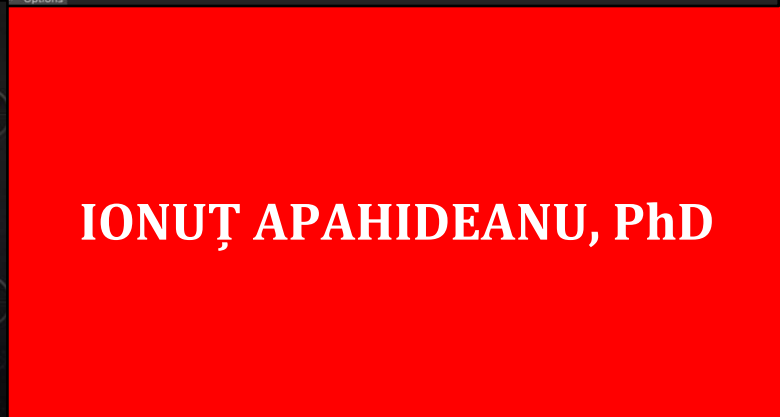
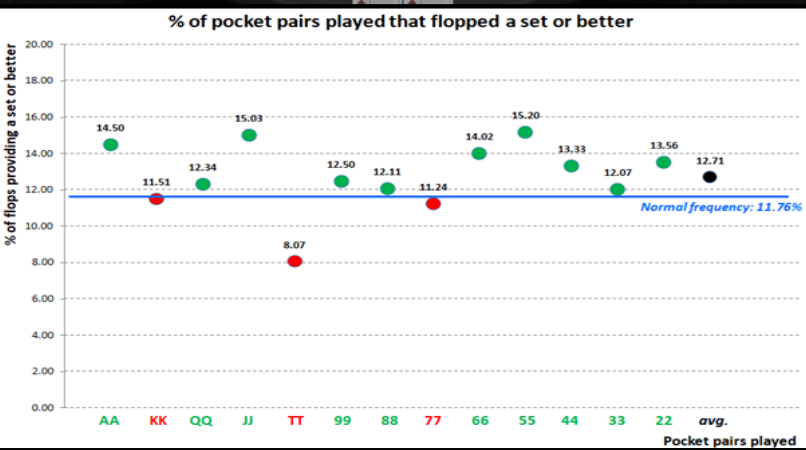
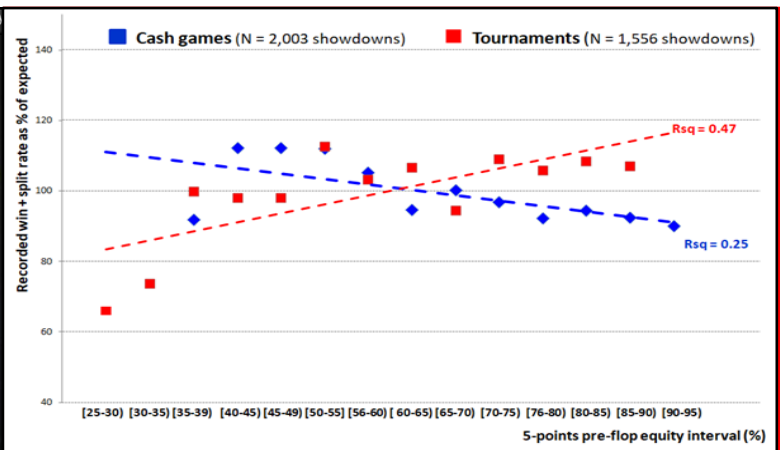


2017

ONLINE POKER - RIGGED OR NOT?

A CASE STUDY: POKERSTARS



IONUȚ APAHIDEANU, PhD

The story

My relationship to poker has been a sinuous one for as far as I remember. In hindsight, it seems like the kind of first love that one, unable, or unwilling, to forget, keeps returning to repeatedly over a lifetime.

I remember first trying the game back when I was a kid, maybe eleven-twelve years old. I was playing with my cousin - the classic five cards draw. Back then, it was the only type of poker we knew. Nowadays there are so many versions of the game, one can hardly keep track of them. I also vividly remember how, in order to make every hand more spectacular, more adrenalin-laden, like the ones we saw in the movies, we used to eliminate from the deck all cards lower than seven. Thus, we got to enjoy plenty of "sensational" duels - Aces full of Jacks vs. three Queens, Kings quads vs. the nut flush, etc. Nowadays, they seem to be called "coolers" and omnipresent on online poker sites. But let's not jump there, yet.

Time passed, with me occasionally playing the game with friends, until I got to college. There, and then, I rediscovered poker. Or vice versa, can't say exactly. We engaged in the most passionate relationship possible. True love, what can I say!

It lasted for about two years.

Then time again passed, with me getting older, marrying, getting a job - you know, the usual stuff. Until the dawn of the Golden Age of poker: Chris Moneymaker winning the WSOP main event. All of a sudden, everywhere I looked around, it seemed the whole planet was playing Hold'em! Specialized sports TV station were broadcasting tournaments or high stakes cash games, there was talk everywhere about some hand Ivey had won against Antonius, Negreanu was becoming the most popular player around, the "Poker Brat" was having a problem with Northern European players to the amusement of TV viewers worldwide, and it seemed that everyday a new poker platform popped up on the Internet.

It was simply impossible for me to resist the temptation. I downloaded the Pokerstars platform, the first one that popped up when searching on the Internet, and I started playing again. Only this time solely on play-money: I felt I had gotten older, or shall we say 'matured', and didn't need the adrenalin of real money anymore. In parallel, I met with friends on poker nights. We had all bought one or another version of a poker kit, and played whenever we could, as a hobby. It was fun!

