables to be bigger and more diverse in 2015, because the game should have developed to be more analytical and consequently all factors should be given a bigger importance. But the real data varies vastly due to strategic reasons, as some influences might not be considered as important as well in 2015. Consequently, it is not easy to predict or expect anything from these interactions, but one can definitively draw some conclusions with the results.

As mentioned before the number of players has a big influence and now we will examine in which year the influence is even more important.

According to the data, the number of players reaching the flop in 2015 ranges from 46.6% with three players at a table to 28.2% with six players at a table. The difference is bigger than the one of 2009 with 42.9% to 27.5%. Even though the differences between the number of players is more important in 2015 it seems difficult to conclude anything about strategy but we could guess that people in 2009 are less aware of the consequences of a different number of players at their table.

The influence of the blind's size is bigger in 2015 as well. In 2009, there is nearly no difference between the two blind levels (28.3 to 28.7%) while in 2015 more players reach the flop at the lower blind level with 31.9% than on the higher one with 28.7%. This suggests that the difference between those two groups has increased a bit over the years. Versus 2009 this also hints towards more influence of the categorical vari-

ables in 2015.

Concerning the positions we examine the difference between the button, the small and the big blind position as they are represented for each number of players at a table.

The difference between the positions is bigger in 2009 (highest difference: 2.1%) than in 2015 (1%). This shows that positions are taken more seriously in 2009 than in 2015, which normally should be an indicator for better play. Consequently, this contradicts the previous expectation of more awareness of categorical influences in 2015. According to [1] the position plays a big role in the pre-flop decision process. This is not reflected in either subset concerning the probability to reach the flop.

In conclusion, the interactions only live up to the expectations to some extent. But there can always a difference be found between the years suggesting that the game has changed over the years. It can be argued that variance causes differences between the two datasets, but the very high number of observations reduces this factor to a dismissible minimum.

Overall, the data shows all variables examined to be of some importance for the players. The influence varies between the years suggesting conclusions about the improvement of strategy. Some expectations were not met in the analysis but the overall trend seems to be as assumed. Thus, the data supports the idea of strategic improvement over the years to some extent concerning the probability to reach the flop. As now all the categorical variables available and their interactions are examined with regard to their influence towards the probability to reach the flop, we can now go further and analyse the metric variable of pressure.

The reaction towards pressure is perhaps the most characteristic and interesting part about poker and thus will thoroughly be examined.

Two major questions will be discussed. To what extent does pressure affect pre-flop decisions and how does this influence differ over the years.

6 Behaviour under Pressure

This chapter examines players' decision taking process when being pressurized the first round of pre-flop betting, hence the change of the probability to reach the flop under increasing pressure in both years. We expect the number of players reaching the flop (hence deciding to call or re-raise) to decline with the amount of pressure applied.

First, let us examine the evaluation of poker starting hands. Overall, the amount of money raised the first round of betting should be highly correlated with the strength of the hand.

There are 169 possible starting hands in poker. The evaluation of the strength of

starting hands has been broadly discussed, resulting in a classification into several groups (c.f.[1]). It has to be mentioned, that a common evaluation of starting hands is difficult, due to the dependence on variables like position, strategy and number of players involved, but there is a general opinion about the strength of each starting hand. Poker strategy sources examined for this thesis only slightly differ in their hand evaluation.

We can expect online poker players to roughly know how strong each starting hand is, as it is both intuitive and broadly discussed within poker strategy literature. It is very improbable that an online poker player starts a NL100 or NL200 game without being aware of the strength of each starting hand.

This aspect of poker hand evaluation is important for further analysis because the players usually base their pre-flop actions on the strength of their hand.

The starting hand has a substantial influence on the chance to win the game after common cards are dealt, even though there is some chance for weaker hands to win. For example: The probability for two queens to win against a seven and a two unsuited, with 88.9 %, is extremely high. Thus, poker players do not want to commit too much money into the pot with hands they consider weaker than their opponents' and strive to get more money involved if they consider their hand to be stronger. Chance might still lead to being two more sevens and another two in the flop - but this is nothing one should bet on.

