The Superstar Effect: Evidence from Chess*

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Eren Bilen[†] Alexander Matros[†,‡]

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Abstract. "Superstars" exist in many places – in classrooms, or in workplaces, there is a small number of people who show extraordinary talent and ability. The impact they have on their peers, however, is an ongoing research topic. In competition, they might intimidate others; causing their peers to show less effort. On the other hand, superstars might encourage higher effort, as their existence in a competition encourages them to "step up" their game. In this study, we analyze the impact of a superstar on their peers using evidence from chess. The existence of a contemporary superstar (and the current World Chess Champion) Magnus Carlsen, as well as, past world champions such as Garry Kasparov, Anatoly Karpov, or Bobby Fischer enables us to identify whether the existence of a superstar in a chess tournament has a positive or an adverse effect on other chess players' performance. The results indicate that the effect depends on the intensity of the superstar. If the skill gap between the superstar and the rest of the competitors is large enough, an adverse effect exists. However, when the skill gap is small, there may be slight positive peer effects. In terms of head-to-head competition, the evidence shows that superstars outperform their opponents in all specifications due to their higher ability. Understanding the effect of superstars on peer performance is crucial for firms and managers considering to introduce a superstar associate for their team.

JEL classification: M52, J3, J44, D3
Keywords: superstar, tournament, effort, chess

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[†]Department of Economics, University of South Carolina, Columbia, SC 29208. Email: eren.bilen@grad.moore.sc.edu, alexander.matros@moore.sc.edu

[‡]Department of Economics, Lancaster University, Lancaster, LA1 4YX, United Kingdom Email: a.matros@lancaster.ac.uk

1. Introduction

> *"When you play against Bobby [Fischer], it is not a question of whether you win or lose. It is a question of whether you survive."*
>
> –Boris Spassky, World Chess Champion, 1969 - 1972.

Maximizing their employees' effort is one of the chief goals of the firm. To this extent, firms typically encourage competition among their employees and allocate bonuses according to their performance and effort. At the same time, firms want to hire the best workers – preferably, the ones who are "superstars" in their fields. For this reason, it is not unusual to see million-dollar hiring contracts among the Forbes top 500 firms.

However, there might potentially be unintentional side effects of hiring a superstar employee. The seminal work done by Brown (2011) took a new and creative approach to analyze these potential side effects. She considered a famous superstar from golf: Tiger Woods. Her goal was to uncover whether Tiger Woods had any effect −adverse or positive− on his competitors' performance. She compared performances in tournaments with and without Tiger Woods and unveiled that there was a sharp decline in performance in tournaments in which Tiger Woods competed in. This evidence points out that Tiger Woods, as a superstar, creates a psychological pressure on his competitors which has a discouraging effect, causing them to perform worse than their typical performance.

In this study, we analyze the superstar effect using observations from chess. Employing a rich move-level dataset from 1962 to 2019, we study the impact of six different superstars in different time periods on tournament performance: Magnus Carlsen, Garry Kasparov, Anatoly Karpov, Bobby Fischer, Hou Yifan, and Igors Rausis. Using computer evaluations with a state-of-the-art chess engine, we find that a superstar lowers the performance in a tournament if there is a very large skill gap between the superstar and the competitors. This effect seems to be driven by the players' belief that their chances to win the tournament are slim. There appears to be a slight positive effect with superstar presence when the players believe they indeed have a chance to win the tournament. In terms of head-to-head competition, the effect is clear. For all samples, the superstar players strongly dominate their opponents, and some superstars are more dominating than others.

Chess provides a clean setting to analyze the superstar effect for the following reasons. First, non-player related factors are minimal to non-existent in chess since every chess board is the same for all players. Second, both game-level and move-level performance indicators can be obtained with the use of computer algorithms that can evaluate the quality of each move. Third, multiple chess superstars exist who lived in different time periods and come from different backgrounds, improving the external validity of the study.

The literature following Brown (2011) use alternative settings ranging from professional track and field competitions to swimming. A study in a similar spirit to Brown (2011) that also analyzes a superstar from golf is Tanaka and Ishino (2012). Their superstar is Masashi Ozaki from Japan who competed in Japan golf tour and dominated the tournaments he participated in throughout the 1990s. Their results are in parallel with Brown (2011): the presence of a superstar affects adversely the scores of the other players. Guryan, Kroft and Notowidigdo (2009) is another study that focuses on the partners' performance. They measure how a golfer's performance is affected by their partner's performance and find that the partner's performance has very little impact on a player's own performance. This finding differs from previous studies focusing on peer effects in the workplace or in the classroom where typically positive peer effects exists. (Mas and Moretti 2009, Duflo, Dupas and Kremer 2011, Cornelissen, Dustmann and Schönberg 2017)

Further work done by Hill (2014*b*) focuses on a different superstar: Usain Bolt. He compares the performance of athletes in a run where Usain Bolt is competing and where Usain Bolt is not present. His results are the opposite of the results in Brown (2011). Athletes perform much better when Usain Bolt is competing. This can be attributed to non-superstar athletes being motivated by having Usain Bolt running just "within their reach", enabling them to push one step further and show extra effort. Findings in Hill (2014*a*), focusing on track and field events are similar to those in Hill (2014*b*): higher performing athletes are creating a positive impact on their competitors' performance.