Gradually, the popularity of the game decayed worldwide. One day or another, I remember replacing my desktop computer with a new one, when noticing the poker application on the old one. I asked myself: do I still need this? Nah, barely played it the last two years, and most likely won't need it anymore.

Almost another decade passed yet again, with me playing the game on maybe a handful of occasions, live, among friends, before I once again returned to poker, but this time in a significantly serious manner. Feeling a bit rusty after the prolonged break, I re-installed the Pokerstars application and granted myself about two months of playing on virtual, play-money, to get back in shape, before jumping to real-money games. Eight to ten, sometimes twelve or more hours a day. Simultaneously, every day I kept (re-) studying the game theoretically, devouring every book or article I could get my hands on: the psychology of the game, video analysis, the tactics, the mathematics.

Admittedly, the first time during this training period that I lost three times in a row holding pocket Kings, it felt a bit awkward, and even more so after I calculated the probability of this chain of "accidents" happening. But, still, I had barely restarted playing, right, and accidents do indeed happen in nature, right? The next day or so, at a six-players table, three player had been dealt hole cards of the same suit, all of them eventually making a flush. It did make me suspiciously raise an eyebrow, but, again, this accident was also

"possible", as some online poker spokesperson always say. Another day, in another session, I bumped into a higher pocket pair three of the five times. Again, I jumped into calculating the probability. The next day, I lost with Aces against Kings, on the river. A few minutes later, however, my pocket Queens defeated the opposition Aces. And so on, for the whole two months or so of training. Things seemed a tiny little bit dubious, but all my theoretical and practical knowledge of probabilities, my very background of a researcher made me 'know better': the sample of hands played was still arguably small, randomness in nature implies even such "accidents", overall the figures could have been normalized, etc. Convincing enough for me to dismiss all of the online allegations that were claiming online poker in general and Pokerstars in particular would be "rigged", allegations that I had begun stumbling upon on the Internet, I didn't find any solid, scientific and therefore credible demonstration of such preposterous-seeming claims. Moreover, despite those awkward events that I had occasionally witnessed on the platform, I thought my training was going better than I hoped for: I had more than doubled my initial stack of play-money, gaining almost 20k big blinds in a couple of months.

All these elements considered, I threw in a couple hundred dollars (not more, given my remnant suspicions), then also bought online a poker data-analysis software, and started playing against the "grinders" at the lowest stakes levels. With no effort of readapting to everything a real money game supposes, things were going smoothly. True, already on my first day of playing (April the 9th), I flopped directly an Aces full, then I lost with pocket Queens against KJ off-suite, the opponent flopping a trip of Kings, but only eight minutes later, I was once again dealt pocket Queens, this time winning the pot, etc. In retrospect, maybe it was the fact that I had ended the session on a little profit that made me not pay much attention to some otherwise relatively suspect events.

Things went on and after a good ten thousand hands played, I was on profit, and in full line with my elaborated plan of gradually moving up through the stakes in order to cash in enough to pay the entry fees at live tournaments. All the way to the WSOP series! However, despite everything going according to the plan, I couldn't nevertheless notice that I had already witnessed some truly horrendous "accidents" in terms of anything that a genuinely "random" generator of numbers would actually suppose. Some of them were so truly grotesque, that I instantly screen-shot them, posting of few on my social media accounts. I had for instance already been through Aces vs. Kings duels twice as often than normal at a 6-players table, I had seen some of the most improbable flops imaginable, the kind of one in tens of millions of hands, within pair vs. pair duels I seemed to win visibly more often as an underdog than expected to or than as the favorite in proportional terms, while my pre-flop all-ins were completely off the charts, the majority of them having an outcome contrary to the mathematically normal and expected one. I went back to what still seemed like nothing more than online folklore. I revisited all the hundreds of allegations and complaints already read and explored other thousands new ones. On the basis of my mere 10k hands played, plus other over 60k played on play-money, I could relate to many of them. What was being said there had also happened to me! And things on Pokerstars did indeed seem a little "fishy", to say the least.

Still, I was torn. My inner voice of a researcher kept telling me that at least some of the events witnessed were hardly classifiable as anything closely related to randomness, and that the situation definitely needed to be investigated scientifically, while the voice of the poker player in me pushed me to continue playing, to win more money and follow my initial plan. Eventually, the researcher's voice prevailed. I threw in another USD 150 or so, speculating a deposit bonus offered by the platform, then won some profitable Spin & Go-s, gathering enough money to even start experimenting things, without the risk of going bankrupt. Thus, contrary to what any rational poker player would do, I started calling my opponents tens of times, despite all the signals telling me I was already beaten, only to reach showdown, so that I could check if another "accident", like AA vs. KK vs. some third pocket

pair, or more generally some other form of "cooler" had once again, absolutely "randomly", happened on Pokerstars. Whenever I was losing too much money on these little experiments at the lowest stake levels, I climbed a level or two, where I went back to playing seriously, meaning win-oriented, in order to regain enough money to continue testing things. And the more I played, the more showdowns I got to see, and the more anomalies I discovered. In fact, any frequency, any indicator, any parameter I was regularly checking did not seem right: from the frequency of triple pair situations to the one of flopping at least a set when holding a pocket pair; or from the conversion rate of my flopped flush draws into flushes up to the recorded rate of winning as a favorite on the turn calculated as a percentage of the expected rate indicated by my equity.