Now, let us examine possible reasons to raise pre-flop. As mentioned before there is a difference in strength between starting hands, thus players want to benefit if being dealt a good hand pre-flop. They can do so by raising, hence signalling a strong hand and putting the other players under pressure. One further reason to raise might be to gamble on other players having weak hands as well and thus winning the blinds (the later the position the more common are such procedures)(c.f.[11]). This is considered to be pre-flop bluffing and might be a good strategy in several cases.

Overall, players' pre-flop actions should depend on their, to some extent, subjective strength of hand, usually leading to high raises with strong hands and folds or calls with weaker ones (c.f.[1]).

Because of this well known option to bluff in poker, meaning not to align the strength of the hand with the action taken, the ratio of strength of the hand to the action taken can not be approximated in a strictly linear way because players bluff due to strategic aspects in order to maximise their winnings (c.f.[5]). Non the less, for the following analysis we can expect players to have on average stronger hands when raising than if they are folding or calling (c.f.[24]).

There is also a tactical implication in poker, in which people try to see the flop cheap, in order to exploit cards that turn out to be winning regardless of their original strength. This is called "loose" play amongst poker players and is considered to be weak by most poker books (c.f.[2]). This strategy can often be exploited by a

tight-aggressive style of strategy, as there are no more cheap calls and committing too much money with weak cards is considered to be a bad move.

All poker players strive for the advantage to win, thus no one will willingly face an opponent holding worse cards, hence facing bad odds.

As we now established that raises often follow one out of the two motives, we can look at the reactions towards pressure.

A player who has been raised faces one of three options (or conclusions due to the opponents actions). One: He considers the opponents hand to be stronger than his own and thus folds. Two: He believes that the opponents hand is strong, but considers his own hand to be even better or at least equal hence re-raises or calls. And three: He does not consider the opponent's hand to be strong at all and decides to re-raise or call regardless of his own hand.

This conclusion has to be drawn in a short period of time and often with lot a of emotions involved.

After all, it breaks down to the evaluation of the own hand versus the opponent's, who has raised. A player is only aware of his own cards and must decide whether he estimates the own hand to be better or at least equal and thus continues in the game.

One further aspect which has to be mentioned is that if a player has already committed money in the pot he is more likely to continue in the game to protect his investment (c.f.[5]). This is not as important in the pre-flop game as in the following rounds, because only the small and big blind position have already contributed money to the pot before the first round of betting. But it applies for a possible second and third round of pre-flop betting.

6.1 Variable Preparation and Model Introduction

Every player has got to contribute at least the size of the big blind to the pot in order to stay in the game, with the exceptions of the small and the big blind position. Thus, nearly all players are, at any time, at least under the pressure of one big blind. This amount of money is considered to be pressure as well, but as it applies to any player it will be left out of the analysis. Consequently, there will be only players observed who are pressurized above one big blind, hence who were raised. Afterwards, we compare them to those not affected. This severely reduces the data observed because many people fold without facing any pressure.

Because of this, the earliest position who is exclusively under the pressure of one big blind the first round of betting, will drop out of the analysis almost completely.

As shown in chapter 4 only about 16% or 19% of players raise pre-flop depending on the year the game was played in. Thus, only some players who have been raised, hence are under pressure, are used for the analysis of the reaction to pressure.

For this paragraph we only examine the influence of the most important first round of betting pre-flop. Because if a player faces a second or third round of betting he has already committed money to the pot, which he does not want to lose. This changes the influence of pressure, as he would lose money by not staying in the game thus has an incentive to call even if he holds weaker hands than his opponent. Players who haven't committed any money don't have any direct monetary loss by folding.

Further, all raises above 25 big blinds will be analysed separately, because nearly all pressure above 25 big blinds either leads to an all-in push or folding. Some of these raises are all-in raises themselves by players with small stacks. Thus, there is no severe difference between the pressure of 25 or a bigger one and only few data is affected. The effect of higher raises than 25 big blinds will be shortly discussed after the main analysis.