Swimming is used in Yamane and Hayashi (2015) and Jane (2015). Yamane and Hayashi (2015) compare performance of swimmers who compete in adjacent lanes and find that the performance of a swimmer is positively affected by the performance of the swimmer in the adjacent lane. In addition, this effect is amplified by the observability of the competitor's performance. Specifically, in backstroke competitions where observability of the adjacent lane is minimal, there appears to be no effect; whereas the effect exists in free-style competitions with higher observability. Jane (2015) uses data on swimming competitions in Taiwan and finds that having faster swimmers in a competition increases the overall performance of all the competitors participating in the competition. This finding agrees with Yamane and Hayashi (2015) and Hill (2014*b*,*a*).

Connolly and Rendleman (2014) and Babington, Goerg and Kitchens (2020) re-assess the findings in Brown (2011). Their evidence points out that an adverse superstar effect may not be as strong as suggested by in Brown (2011), and that the results from Brown (2011) are not robust to alternative specifications. They suggest that the effect could work in the opposite direction – that the top competitors can perhaps bring forth the best in other players' performance. In addition, Babington, Goerg and Kitchens (2020) provide further evidence using observations from men's and women's FIS World Cup Alpine Skiing competitions and find little to no peer effects when skiing superstars Hermann Maier and Lindsey Vonn participate in a tournament.

A set of studies investigate the effect of superstars in tournaments from Topcoder competitions. Topcoder and Kaggle are the two largest crowdsourcing platforms where contest organizers can run online contests offering prizes to contestants who score the best in finding a solution to a difficult technical problem stated at the beginning of the contest. Arkhak (2010) finds players avoid competing against superstars in Topcoder competitions. Studying the effect of increased competition on responses from the competitors, Boudreau et. al. (2016) find lower-ability competitors respond negatively to competiton, while higher-ability players respond positively. Lastly, Zhang et. al., (2019) suggests there may be potential future benefits of competing with a superstar via competitors learning from the superstar contestant.

There is ample empirical evidence showing that incentives matter in rank order tournaments. Earlier empirical work in Ehrenberg and Bognanno (1990*a*,*b*) −which also use observations from PGA golf tour as in Brown (2011)− find that offering higher prizes in tournaments improves performance.[1] Coffey and Maloney (2010) compare horse and dog races to separate out the selection of stronger competitors in tournaments when large monetary prizes are offered. They find stronger responses to prizes in horse races where handlers are with their horses during the races while in dog races they are not. Sunde (2009) documents incentive effects in tennis tournaments.

There is a growing literature studying a broad range of questions using data from chess competitions. Gerdes and Gränsmark (2010) test for gender differences in risk taking using evidence from chess games played between male and female players. They find that women choose more risk-averse strategies playing against men. In terms of performance differences, Backus et al. (2016) find that female players make more mistakes playing against male opponents with similar strength.[2] On the other hand, Stafford (2018) has an opposite finding in which women perform better against men with similar ELO ratings. Further set of research testing different questions using chess; Dreber, Gerdes and Gränsmark (2013) test the relationship between attractiveness and risk taking using chess games; Künn, Palacios and Pestel (2019) and Klingen and van Ommeren (2020) find indoor air quality effects on performance and risk taking behavior of chess players; Moul and Nye (2009) show evidence of Soviet collusion in top level chess tournaments; Levitt, List and Sadoff (2011) test whether chess masters are better at making backward induction; Kunn and D. (2020) show adverse effects in performance in online chess tournaments compared to offline tournaments.

Economic theory on contests suggests an adverse effect to exist when players with largely different abilities compete for a prize. Rosen (1981) makes the

[1] Orszag (1994) shows results in Ehrenberg and Bognanno (1990*a*,*b*) may not be robust using data from a different PGA golf tour season (1992) and the weather conditions.

[2] In a more recent work, Smerdon et al. (2020) agrees with findings in Backus et al. (2016) showing evidence from a different sample.

first contribution in understanding "superstars" by shedding light on how skill sets in certain markets become excessively valuable. Contributions in Lazear and Rosen (1981), Green and Stokey (1983), Nalebuff and Stiglitz (1983), and Moldovanu and Sela (2001) describe the incentive effects of heterogeneous players in rank-order tournaments with relative performance. Baik (1994) and Nti (1999) analyze Tullock (1980) contests with two-players with heterogeneous abilities, and show a decrease in the equilibrium effort for the competitors as the relative ability difference increases. Brown (2011) provides a Tullock contest extended to n-players in which the players are adversely affected by the presence of a high ability superstar. Xiao (2020) shows the possibility of having a positive or a negative incentive effect when a superstar participates in a tournament. His work suggests the effect to depend on the prize structure, ability composition of the participants, and the degree of difference between the ability types.