Somewhere along the way, probably half way through my series of 55k hands played on real money, I entirely gave up any intention of making money on the platform. My new goal was clear: produce a serious, solid, statistically-based investigation of how truly "random" Pokerstars' algorithm is dealing the cards. I once again returned to the thousands of complains spread all over the Internet, this time evaluating them in a more applied manner and trying to reformulate them in the form of statistically verifiable hypotheses. Gradually, the design of the research was outlined. Then the methods and items to be tested were expanded and refined. As a sample volume, I targeted a number of 50k hands played. I ended up having played over 55k. As a final step taken during the last three days of playing, I even engaged into a full-scale experiment over more than 2.5 k hands: every time I had been dealt a pocket pair, regardless which one exactly, I simply open-limp-check-called and each and every street, with the sole purpose of dragging my opponent(s) to showdown, where I could see his/her hole cards, which enabled me to expand and refine the data gathered.

In petty terms, let's put it like this: at the end of this enterprise, my net financial loss, all things considered, barely surpassed USD 110. It has been one of the most profitable investments I could possibly have made: it has led to a research that represents, to the best of my knowledge, the first statistical investigation of an online poker platform done by an external and truly independent source and simultaneously made freely available to anyone in the world.

Above anything else though, the truth is the truth. One cannot put a price tag on it. And if the game on a poker platform is rigged, than the truth needs to be known. All the players still actively engaged in online poker deserve the truth. The game of poker - my kind of first love that one cannot or will not forget, deserves the truth.

The following presents this research.

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I. INTRODUCTION

"Online poker - rigged or not?" Quite an interrogation, right? Most crucially: how does one actually establish whether it is rigged or not? And, on second thought: what would "rigged" mean, precisely?

It is exactly the nature and scope of such a line of questioning and its implicit methodological, not to mention truly epistemological, issues raised that may explain why, from this very beginning and all the way through its four chapters up to the Conclusions, this undertaking may look like something totally unusual. It is not, strictly speaking, an academic paper, since it does not fully comply with the rigors of academic writing¹. But nor is it an investigative, non-academic, report, since all concepts, methods and instruments employed are entirely and directly transferred from the academic, scientific world. Let's put it like this for the moment: it's none of these entirely, but it's simultaneously both of them.

It is at least something for sure: a pioneering effort. Despite thousands, if not tens of thousands, of complaints spread all over the Internet about online poker in general, and the Pokerstars platform as a case in particular, being "rigged", so far, to the best of my knowledge, there has been no single attempt, by a truly independent source², at providing a rigorous, extensive, and ideally credible (as in "reliable") demonstration of one or more of the accusations formulated in social media discussions. As a consequence, all that remained essentially within the public debate realm has been something like a dialogue of the deaf: demoralized players, thousands of them deserting Pokerstars in recent years, kept accusing the platform of being rigged, while the latter's representatives kept delivering the same, already standardized, excuses as answers, such as: online, people play far more games than in real life, so that those terrible "accidents" invoked by so many critics would in fact be only natural to occur over so many hands; people tend to remember only, or to a higher rate at least, those situations where they were unlucky, and not also the ones where they have been lucky; the samples of hands gathered as evidence by one or another criticizing player have been too small to allow any reliable generalizations, etc. Such answers seemed to only further frustrate many critics, with the accusations escalating and expanding slowly, but surely, up to the point where pejorative terms such as "Riverstars" or "Jokerstars" actually became so widespread, that they turned into distinct hashtags on Twitter and even made their way into urban dictionaries³. To this, Pokerstars retaliated by apparently hiring an entire legion of paid "drones" entrusted with the sole task of countering criticism and "cleaning" the company's reputation all over the Internet.

I.1 The (more than) methodological challenge

The conflict continues to this day. No serious and credible statistical testing has been advanced to break the deadlock one way or the other. And it was only after concretely engaging in the enterprise detailed below that I have - or I think I have, at least in part - understood why. No wonder it hasn't been done before: aside from the tremendous amount of necessary work, the actual, core-problem is one of a (more than) methodological nature: how does one reformulate online accusations, so differently expressed, respectively understood, by people all over the world wide web, in a form that allows a rigorous scientific testing, and would be approved as such by the scientific community, while nevertheless trying

¹ Some expressions in the text may seem frivolous, there are bold-marked fragments in the middle of a text and other "unorthodox" editing instances, partially anecdotic analogies, numerous screen captures of hands played, meant to simplify the understanding of the reader, etc.

² Meaning any other source than the one company who "audits" the world's biggest online poker platforms.

³ See for instance <http://www.urbandictionary.com/define.php?term=RiverStars> (retrieved July 16, 2017).

permanently to also make it fully understandable for poker players who are not familiarized with statistics? And therein lies the problem: in order to adequately tackle the problem addressed in this investigation, one would normally need two simultaneous sets of knowledge: of poker and of statistics. Reckoning that such a double requirement would inevitably and severely narrow down the audience, whereas the problem of online poker potentially being rigged seems a problem of a much bigger impact, and as such of interest to a considerably broader audience, I was left with a first fundamental challenge, the one of bridging, as much as possible⁴, a serious gap between two types of potential readers.

Thus, on the one hand, readers who know solely statistics, but not poker, may for instance not understand why in some instances, classic methods and associated instruments and terms of statistical hypothesis testing (T-test, p and α , "false positive", Z-test, etc.) could not, unfortunately, be applied in this investigation - it has to do with the specific way the game is played, and, more importantly, with how a data-storing software actually stores, processes, and displays all data (more about this below). For the same reason, the usual approaches such as testing a "null hypothesis" also encountered certain limits of their applicability. Or, to give just another example as a preface: this first category of readers, unless knowing poker, might not fully understand why for instance an analysis of the series of the river cards (or the first cards on the flop, for that matter) across all my games played - otherwise a correct randomness testing solution - cannot be applied, since, when looking how exactly the game is played, specifically what hole cards are usually kept and played by most players, it becomes clear that the distribution of the cards on the river street actually should not be expected to be random.