Furthermore, the pressure is rounded to one digit to provide clearer results and improve illustration.

The two graphics provided, one for each year, show the percentage of players reaching the flop depending on the first round pressure the player is under. Each dot represents the percentage of players reaching the flop for a certain amount of pressure applied. Hence we get 25 dots each year.

The blue line is a so called smoother or spline function, created with the `ggplot2` r package (c.f.[25]). This smoother delivers a multi-dimensional polynomial which approximates the influence as a function. The spline function delivers a clearer insight into tendencies within the data and thus makes trends more easily recognizable. Furthermore, the function also takes weighting into account, reacting to the amount of players affected, thus resulting in a more accurate function (c.f.[12]).

The smoothing function also provides the variance of the estimation, which increases with the size of the pressure and the fewer players there are at a table. It can be seen as a grey area in figure 4 and 5. Overall, the variance is very low for our function due to the big amount of data observed.

There is also a linear approximation provided within the figure, creating a linear regression over all the data provided using the maximum-likelihood estimation. This illustrates the weighted, linear trend of the influence of pressure over all the observations (c.f.[12]).

As there is only few data available for tables with three or four players thus the uncertainty of the estimate rises, our interpretation will mostly focus on tables with six or five players.

6.2 Interpretation

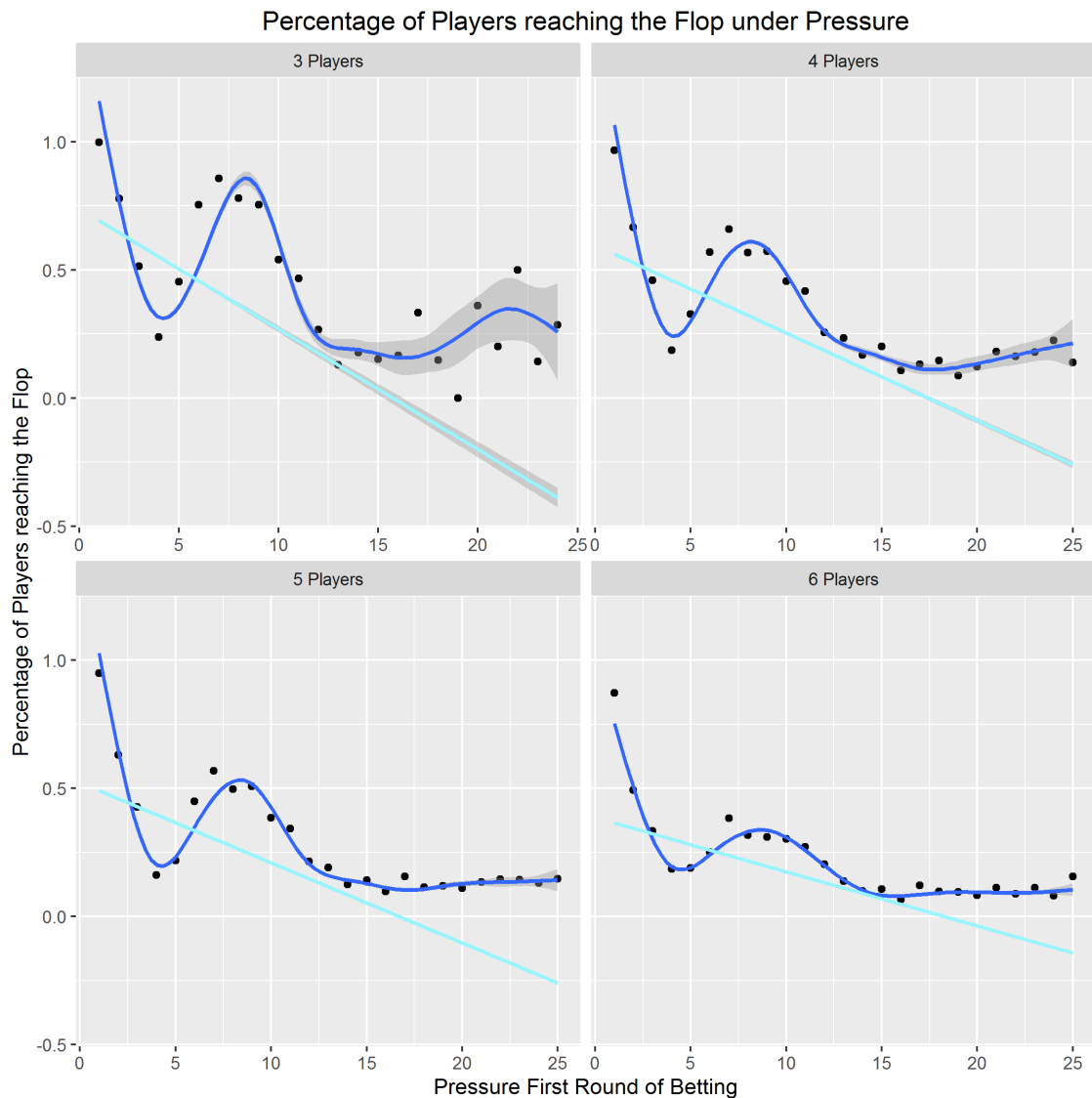


Figure 4: 2009 - Reaction Towards Pressure

The percentage of players reaching the flop for a certain level of pressure can also be seen as the percentage of the in average strongest cards which are considered to be good enough to face the ones with which was raised. All 169 card combinations are about equally likely to be dealt, thus if for example 60% of players do not fold facing a certain amount of pressure, they have to play using the best 60% of card combinations. If less people fold inevitably worse cards have to be played.

The pressure is considered as an indicator of the strength of the hand and results will be interpreted accordingly.