The rest of the paper is organized as follows: First, a two-player tournament model with heterogeneous ability and multiple prizes is presented in section 2. Section 3 gives background information on chess and describes how chess data is collected and analyzed. Section 4 provides the empirical design. Section 5 presents the results, and section 6 concludes.

2. Theory

Proposition

Consider a two-player model in which a player competes against a superstar. We model such face-to-face competition as the following two-player contest. Player 1 maximizes his expected payoff

$$\max_{e_1} \quad \frac{e_1}{(e_1+\theta e_2)}V_1 - e_1$$

where V_1 is the prize (monetary or ELO points) which player 1 can win. Player 2, who is a superstar, has ability $\theta \geq 1$ and maximizes her expected payoff

$$\max_{e_2} \quad \frac{\theta e_2}{(e_1+\theta e_2)}V_2 - e_2$$

where V_2 is the prize which player 2 can win. The first order condition for player 1 is

$$\frac{\theta e_2}{(e_1+\theta e_2)^2}V_1 - 1 = 0,$$

and for player 2,

$$\frac{\theta e_1}{(e_1+\theta e_2)^2}V_2 - 1 = 0.$$

It must be true that in equilibrium

$$\frac{e_2}{e_1} = \frac{V_2}{V_1}$$

which yields the equilibrium effort level for player 1,

$$e_1^* = \frac{\theta V_1 V_2}{(V_1 + \theta V_2)^2} V_1$$

and similarly for player 2,

$$e_2^* = \frac{\theta V_1 V_2}{(V_1 + \theta V_2)^2} V_2.$$

The probability of success for player 1 in equilibrium is

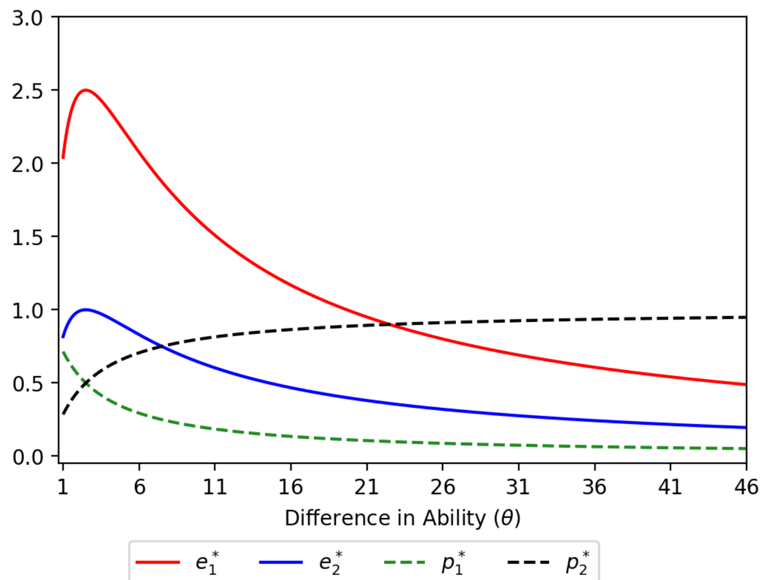
$$p_1^* = \frac{e_1^*}{e_1^* + \theta e_2^*} = \frac{1}{1 + \theta \frac{V_2}{V_1}}$$

and for player 2,

$$p_2^* = \frac{\theta e_2^*}{e_1^* + \theta e_2^*} = \frac{1}{1 + \frac{V_1}{\theta V_2}}.$$

Figure 1 shows how equilibrium efforts and win probabilities change for different levels of heterogeneity. Initially, when the ability difference is small, the effort level for both players increases. As the ability difference increases, players show less effort. In other words, if a superstar is "super", the model predicts an adverse effect, whereas if the gap between the superstar and the underdog is small, the effect is positive with both players showing higher effort.

Figure 1: Equilibrium effort and win probabilities with differences in ability



Note: Prizes are taken as $V_1 = 10$ and $V_2 = 4$ reflecting that the prize for a non-superstar player is greater than of the superstar's. By assuming $V_1 > V_2$, we assume the underdog to enjoy a greater benefit if he manages to win the competition against the superstar. This is also evident in chess: in ELO rating calculations, the lower rated player gains more rating points if he wins against a higher ranked player.

3. Data

3.1 Background for Chess

Chess is a two-player game with origins dating back to 6th century AD. Chess is played over a 8x8 board with 16 pieces for each side (8 pawns, 2 knights, 2 bishops, 2 rooks, 1 queen, and 1 king). Figure 2 shows a chess board. Players make moves in turns in which the player with the white pieces moves first. The ultimate goal of the game is to capture the enemy king. A player can get close to this goal by threatening the king through a "check": if the king has no escape, the game ends with a "checkmate". A game can end in three ways: white player wins, black player wins, or the game ends in a draw.