One of the biggest issues in this regard has been the otherwise classic problem of dealing with incomplete series of data, and consequently the nature, limits, and reliability risks of extrapolations.

Subsequently, but only in part overlapping, over the course of the research, I came up with methodological instruments that may seem difficult to understand at first glance, such as the matrix combining two plus one dichotomies:

- a) the one between *a.1.*) hands played effectively by me (meaning hands where I did remain actively engaged in the game to showdown), and *a.2.*) hands where I folded somewhere along the way before showdown, but at least two players have continued playing all the way till showdown. The latter allows the Hold'em Manager 2 software⁵, directly connected to the platform's software (in certain limits, obviously) to display a series of information such as: the known hole cards of both the two players having reached showdown, and mine, together with the equities, thus allowing me to somewhat counterfactually establish whether I would have actually won the hand, had I stayed in the game;
- b) the one between *b.1.*) hands with a *certain* "outcome" (a term employed either with reference to the winner or, and more often so, in relation to my hole cards and targeted combination⁶) vs. *b.2.*) hands with an *uncertain* outcome, meaning for instance hands that have ended on the flop, or on the turn, before thus knowing for a fact whether I would have hit my targeted combination or not, respectively if I would have won.

The latter category raised a whole new category of problems in terms of how to correctly approach the factual/counterfactual outcome, etc.

⁴ Meaning that, even considering all my clarifications and simplifications of explanations and interpretations, the reader will still require a minimal knowledge of, especially, the ABC of poker (the hierarchy of combinations, the positions at the table, etc.). I can only hope I have let this amount to indeed be the minimum possible.

⁵ See below.

⁶ E.g. the binary outcome of me making, or not, a flush, starting from a flush draw on the flop.

		<i>My participation in the game:</i>	
		hands effectively played by me	hands folded (but continued by ≥ 2 opponents)
<i>Outcome of the hand:</i>	certain
	uncertain

in relation to the winner of the hand | in relation to my targeted combination

As such, throughout my research, I had to often innovate, and sometimes even build from scratch, (new) approaches, methods and indicators, such as the above matrix, or the alternation of personal and favorite's perspectives in terms of equities and corresponding ways of accounting the results of the analysis, or the 13-lines of cards scale, etc.⁷

Aside from these methodological issues, for this first category of readers there is potentially the additional problem of some of the very main, most commonly used, terms used by this paper, many of them possibly unknown to a non-poker player, a problem which I already tried addressing preliminary in the table below, and more extensively, whenever I felt necessary, throughout the four chapters of this investigation.

On the other hand, readers who know only poker, without however a certain amount of knowledge and skills in statistics and more generally in methodological issues, might find it difficult to form an opinion on some of the significance of the statistical indicators used throughout the analysis: correlation coefficients, standard deviations, squared Rs, probability values and confidence intervals, sample representativeness, kurtosis and skewness⁸ of a particular distribution of hole cards or of the conversion rates of a draw depending on the type of the hole cards, average recorded frequencies as percentages of the corresponding expected one, etc. Nor may they know how many of the probabilities discussed throughout the analysis are actually calculated (although in many more complicated, or at least unusual, cases, I did display the exact method of calculation in order to also avoid any potential controversy).

It is in consideration of this latter category of audience that, without any intention of offending the former one, I have tried, sometimes maybe in a frivolous manner, to simplify the explanations and interpretations as much as possible without altering the very meaning and significance of the findings, by employing various accessible analogies and metaphors, such as mixing boiling and freezing water in order to get a normal temperature, or playing the roulette in a casino, or flipping a coin, or making a poll, etc.

Additionally, the same task of trying to make everything understandable to an audience as broad as possible, combined with the pioneering profile of the research and the peculiarities of the reality investigated, may also explain in part the considerable size of this document: a final table for instance, with data reprocessed in chain, which in itself occupies - let's say - only a few lines, however required a considerably larger space in advance for me to explain, in a broadly accessible manner, what, why and how I measured something.

And now, before moving on to what, under any other circumstances, an Introduction should actually address, allow me to briefly clarify, to all readers, the most commonly used abbreviations or terms used in an adapted meaning⁹:

⁷ And it is also in this sense that the present Introduction is an atypical one: if, as customary, it would outline to the needed depth level the methodological approach employed, the Introduction would risk becoming - and this is no exaggeration - as voluminous as two chapters combined.

⁸ The very second I typed this term, the Microsoft Word dictionary immediately notified me, by underlining it in red, that it does not recognize the word. This illustrates exactly my point above.

⁹ In addition to these common terms, sometimes, for reasons of simplicity, I have used slang terms maybe unfamiliar to persons not playing poker, such as "quads" (instead of "four of a kind"), "cooler", or certain expressions such as "to hit a two outer", "to draw dead", "to flop a full house", etc.