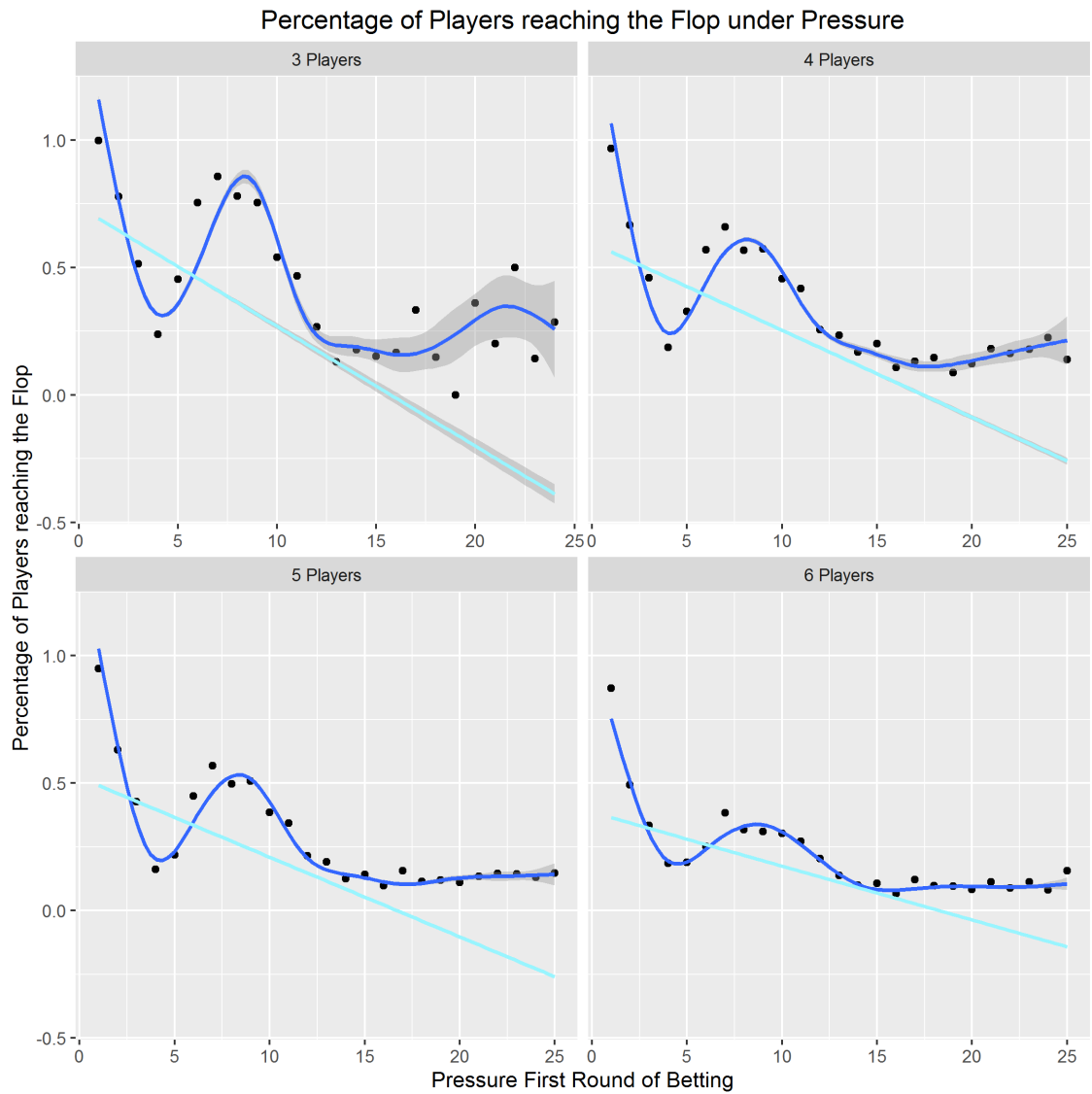


Figure 5: 2015 - Reaction Towards Pressure

Expectations:

As mentioned in the introduction of this chapter and as literature suggests, we can expect players' hands to improve with the amount they choose to raise. Consequently, the number of cards good enough to call bigger raises should decline. However, it is not clear to what extent the number of players folding rises with increasing pressure. According to neurological research (c.f.[9]) people tend to have rather a logarithmic understanding of numbers than a linear one. This would suggest that the influence of an increase of one big blind in pressure depends on the overall pressure and declines with rising pressure. Hence the difference between a player who is raised three compared to four big blinds could be higher than the difference between 13 and 14 big blinds.

There are also some really strong hands which most poker players in principal do not fold with. These about 3-5% of cards will most likely never be thrown away, no

matter what pressure is applied. Thus, we can expect the rate of players reaching the flop under pressure never to be below 5%.

But still, from a rational, logical point of view the number of calls and raises should decline with increasing pressure.

Results:

We will first compare and interpret both figures together and afterwards focus on the differences between the years.

The results illustrated in figure 4 and 5 suggest an entirely different approach of players' reaction towards pressure.

Even though the linear approximation of the influence declines with rising pressure as expected, the spline function is not following a linear trend at all. All in all, fewer people reach the flop if the pressure is increased, as the linear regression line over the entire data shows. But according to the spline function for some segments the number of players reaching the flop is not declining with rising pressure.

The most interesting information is provided within the local gradient of the smoothing function. Even if the number of players reaching the flop overall declines with increasing pressure, it locally rises in few occasions. In other words: The probability to reach the flop does not always decrease with an increase of pressure. Especially if you look at the points between the pressure of five to eight big blinds, we can examine this phenomenon in both years and throughout all numbers of players at a table.

From a strategic point of view this means if all players act rational, that cards of an opponent who raised seven big blinds are evaluated to be weaker over all observations than the cards of someone raising five big blinds.

It has to be mentioned that this only holds if players base their decision on the strength of the opponent's hands. The strength of the own hand is considered, as concluded before, if more players stay in the game they have to do so with on average weaker hands.