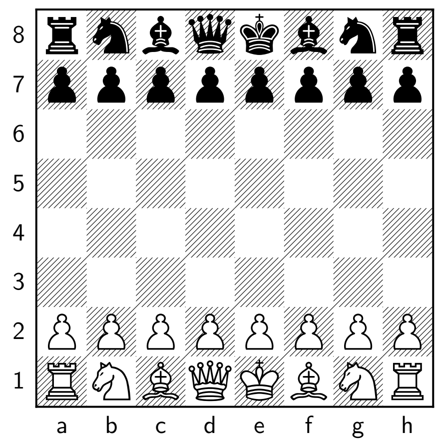


Figure 2: A chess board

The possible combinations of moves in a chess game is estimated to be more than the number of atoms in the universe.[3] However, some moves are better than others. With years of vigorous training, professional chess players learn how to find the best moves by typically employing backward-induction and calculating the consequences of each move to a certain complexity level. Failing to find the best moves in a position typically leads to the player losing their game at the top level. The player who performs better in general is the player who manages to find the correct moves more often.

The standard measure of player strength in chess is the ELO rating system first adopted by FIDE in 1970. This system was created by the Hungarian physicist Arpad Elo (Elo 1978). Elo considers the performance of a player in a given game as a random distribution distributed normally centered at their unobservable true level of performance. Each player gets a starting ELO rating which is

[3] A lower bound on the number of possible moves is 10^{120} moves, per Shannon (1950) while the number of atoms in the observable universe is estimated to be roughly 10^{80}.

updated according to the outcome of each game via

$$ELO_{R,t+1} = ELO_{R,t} + K\left[S_i - E_t\left(S_i \mid R_i, R_j\right)\right] \tag{1}$$

where S_i is the outcome of a game where S_i=1 if player i wins their game, S_i=0 for a loss, and S_i=1/2 in case of a draw; $E_t\left(S_i \mid R_i, R_j\right)$ is the expected probability of player i winning their game given the ELO ratings of the two players R_i and R_j which equals $E(S_R \mid R_R, R_B) = \Phi\left(\frac{R_R - R_B}{400}\right)$ where $\Phi(.)$ is the c.d.f. for the normal distribution.[4] K is a parameter for rate of adjustment.

Having such rating system allows for making comparisons on player strengths. For instance, every month, FIDE publishes Top 100 players in the world according to their ELO ratings. Specifically, World's Top 10 players are considered the most elite players in the world who earn significant amount of prizes and sponsorships. Moreover, chess titles have specific ELO rating requirements. For instance, the highest title in chess, Grandmaster, requires the player to have an ELO rating 2500 or higher; for International Master title 2400 or higher; and FIDE Master title 2300 or higher.[5]

Over the past decades, computer scientists have developed algorithms, or "chess engines" that exploit the game-tree structure of chess. These engines analyze each possible tree branch to come up with the best moves. The early chess engines were inferior to humans. After a few decades however, one chess engine developed by IBM in the 1990s, Deep Blue, famously defeated the world chess champion at the time, Garry Kasparov in 1997. This was the first time a world chess champion lost to a chess engine under tournament conditions. Since then, chess engines have passed well beyond the human skill. As of 2020, Stockfish 11 is the strongest chess engine with an ELO rating of 3497.[6] In comparison, the current world chess champion, Magnus Carlsen, has an ELO rating of 2862.[7]

In addition to finding the best moves in a given position, a chess engine can be used to analyze the games played between human players.[8] Quality of a move can be measured numerically by evaluating the move chosen by a player and comparing it to the list of moves suggested by the chess engine. If the move played by a player is considered a bad move by the engine, then that move is assigned a negative value with its magnitude depending on the engine's evaluation.

[4] The probability of player i wins in a given game played against player j is a function of true abilities of both players $P(p_i > p_j) = P(p_i - p_j > 0)$
$= \int_0^{\infty} \frac{1}{\sqrt{2\sigma^2}} \Phi\left(\frac{x - [\mu_i - \mu_j]}{\sqrt{2\sigma^2}}\right) dx = 1 - \Phi\left(\frac{0 - [\mu_i - \mu_j]}{\sqrt{2\sigma^2}}\right) = \Phi\left(\frac{[\mu_R - \mu_B]}{\sqrt{2\sigma^2}}\right)$ where p_i is the probability that fighter i with true ability μ_i wins his game.

[5] Our sample consists of the very elite chess players, often called "Super GMs", with ELO ratings higher than 2700 in most cases.

[6] Modern chess engines, such as Stockfish, have much higher ELO ratings compared to humans. Most modern computers are strong enough to run Stockfish for analyzing chess positions and finding the best moves, which is the engine use in our analyses.

[7] The highest ELO rating ever achieved by a human was 2882 in May 2014 by Magnus Carlsen.

[8] Every chess game played at the top-level is recorded, including all the moves played by the players.