HM2	"Hold'em Manager 2" software
OESD	open-ended straight draw
GSSD	gut-shot straight draw
2xSD	double belly buster straight draw (a.k.a. double-inside straight draw)
RNG	Random Number Generator. According to Pokerstars' website, it is "a system, device or module that creates a sequence of apparently unrelated numbers"
Rsq	R squared = "coefficient of determination", essentially signifying what proportion of the dependent variable's recorded variation can be pinned on, or is predictable from, the independent variable
correl.	(Pearson) (linear) correlation coefficient
"avg."	"average"; unless differently specified, means "weighted arithmetic mean"
XY-s	suited combination(of hole cards)
XY-o	off-suite combination
hole cards	the starting hand (the two cards a player is dealt, as opposed to the "board" or "community" cards)
"hand"	used alternatively in two meanings: <ol style="list-style-type: none"> 1. as an individual game in itself (<i>e.g.</i> "I have played 51,989 hands in cash games on the platform") 2. as a signifier of the 169 versions of hole cards that can be dealt to a player in the Texas Hold'em game. In this second meaning, the term "hand" does not differentiate among the four possible suits, only indicating whether the hand is suited or off-suite. As such there are 169 "hands" corresponding to 1,326 "combinations" possible; <i>e.g.</i> an AA hand consists of 6 possible combinations, a AK-o hand of 12, an AK-s of 4, etc.
"street"	a term used not in its standard meaning, but as an adapted denominator of a game's four phases: pre-flop, flop, turn, and river
"rake"	(cf. Wiki:) the scaled commission fee taken by a card-room operating a poker game
"equity"	the probability of one player to win or tie the hand (as displayed by both Pokerstars and the HM2 software. Both indicate the combined probability of winning or splitting the pot)
"favorite"	the player best positioned in terms of equity at a certain moment of the game

One last final specification: unless differently mentioned, the chapters use the same general 4-color shading system in all tables: **light green**: recorded deviation of < +5% of the normal, mathematically expected, frequency; **dark green**: bigger than +5%; **pink**: smaller than -5%; respectively **red**: bigger than -5%.

I.2 What and how this research investigates

With all of the above being necessarily (pre-) clarified, allow me to now properly "introduce" the research: it analyzes the series of 55,320 Texas Hold'em hands that I played between the 9th of April and the 28th of May, 2017, on real money¹⁰, on the Pokerstars platform¹¹, under the username "Apasu76". Of these hands, 51,989 have been played in cash games of a zoom-format, all of them in 6-players rings, at various stake levels. The other 3,331 have been played in tournaments, within the same timeframe, in different competitions (Sit&Go, Spin&Go, and, mostly, proper multi-table tournaments (MTTs)) in various number-of-players-formats, from a minimum of three up to a maximum of nine.

¹⁰ As opposed to so-called "play money".

¹¹ <http://www.pokerstars.com>

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Game: No Limit Hold'em Stakes: All Max Players: All

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★	Table	Stakes	Game	Type	Plrs	Avg Pot	Plrs/Flop	H/hr
★	McNaught	\$0.01/\$0.02	NL Hold'em	9	346	\$0.23	11%	292
★	Halley	\$0.01/\$0.02	NL Hold'em	6	822	\$0.30	19%	261
★	Hyakutake	\$0.02/\$0.05	NL Hold'em	9	149	\$0.72	11%	265
★	Donati	\$0.02/\$0.05	NL Hold'em	6	464	\$0.66	16%	244
★	Hartley	\$0.05/\$0.10	NL Hold'em	9	142	\$1	12%	247
★	Aludra	\$0.05/\$0.10	NL Hold'em	6	435	\$1	15%	256
★	Nansen	\$0.08/\$0.16	NL Hold'em	9	2			
★	Amundsen	\$0.08/\$0.16	NL Hold'em	6	121	\$1	15%	251
★	Whirlpool	\$0.10/\$0.25	NL Hold'em	9	90	\$3	13%	230
★	Hydra	\$0.10/\$0.25	NL Hold'em	6	309	\$3	17%	258
★	Arp	\$0.25/\$0.50	NL Hold'em	9				
★	Baade	\$0.25/\$0.50	NL Hold'em	6	217	\$7	18%	240
★	Triangulum	\$0.50/\$1	NL Hold'em	6	123	\$14	17%	255
★	Aenna	\$1/\$2	NL Hold'em	6	90	\$31	17%	204
★	Lambda Velorum	\$2.50/\$5	NL Hold'em	6	53	\$76	18%	192

McNaught Player (TARAN)(1990)