This is a very interesting phenomenon, because it does not seem logical that poker players can maximise their profits with this behaviour.

It is unexpected, and possibly hints towards irrational behaviour.

But altogether, fewer people reach the flop if the pressure is increased as the linear regression line shows over the data.

We can conclude that at a certain point, an increase of pressure apparently evokes the pressurized player to consider the strength of the opponent's hand to be weaker. In the next subsection, we will develop explanation approaches of several kinds and afterwards, in a following subsection we will focus on the difference between the years.

6.3 Explanation Approaches

There are three different explanatory approaches provided within this thesis to explain why in some segments of figure 4 and 5 an increase of pressure does not reduce the number of players reaching the flop. All of which do not explain the results completely but will deliver ways to understand the reasons for players' behaviour to some extent.

A socio-economic, a psychological and a strategic explanation approach will be examined.

The first explanatory approach deals with irrational behaviour of poker players and possible reasons for misconduct in online poker.

Within his book "Thinking, Fast and Slow" (c.f.[17]) the socio-economist Daniel Kahnemann elaborates a theory, according to which intuitive decisions differ from "slow", well thought out ones due to their completely different decision making process. According to him intuitive decisions are a lot more bias and mistake prone and often lead to bad judgement and bad evaluation of situations within decisions. Further, according to Kahnemann most people do not take the trouble to sufficiently think through decisions. Additionally, involvement of emotions favour irrational decisions.

As mentioned, the reaction under pressure is nearly always an intuitive decision. Most online poker sites only give a window of 30 seconds to make up ones mind about the next decision. Thus, it seems natural that some players take bad decisions in the realm of intuition.

Furthermore, according to [21] there are gambling addicts involved in online poker. Those players tend to seek the thrill of gambling and thus are more likely to react irrationally under pressure (c.f.[4]). There is a major tendency towards unrealistic reactions under pressure in online poker for gambling addicts, which could explain that some people rather stay in the game under higher pressure, making the game more exciting. Additionally, gambling addicts are more prone to fall for wrong decisions if they are taken intuitively (c.f.[17]).

According to [21], loosing control over the decision taking process because of emotions, so called tilting, is common amongst online poker players. This topic has been researched during the past years and delivered results, pointing out irrational behaviour of online poker players. (Quite funny that the biggest online poker website is called Full Tilt Poker)

Overall, tilting is suggesting that players in online poker who act irrationally are less likely to fold when being put under more pressure. Research confirmed that a lot of poker players indeed act irrationaly (c.f.[19]).

As mentioned, this is only one aspect, but provides a possible reason for the results observed. Obviously, not all poker players react irrationally when being pressurized and the results of chart 4 and 5 do not automatically imply irrational behaviour but it has to be pointed out that some players might act irrationally, due to reasons explained within behavioural and socio-economics.

The second explanatory approach focuses on the psychological aspects of being put under pressure and the psychological aspect of the game itself. This paragraph will examine parallels of the pre-flop decision taking process with the so called ultimatum game.

There are numerous sociological experiments stressing how people tend to act irrationally concerning their own pay-off if feeling pressurized.

A good example is the ultimatum game in which players tend to accept losses for themselves in order not to let the other player get away with pressurizing them (c.f.[20]).

In this game player 1 divides a given amount of money provided by a third party into two parts. Afterwards, the other player has to choose between two possibilities: Either he can take the money offered to him by the first player, or he could reject the money and neither player gets anything at all. From a rational point of view, the second player has to accept any amount of money offered as long as it exceeds zero, to maximize profit.

Let us now examine a situation in which player 1 offers less than a third of the total amount of money, thus is pressuring the other player to take the deal.

Results show that most of the time player 2 is not willing to accept this offer (c.f.[20]). There are several reasons for this, one of which emphasises that people generally do not want to give in when pressurized.

This psychological phenomenon can be seen in a huge variety of games and real life situations, and even to some extent in online poker (c.f.[21]). Hence, provides yet another reason to explain the results of figures 4 and 5.