3.2 Chess Superstars

The first official world chess champion is Wilhelm Steinitz who won the title in 1886. Since Steinitz, there have been fifteen world chess champions in total. Among these fifteen players, four of them have shown an extraordinary dominance over their peers: Magnus Carlsen, Garry Kasparov, Anatoly Karpov, and Bobby Fischer.[9]

Magnus Carlsen is the current world chess champion who first became champion in 2013 at age 22. He reached the highest ELO rating ever achieved in history. Garry Kasparov was the world champion from 1985-2000 and was the number one ranked chess player for 255 months, setting a record for maintaining the number one position the longest duration of time. Anatoly Karpov was the world champion before Kasparov in the years 1975-1985. He won over 160 tournaments, which is a record for the highest number of tournaments won by a chess player.[10] Lastly, Bobby Fischer was the world champion before Karpov between 1972-1975. He won all U.S. championships he played from 1957 (at age 14) to 1966, with a 11/11 score in the 1963 U.S. championship in which no other player in history has ever achieved a perfect score on a U.S. chess championship other than Fischer to this date.[11]

In addition to the four male superstar world chess champions, there exists a female chess superstar: Hou Yifan, a four time women's world chess champion between the years 2010-2017. She played three women's world chess championship matches in this period and did not lose a single game against her opponents.[12] She dominated the tournaments from 2014 until she decided to stop competing in women's tournaments and started to play solely in men's tourna-

[9] In his classic series, "My Great Predecessors", Kasparov (2003) gives in depth explanations on his predecessors, outlining qualities of each world champion before him. In this paper, we consider the "greatest of the greatest" world champions as "superstars" with sufficient observations available on the tournaments of top players in their era. We present evidence why these players were so dominating and were considered "superstars" in each era.

[10] Kasparov (2003) shares an observation on Karpov's effect on other players during a game in Moscow in 1974: *"Tal, who arrived in the auditorium at this moment, gives an interesting account: "The first thing that struck me (I had not yet seen the position) was this: with measured steps Karpov was calmly walking from one end of the stage to the other. His opponent was sitting with his head in his hands, and simply physically it was felt that he was in trouble. 'Everything would appear to be clear,' I thought to myself, 'things are difficult for Polugayevsky.' But the demonstration board showed just the opposite! White was a clear exchange to the good – about such positions it is customary to say that the rest is a matter of technique. Who knows, perhaps Karpov's confidence, his habit of retaining composure in the most desperate situations, was transmitted to his opponent and made Polugayevsky excessively nervous."* p. 239 "My Great Predecessors" Vol 5.

[11] Kasparov (2003) on Fischer's performance in 1963 U.S. championship: *"Bobby crushed everyone in turn, Reshevsky, Steinmeyer, Addison, Weinstein, Donald Byrne... Could no one really whitstand him?! In an interview Evans merely spread his hands: 'Fantastic, unbelievable...' Fischer created around himself such an energy field, such an atmosphere of tension, a colossal psychological intensity, that this affected everyone."* p. 310 "My Great Predecessors" Vol 4.

[12] Not losing a single game in world championship matches is a very rare phenomenon, since the world champion and the contestant are expected to be at similar levels.

ments.

Figures 3-12 show how the four world chess champions, Carlsen, Kasparov, Karpov and Hou Yifan performed compared to their peers across years.[13] The ELO rating difference between each superstar and the average of world's top 10 players in each corresponding era is about 100 points. This is a very significant gap especially at the top-level competitive chess. For instance, expected win probabilities between two players with a gap of 100 ELO rating points are approximately 64%-36%.

Lastly, we consider a chess grandmaster, Igors Rausis, who competed against non-masters in the years between 2012-2019. He was one of the top 100 chess players in the world at the time he competed in tournaments against players who had ELO ratings 500 points less than him. The ELO rating difference between him and the average opponent in the tournaments he competed in between these years is similar to Magnus Carlsen, with an ELO rating of 2882 competing against Stockfish 11 with an ELO rating 3497. Figure 13 shows the ELO rating distribution of such tournament. Rausis' participation in such tournaments creates a unique setting in which a very strong chess grandmaster plays in tournaments against much lower rated non-master opponents.[14]

Table 1 presents further statistics on the dominance of the superstars in the sample showing their tournament win probabilities. Panels A-E includes the world's top 10 chess players for the corresponding era and a summary of their tournament performances. Our contemporary superstar, Magnus Carlsen, participated in 35 tournaments with classical time controls between 2013 and 2019, and won 21 of them. This 60% tournament win rate is two times higher than World's #2 chess player, Fabiano Caruana, who has a tournament win rate of 30%. A more extreme case is with Anatoly Karpov who won 26 out of the total 32 tournaments he competed in scoring a 81% tournament win rate while the runner up Jan Timman had a tournament win rate of 22%.[15] The final panel, Panel F, shows the tournament performances for Rausis and his top performing opponents. Rausis showed an outstanding performance by winning all eight tournaments in the sample without facing a single loss.

Figures 8-12 show individual tournament performances across years for each superstar with the vertical axis showing whether the superstar gained or lost rating points at the end of a tournament. For instance, in 2001, Kasparov played in four tournaments and won all four of them. Despite winning all four tournaments, he lost rating points in one tournament. For the world's strongest player, winning tournaments alone is not sufficient to maintain their number one position: they also have to win tournaments decisively.

[13] ELO rating information is not available for Fischer's era. FIDE adopted the ELO ratings system in 1970.