1 W 1

11mj04

11shkolnik

13proton13

5432Fold

AlexRouda

almahotz

Ames21x

amper93

anas63

Anderson8786

androids81

Andy_Plant1

anton_mrk

ariana51130

armslol

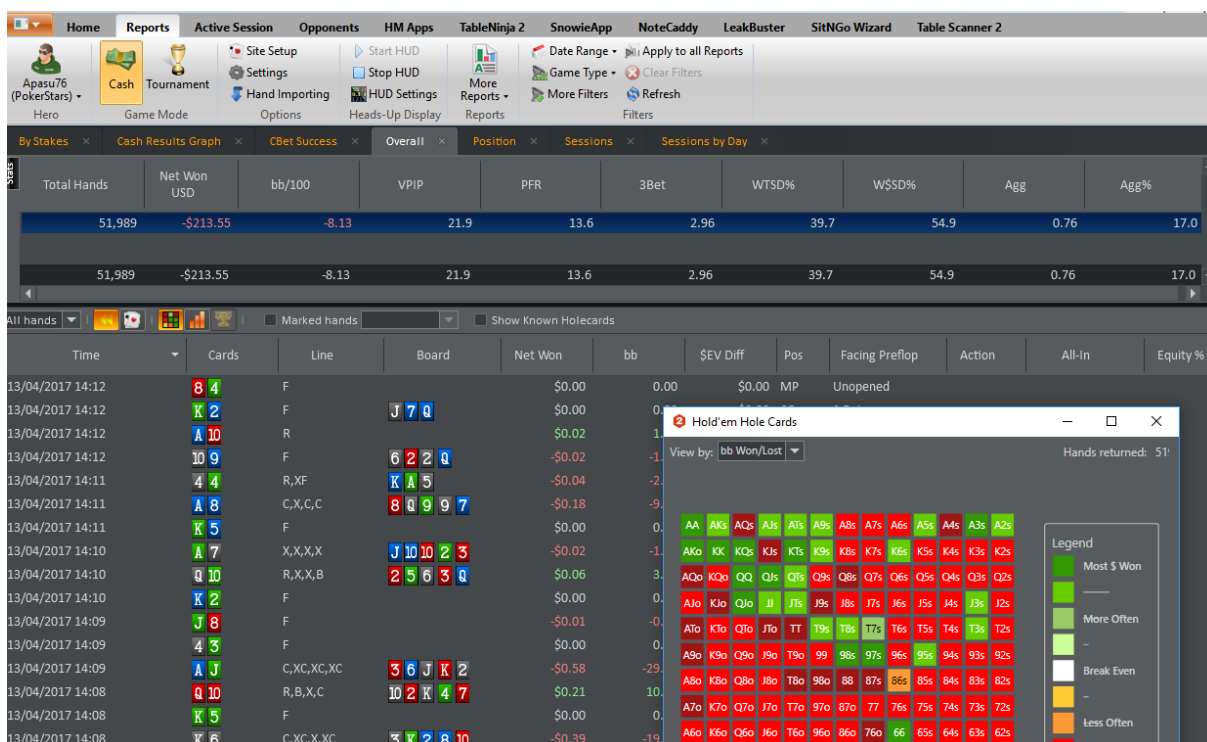
Given certain problems of standardizing probabilities, many of which differ depending on the number of players at the table, most of the analysis covers only my 51,989 hands played in cash games. Whenever though methodologically possible (and always specified as such), the analysis is expanded to cover all hands played in both cash games and tournaments.

In terms of the representativeness of this sample of hands, for the reader who is not familiarized with either statistics, or the game in itself, allow me to put it like this: there are 169 distinct hands, respectively 1,326 distinct combinations that a player can be dealt in a Texas Hold'em games. In relation to my combined number of 55,320 games, this means that, on the average, I have been through each starting hand 327.3 times¹², and through each starting combination a number of 41.7 times.

As a technological support of the research I have used the Hold'em Manager 2 software. Available for purchase online, this software stores a multitude of data, including video storage, pertaining to all hands one plays on a mutually agreed poker platform, such as Pokerstars. In addition to the storing function, it also allows certain processing of the data collected.

Specifically, for those not familiar with it, it separately stores data from tournaments and cash games, and displays among other things, in different selectable ways of arranging:

- the hole cards of the user,
- the time and date of each hand,
- his actions on the four streets (e.g. "X" for check in the third column below, "F" for fold, etc.),
- the board / community cards,
- the stakes,
- the user's net win or loss,
- the pre-flop actions,
- the frequency of dealing of all 169 hands (the lower-right smaller icon overlapped), etc.



Crucially, it also has video footage of the hands played. If a certain hand has not been played all the way till showdown, only the user's cards remain visible when double clicking it:

¹² For more details, see the first table of the next chapter.



In the hand screen shot above, holding pocket 4s, I check-folded on the flop, so that all the other players' hole cards remain unknown.

If, however, a hand has reached showdown (regardless whether with the user still present at the table, or by (at least) two of his/her opponents doing it), HM2 will display all known hole cards and, for the first streets within the game, pot size, playing parameters of the opponents, each player's equity (the red figure below the hole cards), meaning the probability of him/her winning or splitting the pot at the given moment of the game (bottom left), etc:



This is how a hand looks when screen-shot directly on the Pokerstars platform (with me holding 54-s and having folded pre-flop):



And this is how the same hand is displayed in the HM2 database, captured at showdown, with my cards hidden, since I had already folded pre-flop, meaning my equity evolution in the left bottom icon is also not shown:

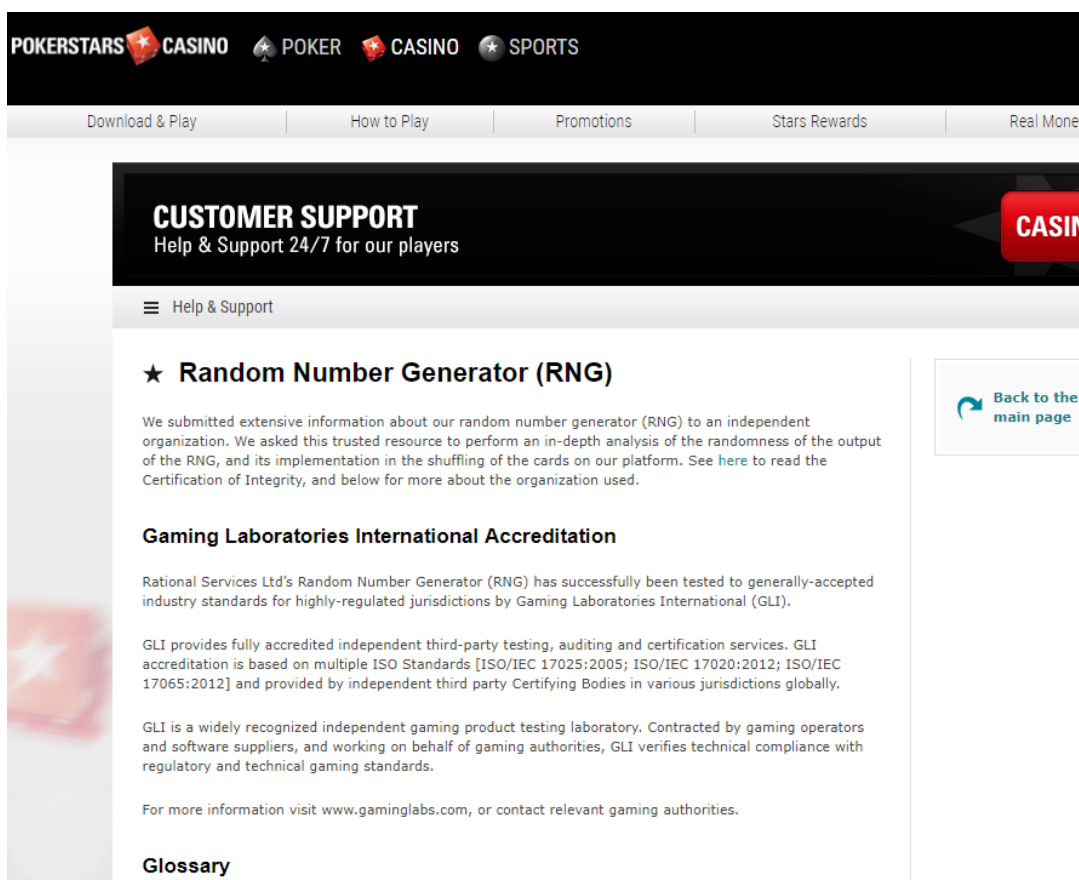


With - as far as I remember - no more than maximum seven exceptions, all screen captures presented throughout the paper are made from within the hands where I was personally involved in the game, and technically from within the HM2 database and not from the platform itself, for reasons of convenience related to the data that are displayed and can be correspondingly processed in a facile manner.

I.3 Main hypotheses tested and limits of interpretation

With these technical support issues now also being clarified, let us move forward, and get to **the actual point of this enterprise: to test whether online poker, in this case the Pokerstars platform, is "rigged" or not.** As said, over the last years there have been thousands of complaints all over the Internet supporting this idea - discussions on online poker forums, mass media articles, innumerable screen and video captures of millions of hands, even a few lawsuits, etc.¹³ However, exactly because of this spectacular variety of statements, there has never been a clear, unified, precisely formulated, and universally accepted meaning, let alone demonstration, of what "rigged" actually means.

Hereby I propose an operational meaning of the term, defined by opposition to what the Pokerstars, and most online poker websites more generally, claim, *i.e.* that the software operates on the basis of a "Random number generator" (RNG), which, self-understood, deals the cards in a *random* manner. Conversely, in my lecture, what the critics argue is exactly that Pokerstars' RNG distributes cards non-randomly.



The screenshot shows the Pokerstars website's customer support section. At the top, there is a navigation bar with 'POKERSTARS CASINO', 'POKER', 'CASINO', and 'SPORTS'. Below this is a secondary navigation bar with 'Download & Play', 'How to Play', 'Promotions', 'Stars Rewards', and 'Real Money'. The main content area is titled 'CUSTOMER SUPPORT' with the subtitle 'Help & Support 24/7 for our players'. A red 'CASINO' button is visible on the right. The page content includes a 'Help & Support' menu, a section for '★ Random Number Generator (RNG)', and a 'Gaming Laboratories International Accreditation' section. The RNG section contains text about an independent organization's analysis and a link to 'Back to the main page'. The accreditation section mentions Rational Services Ltd's RNG and GLI's testing services. A 'Glossary' link is at the bottom.

¹³ See for instance, among so many: <https://legitorscam.org/pokerstars-is-a-scam/>, <https://www.pokertube.com/article/is-pokerstars-rigged>, <http://www.pokerupdate.com/poker-opinion/1122-is-pokerstars-rigged/> (see the comments, especially), <http://www.pokerscout.com/AllReviews.aspx?id=1>, <http://forumserver.twoplustwo.com/25/probability/pokerstars-rigged-447349/>, <http://forumserver.twoplustwo.com/54/poker-beats-brags-variance/pokerstars-rigged-proof-tba-1559406/>, <https://www.youtube.com/watch?v=2Ty5NmT-4-4>, https://www.youtube.com/watch?v=kuBvAWwRY_o, <https://www.youtube.com/watch?v=EHQidtk9IY>, <https://www.youtube.com/watch?v=dt7cfdaTCbg>, <https://www.youtube.com/watch?v=vSnfaik92pc>, <https://www.youtube.com/watch?v=92tDwMyn0pI>, <http://pokerstars-rigged-scam.blogspot.ro/>, <https://www.complaintsboard.com/complaints/pokerstars-anaheim-california-c366882.html>, <https://bonuscodepoker.com/aga-pokerstars-battle>, or <http://forumserver.twoplustwo.com/153/high-stakes-pl-omaha/massive-bot-ring-pokerstars-party-how-spot-them-1537778/>

Now, under any normal circumstances, there actually should be no debate and nothing for me to research, since any, and I repeat, *any* IT specialist will tell you there simply is no such thing as a (truly, genuinely) "random" number generator. Any software operating with such an algorithm is conceived by a human mind, which makes it by default anything, but random. What players should expect at best is a *pseudo*-random distribution of cards. In this adapted meaning, what an online poker platform could do is at best a satisfactory enough mimicking, or simulation, of the randomness otherwise existent, and measurable as such, in nature. Depending on the degree to which their distribution of cards comes close to what a natural random distribution would look like, poker sites RNGs might subsequently be evaluated individually and hierarchically classified as *more or less close to randomness*.