We can conclude that players tend to react controversial under pressure. Sometimes even do not act profit maximizing on purpose the only reason being not to give in when pressurized. Psychologically speaking as shown in [28], people do not like to give in when pressurized. The subconsciousness resents the thought of being controlled by another person by the means of pressure and thus feels the urge to oppose it (c.f.[28]). This reaction is caused subconsciously and a by a feeling, hence we can not directly conclude to what extent decisions are based on this phenomenon. But it seems natural that it influences the process of taking a decision when pressured even in the online poker pre-flop game.

If players feel more pressurized by a raise of eight than five big blinds and thus want to oppose the opponents higher pressure, they might be less likely to proceed in the game when being raised five big blinds instead of eight. This hypothesis insinuates irrational behaviour.

One further aspect not insinuating irrational behaviour is provided by strategic implications of the game. People normally raise, as suggested by poker literatur one to five big blinds the first round of betting (which affects 76% of our data examined)(c.f.[1]).

If a player exceeds this amount it attracts attention and reactions are more likely to be thought through more exceedingly than the more common, one to five big blind raise. It is not considered to be normal to raise more than five big blinds the first round of betting pre-flop. Hence, players could wonder what the reason for such a high raise might be.

If they conclude it is not due to the strength of the hand but because of strategic aspects, calling or re-raising seems to be the right thing to do.

This raises the question whether starting hands which raises over five big blinds are made with, are better or worse than the other ones.

As mentioned before it is not easy to determine the exact strength of the starting hand. But poker literature mostly agrees on the top 20 of the best pocket cards (c.f.[13],[1]). To provide a possible answer to this question, we will examine how many percent of the hands, which was raised a certain amount of big blinds with, are amongst these top 20 hands. Thus, the probability for a player who is staying in the game to face a really strong hand for a certain segment of pressure.

We will conduct this analysis with the entire dataset, hence regardless of the year or the number of players at each table.

Further, there are only about 5% of pocket cards available within the data, as cards usually are only shown when a player reaches the show down. This implies that nearly all cards shown were not folded during one of the pre and post flop betting rounds and thus are likely to be stronger than the average starting hand.

Afterwards, we divide the dataset into two subsets, one in which players choose to raise 4 or 5 big blinds with their starting hands and the other in which they raised 6, 7 or 8 big blinds. As previously examined more players fold if being raised the lower amount of blinds for these two subsets in both years.

Results show, that about 50.7% of the pocket cards which were raises four or five big blinds were amongst the really strong top 20 pocket cards. While 67.2% of the ones that had been raised between six and eight big blinds were one of these top combinations.

This shows that the pocket cards which the higher amount of big blinds was raised with can be considered to be stronger. Thus, reactions towards higher raises should be considered with care, as playing against one of these top 20 starting hands is only advisable if one holds a very good one as well.

This implies that from a rational point of view less people should try to reach the flop when being raised six to eight instead of four to five big blinds over all the data examined. This suggests irrational behaviour within both years, because folding was less likely facing the higher raises in both charts.

Thus, we can conclude that there has to be irrational behaviour to some extent. This is not a rule which applies for all individual cases but provides a broad conclusion over all hands played. Even though higher pre-flop first round raises might be connected to bluffs, the overall chance of facing a really strong hand is higher than when facing a smaller raise. After all, we can not conclude irrational behaviour for individual cases, but can see misconduct over all the hands examined.

Now let us examine the influence of the second and third round of betting. These rounds can not be analysed like the first round as all players involved already contributed money to the pot, thus have a higher incentive to stay in the game.

Consequently, players who enter a second or even third round of betting are way

more likely to reach the flop. The reaction towards raises in these rounds of betting depend on the amount of previously committed money to a great extent, thus we can not draw conclusions the same way as for the first round. If a player has already bet money the first round he signals a strong hand and could continue in the game even if his chances to win are not better than the opponent's, as he loses money if he folds immediately.