[14] Additionally, Igors Rausis was banned by FIDE, the International Chess Federation, in July 2019 due to cheating using a chess engine via his phone during tournaments.

[15] Restricting the runner ups' tournament wins to tournaments in which a superstar participated lowers their tournament win rate significantly. (tables available upon request)

Table 1: World's Top 10 chess players and their tournament performances

years: 2013-2019 — *PANEL A*

Name	# of tournament wins	# of tournaments played	% tournament wins	$\overline{ELO}$	proportion of games won	proportion of draws	proportion of games lost	$\overline{ACPL}$	# of moves	# of games
Carlsen, Magnus	21	35	60%	2855	0.352	0.576	0.072	6.281	16,296	340
Caruana, Fabiano	15	49	30%	2802	0.283	0.592	0.126	7.238	22,468	468
So, Wesley	6	27	22%	2777	0.226	0.666	0.108	5.733	11,773	276
Aronian, Levon	5	33	15%	2788	0.196	0.662	0.142	6.319	13,646	316
Giri, Anish	3	31	9%	2770	0.149	0.719	0.131	7.377	14,393	319
Karjakin, Sergey	3	28	10%	2768	0.168	0.689	0.143	6.113	12,919	291
Mamedyarov, Shakhriyar	3	22	13%	2777	0.172	0.674	0.154	6.046	9,532	229
Vachier Lagrave, Maxime	3	26	11%	2777	0.163	0.703	0.134	5.770	10,368	242
Ding, Liren	2	10	20%	2784	0.221	0.696	0.082	6.097	5,140	111
Grischuk, Alexander	0	15	0%	2777	0.183	0.633	0.184	8.405	6,946	156

years: 1995-2001 — *PANEL B*

Name	# of tournament wins	# of tournaments played	% tournament wins	$\overline{ELO}$	proportion of games won	proportion of draws	proportion of games lost	$\overline{ACPL}$	# of moves	# of games
Kasparov, Garry	17	22	77%	2816	0.439	0.510	0.051	4.903	9,173	244
Kramnik, Vladimir	13	30	43%	2760	0.323	0.618	0.059	4.796	11,989	326
Anand, Viswanathan	9	25	36%	2762	0.306	0.595	0.099	5.924	9,783	269
Topalov, Veselin	6	26	23%	2708	0.279	0.515	0.206	8.222	11,447	269
Ivanchuk, Vassily	4	17	23%	2727	0.255	0.582	0.164	7.514	7,320	201
Adams, Michael	3	22	13%	2693	0.258	0.574	0.168	8.321	9,339	232
Short, Nigel D	3	18	16%	2673	0.272	0.475	0.253	8.872	6,867	174
Svidler, Peter	3	13	23%	2684	0.234	0.609	0.157	6.369	4,972	141
Karpov, Anatoly	2	12	16%	2742	0.208	0.684	0.108	5.131	4,797	116
Shirov, Alexei	1	26	3%	2706	0.288	0.459	0.253	12.033	11,596	283

Table 1 (cont): World's Top 10 chess players and their tournament performances

years: 1976-1983 *PANEL C*

Name	# of tournament wins	# of tournaments played	% tournament wins	$\overline{ELO}$	proportion of games won	proportion of draws	proportion of games lost	$\overline{ACPL}$	# of moves	# of games
Karpov, Anatoly	26	32	81%	2707	0.434	0.522	0.044	5.067	14,816	392
Timman, Jan H	8	36	22%	2606	0.338	0.515	0.146	7.799	19,310	482
Larsen, Bent	5	26	19%	2608	0.379	0.336	0.285	11.891	17,009	357
Kortschnoj, Viktor Lvovich	3	7	42%	2667	0.448	0.388	0.164	8.712	3,730	88
Tal, Mihail	3	11	27%	2632	0.296	0.604	0.100	6.937	5,555	164
Portisch, Lajos	2	18	11%	2635	0.318	0.531	0.150	7.367	9,526	249
Spassky, Boris Vasilievich	2	13	15%	2626	0.195	0.686	0.119	5.209	4,999	153
Beliavsky, Alexander G	1	4	25%	2591	0.265	0.514	0.221	10.234	2,214	56
Petrosian, Tigran V	1	9	11%	2608	0.262	0.633	0.105	4.760	4,016	123
Kasparov, Garry	0	2	0%	2627	0.252	0.573	0.175	10.759	870	24

years: 1962-1970 *PANEL D*

Name	# of tournament wins	# of tournaments played	% tournament wins	$\overline{ELO}$	proportion of games won	proportion of draws	proportion of games lost	$\overline{ACPL}$	# of moves	# of games
Fischer, Robert James	12	16	75%	.	0.639	0.283	0.078	6.070	10,843	254
Kortschnoj, Viktor Lvovich	7	12	58%	.	0.469	0.459	0.072	6.269	7,829	197
Keres, Paul	4	8	50%	.	0.420	0.547	0.032	5.133	4,900	139
Spassky, Boris Vasilievich	4	9	44%	.	0.410	0.570	0.020	4.214	4,441	138
Botvinnik, Mikhail	3	5	60%	.	0.529	0.414	0.056	4.011	2,287	63
Geller, Efim P	2	12	16%	.	0.426	0.506	0.068	5.213	8,484	221
Tal, Mihail	2	8	25%	.	0.466	0.402	0.133	7.862	4,688	123
Petrosian, Tigran V	1	13	7%	.	0.334	0.621	0.045	4.503	7,743	227
Reshevsky, Samuel H	1	11	9%	.	0.258	0.505	0.237	5.938	5,327	140
Bronstein, David Ionovich	0	6	0%	.	0.283	0.628	0.089	7.435	3,091	94