In direct relation to this new adapted meaning and understanding, when further exploring the allegations made in the online realm, the all-so-frequent term "rigged" would implicitly define a *deliberate, systematical*, and (statistically) *significant* distancing from what randomness would imply. And this, as probably already obvious, suddenly becomes considerably more difficult to verify and, if the case, demonstrate: whereas certain recorded variations and deviations from randomness pose no difficulty in terms of measurement and evaluation, given the existence of multiple exact, precise, evaluations of the normality (*i.e.* randomness) of a distribution, universally employed and accepted, a demonstration of intent, of deliberation, of premeditation, is a completely different matter. After all, accidents do indeed happen in nature. Similarly, an online poker RNG may suddenly be affected by an unintentional error, by a glitch, etc. Where does true intent begin, and how does one demonstrate it beyond any reasonable doubt? Obviously, there is no single, universally accepted, answer to such a question.

And herein lies the second fundamental challenge for the researcher of such a topic: how to interpret and evaluate whatever deviations from randomness may be found during the investigation in such terms that both the scientific community approves and the ordinary poker players understand. Should, for instance, a measured linear correlation coefficient of minus .81, covering 3k+ showdowns, between a player's recorded equity on a specific street of the game and the factual outcome of the hand, meaning him/her winning, losing, or splitting the pot, be enough? Of course, correlation does not equate causation, but what if such correlations are repeatedly discovered throughout the testing, and, additionally, and crucially, *they all work the same way*, meaning their effect is always the same, for instance making the underdog win more frequently than mathematically expected to? Or what if, for instance, when analyzing a player's pre-flop engaged heads-up all-ins, it is discovered that not only did he actually win at a rate of little below 3/4 of the expected win rate, but also, that this "deficit" has been recorded in seven of the eight methodologically separated all-in categories? Does this indicate something like a deliberate and systematic non-random action of the software? Or, for statistics fans: what does a *p* value of, say, 0.044 suggest and how should one relate to it when interpreting the results of a measurement? Interrogations such as these converge towards a fundamental idea: the heuristic limits of any methodological approach, and hence the need to take all figures for what they are and nothing more, nor less: statistical indicators, usually operating in a specific context pertaining to a certain confidence interval, a certain level of statistical significance, etc.

For both potential categories of audience, here is a quote from one of the best books on poker I have ever read - Barry Greenstein's *Ace on the River: An Advanced Poker Guide*.¹⁴ Amusing as it is, this hypothetical situation does seem to capture the very heuristic nature of the above-discussed problem and spare me a considerable and most likely redundant amount of further explanation:

¹⁴ Last Knight: Fort Collins, CO (2005, p. 154).

Someone shows you a coin with a head and a tail on it. You watch him flip it ten times and it comes up heads. What is the probability that it will come heads on the eleventh flip?

A novice gambler would tell you, "Tails is more likely than heads, since things have to even out and tails is due to come up."

A math student would tell you, "We can't predict the future from the past. The odds are still even."

A professional gambler would say, "There must be something wrong with the coin or the way it is flipped. I wouldn't bet with the guy flipping it, but I'd bet someone else that heads will come up again."

On a more serious note, it is within the frontiers of the above indicated limits of interpretation and adaptations of some common, but otherwise inoperative terms such as "rigged", that I formulated the main hypotheses of this investigation and subsequently tested them. A careful reading, over weeks, of the main allegations roaming on the Internet has led me to summarize the most frequent and serious ones as follows:

- the hole cards on Pokerstars would be dealt in a non-random manner; most of these allegations further targeted a specific type of situation - the so-called "coolers" such as, notorious among the platform's clients, AA vs. KK vs. QQ three-way duels;
- the pre-flop engaged all-in duels in a heads-up format (meaning 1 vs. 1) would show spectacularly abnormal deviations from anything mathematically expected;
- the flop cards would further multiply the "cooler" situations, way beyond anything normal in terms of frequency, by simultaneously providing the players that remained at the table with promising, attractive combinations; Some critics specifically use the term "second shuffle", one supposedly occurring after the pre-flop round is finished.
- after the flop, the turn and especially the river cards (hence the nickname "Riverstars") would also be dealt non-randomly, usually to the direct favor of the underdog, who, it is alleged, would win considerably more often than mathematically correct in probabilistic terms - hence frequent terms such as "leveling the field" or "balancing the odds";
- roughly every - and here estimations differ - every fifth, tenth, or twentieth hand would be "manipulated" by a non-random acting software, meaning these hands would register an outcome contrary to the mathematically expected one;
- many players at the cash games tables (but not only) would actually be bots, some of them acting to the direct benefit of Pokerstars, and with their tacit consent.

The general logic underpinning these allegations in terms of purpose, or motivation, is one and the same: these deviations from statistical normality implying randomness are deliberate and systematic and serve one purpose: the increase of the proportional rake the platform collects and is ultimately making a living of: "coolers" will make players bet, raise, and re-raise higher, which translates into a bigger rake to be collected; enticing flops act towards the same final outcome; a insidious assisting of the underdog prevents recreational players to lose too much money too fast, thus protecting the player base and the platform's source of income, etc.

With the last accusation, albeit it an extremely serious one, remaining obviously un-testable, at least from my position, I have rephrased and regrouped all the other ones in forms that will hopefully be approved by both the scientific community as being correctly formulated and verifiable and the poker players as accurately reproducing the content of the accusations. Oppositely to the general-umbrella equivalent of a "null hypothesis", which would state that anything pertaining to cards distribution on Pokerstars is entirely random (or

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