We can not observe any tendency within the data for players facing pressure above 25 big blinds. Due to reasons provided above, no player is likely to fold holding one of the top 10 or 20 hands and raises of 25 big blinds and above are usually only called with very good pocket cards. Thus, there is not that much of a difference between raises of 25 big blinds and those above.

One different aspect is the so called committing to the pot. This arises if a player puts enough money into the pot to make a later fold very expensive or even irrational. This does not occur if a player calls five to eight big blinds, but it does if they post 25 or more big blinds in the pot the first round. If raised a big amount of blinds players feel they have to commit to the hand entirely if they stay in the game and thus only choose very strong hands to do so. Consequently, the difference between a raise of 25 big blinds or one above is not that high. Additionally, a decision facing a raise of 25 big blinds or above is influenced by the risk attitude of the player (c.f.[10]).

Furthermore, there is only few data observed with players under the pressure above 25 big blinds. Thus, the variance plays a bigger role.

After all, it seems natural that the pressure caused by a raise of 25 big blinds is already the maximal amount possible, as it attacks a substantial amount of money from the opponent and most of the time leads to all-in pushes.

6.4 Difference between the Years

Now let us compare the reaction towards pressure in the two different years.

All in all, the general course of the smoothing and linear approximations is quite similar for both years. As mentioned in the introduction of this paragraph we will only focus on the results concerning tables with five or six players.

First looking at the linear approximation of the influence of the pressure provided within the linear regression line, we can see the line declining faster in 2015 than in 2009. Thus, the overall influence of pressure computed over all the data is more severe in 2015. This shows that over all the data observed players in 2015 fear higher raises more than players in 2009 do. It further suggests improvement of strategy over the years, because the overall pressure has a higher influence in 2015.

Observing the pressure of five to eight big blinds in either year, we can see a higher increase of players reaching the flop of the data in 2015 than in 2009.

This, as concluded in the previous paragraph, is rather a sign for irrational behaviour and suggests flaws within strategic aspects of the game.

One of the possible reason for this is provided within the results of chapter 4, in which we established that people in 2015 play more aggressively and are more likely to bluff and raise with on average weaker hands. As a consequence, individual assessment of opponents' behaviour becomes more important in the year 2015, which could lead to more people not trusting raises above five big blinds.

There is one further difference concerning raises above 15 big blinds. While the ratio of people reaching the flop for raises above 15 big blinds is almost steady in 2009, it varies a bit in 2015. This might again be caused by the higher amount of players bluffing in 2015 causing a higher variance.

7 Conclusion

This thesis has shown how the online pre-flop poker game has changed over the years.

First, we selected the data which the analysis was conducted with. We chose data from the years 2009 and 2015 subdivided into the two blind levels NL100 and NL200 with about 7.5 Million observations each.

Further, we established the pre-flop options and how frequently each decision and decision-combination was chosen in either year.

Results suggested a more aggressive style of strategy in the year of 2015, which is advised within poker literature.

Then, we focused on the influence of the categorical variables size of the blind, number of players at each table, position and their interactions with the year the game was played in on the probability for a player to reach the flop.

Results showed severe differences between the years for nearly all variables but due to mixed results an improvement of strategy over the years could not be concluded beyond any doubt.

Afterwards we examined the influence of pressure on the probability to reach the flop for both years.

Results gave reason to question the behaviour of players under low pressure compared to intermediate pressure.

The paragraph provided explanatory approaches of strategic, behaviour-economical and of psychological nature, all of which made players' behaviour comprehensible to some extent. Especially psychological aspects provide reasons for flaws within the decision taking process. Overall, pressure has more influence on the probability to reach the flop in 2015 but the difference between the reaction to small and intermediate pressure are more severe. Thus, we can only conclude some improvement of strategy over the years.

All in all, the pre-flop online poker game has changed severely over the years, while an improvement of poker strategy can not be concluded beyond any doubt. The reaction towards pressure in online poker suggests irrational behaviour to some extent due to psychological reasons.

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