Table 1 (cont): World's Top 10 chess players and their tournament performances

years: 2014-2019 — *PANEL E*

Name	# of tournament wins	# of tournaments played	% tournament wins	$\overline{ELO}$	proportion of games won	proportion of draws	proportion of games lost	$\overline{ACPL}$	# of moves	# of games
Hou, Yifan	4	4	100%	2644	0.614	0.364	0.023	5.447	2,038	44
Ju, Wenjun	3	6	50%	2563	0.409	0.515	0.076	3.115	2,946	66
Koneru, Humpy	2	6	33%	2584	0.379	0.424	0.197	8.568	2,957	66
Dzagnidze, Nana	0	6	0%	2540	0.359	0.347	0.295	9.709	3,075	64
Goryachkina, Aleksandra	0	1	0%	2564	0.364	0.636	0.000	5.943	563	11
Kosteniuk, Alexandra	0	7	0%	2532	0.297	0.508	0.195	11.504	3,479	75
Lagno, Kateryna	0	2	0%	2544	0.227	0.682	0.091	5.639	844	22
Muzychuk, Anna	0	5	0%	2554	0.218	0.582	0.200	9.229	2,441	55
Muzychuk, Mariya	0	3	0%	2544	0.242	0.576	0.182	7.006	1,545	33
Zhao, Xue	0	6	0%	2519	0.288	0.424	0.288	8.781	3,029	66

years: 2012-2019 — *PANEL F**

Name	# of tournament wins	# of tournaments played	% tournament wins	$\overline{ELO}$	proportion of games won	proportion of draws	proportion of games lost	$\overline{ACPL}$	# of moves	# of games
Rausis, Igors	8	8	100%	2578	0.783	0.217	0.000	4.631	1,962	55
Patuzzo, Fabrizio	1	3	33%	2318	0.600	0.133	0.267	15.901	672	15
Naumkin, Igor	1	4	25%	2444	0.667	0.228	0.106	6.753	887	24
Reinhardt, Bernd	1	4	25%	2207	0.417	0.233	0.350	6.591	677	17
Bardone, Lorenzo	0	3	0%	2095	0.433	0.267	0.300	12.578	451	12
Gascon del Nogal, Jose R	0	2	0%	2469	0.625	0.250	0.125	5.930	591	16
Lubbe, Melanie	0	4	0%	2316	0.401	0.263	0.336	12.625	875	20
Lubbe, Nikolas	0	4	0%	2467	0.527	0.442	0.031	5.360	851	24
Luciani, Valerio	0	4	0%	2158	0.496	0.083	0.421	16.506	706	20
Montilli, Vincenzo	0	3	0%	2117	0.311	0.422	0.267	5.720	643	13

Notes: Panels A-E show the tournament performance for the World's Top 10 chess players for the corresponding time period. ELO rating was first adopted by the International Chess Federation (FIDE) in 1970, hence this information is absent in Panel D for Fischer's sample.
*: Panel F shows the tournament performance for Rausis and his top performing opponents.

3.3 ChessBase Mega Database

Our data comes from the 2020 ChessBase Mega Database containing over 8 million chess games dating back to 1400s. Every chess game is contained in a pgn file with including information on the player names, player's side, ELO ratings, date and location of the game, tournament name, round, and the moves played. An example pgn file and a tournament table is provided in the appendix Table A2 and Figure A1, respectively. In a chess tournament, each move is recorded by the players, including the details about the players such as their names and their ELO ratings, as well as, game round, date, time and location. A copy of these records are then collected by the tournament organizers and stored for record-keeping. ChessBase collects these games from the organizers and makes them available for those would like to study and analyze the games for a fee.

Table A1 in the appendix provides a summary of variables used and their definitions. Table 2 presents the summary statistics for each era with tournaments grouped according to superstar presence. In total, our study analyzes over 2 million moves from approximately 30,000 games played in over 300 tournaments between 1962 and 2019.[16]

3.4 Measuring Performance

We use two methods to assess a player's performance in a tournament. Our first metric comes from computer evaluations where we identify mistakes committed by each player in a given game.[17] A chess game g consists of $moves\ m \in \{1,\dots,M\}$ where player i makes an individual move m_{ig}. A chess engine can evaluate a given position by calculating layers with depth n at each decision node and make suggestion on the best moves to play. Given a best move is played, the engine provides the relative (dis)advantage in a given position $C^{computer}_{igm}$. This evaluation is then compared to the actual evaluation score C^{player}_{igm} once a player makes his or her move. The difference in scores reached via the engine's top suggested move(s) and the actual move a player makes can be captured by

$$error_{igm} = \left| C^{computer}_{igm} - C^{player}_{igm} \right| \tag{2}$$

If the player makes a top suggested move, the player has commited zero error, i.e., $C^{computer}_{igm} = C^{player}_{igm}$. Notice chess is a game of attrition where the player who is able to make less mistakes eventually wins the game. The evaluation stays constant if top moves are played; while the evaluation goes towards showing advantage to the opponent if a player commits a mistake via playing a bad move.

[16] A list of the tournaments is provided in the appendix.

[17] Guid and Bratko (2011) and Regan, Biswas and Zhou (2014) are two early examples of implementations of computer evaluations in chess. Regan has applied computer evaluations to detect cheating in chess games by investigating the proportion of "engine moves" a human player makes in a game.

We then take the average of all the mistakes commited by player i in game g via

$$\overline{error_{ig}} = \frac{\sum_{m=1}^{M} \left| C_{igm}^{computer} - C_{igm}^{player} \right|}{M} \tag{3}$$

which is a widely accepted metric named Average Centipawn Loss (ACPL). ACPL is the average of all the penalties a player is assigned to by the chess engine for the bad moves they made in a game. If the player plays the best moves in a game, his ACPL score will be small where a smaller number means the player performed better. On the other hand, if the player makes moves that are considered bad by the engine in the game, the player's ACPL score would be higher.

The second method we use employs game-level outcomes. Every chess game ends in a win, a loss, or a draw. The player who wins a tournament is the one who has more wins and fewer losses, as the winner of a game receives a full point towards his tournament score.[18] Thus a player who has more wins in a tournament shows higher performance. In terms of losses, the opposite is true. If a player had too many losses in a tournament, their chances to win the tournament would be slim. Lastly, a draw is considered better than a loss and worse than a win against opponents with similar ELO ratings.

We use Stockfish 11 in our analyses with depth $n = 19$ moves. For each move, the engine was given half a second to analyze the position and assess $|C_{igm}^{computer} - C_{igm}^{player}|$. Figure 14 shows an example for how a game was analyzed. For instance, at move 30, the computer evaluation is +3.2, which means that the white player has the advantage by a score of 3.2: roughly the equivalent of being one piece (knight or bishop) up compared to his opponent. If the white player had come up with the best moves throughout the rest of the game, the evaluation can also stay 3.2 (if the black player also makes perfect moves) or would only go up leading to a possible win towards the end of the game. In the actual game, player with the white pieces starts to lose his advantage by making moves that are considered bad by the chess engine, and eventually loses the game. The engine analyzes all 162 moves played in the game, and evaluates the quality of each move. Dividing the sum of mistakes committed by player i to the number of moves played by player i gives the player-specific ACPL score.

4. Empirical Design

The baseline model compares a player's performance in a tournament where a superstar is present with a tournament where there is no superstar competing.

[18] A draw brings half a point, a loss brings no points in a tournament.

This can be captured by the following,

$$\begin{aligned}Performance_{i,j} = \beta_0 + \beta_1 Superstar_j \times HighELO_{i,j} + \beta_2 Superstar_j \times MidELO_{i,j} \\ + \beta_3 Superstar_j \times LowELO_{i,j} + \beta_4 HighELO_{i,j} + \beta_5 MidELO_{i,j} \\ + \boldsymbol{\Theta X_{i,j}} + \eta_i + \epsilon_{i,j} \end{aligned} \quad (4)$$

where $Performance_{i,j}$ is the performance of player i in tournament j, measured by methods discussed in section 3.4. $Superstar_j$ is an indicator for superstar being present in tournament j. $\epsilon_{i,j}$ is an idiosyncratic shock. Having negative signs for β_1-β_3 would mean the presence of a superstar creates an adverse effect, creating a disincentive for players to show effort resulting in worse performance outcomes. $HighELO_{i,j}$ equals one if the player has an ELO rating on the first quartile in the ELO rating distribution of the tournament participants. $MidELO_{i,j}$ captures the second and third quartiles, and $LowELO_{i,j}$ captures the bottom quartile. $\boldsymbol{\Theta X_{i,j}}$ contains the game and tournament level controls. In addition to tournament level specifications, chess allows for a game level analysis which can be specified as the following,

$$Performance_{i,j,k} = \alpha_0 + \alpha_1 AgainstSuperstar_{i,j,k} + \boldsymbol{\Phi X_{i,j}} + \eta_i + \epsilon_{i,j,k} \quad (5)$$

where $AgainstSuperstar_{i,j,k}$ equals one if player i in tournament j plays against a superstar in round k. In this specification, α_1 captures the effect of head-to-head competition against a superstar.

In terms of which tournaments to join, chess superstars typically consider their schedule. They play in the strongest tournaments; however it is typically not possible for them to play in all top-level tournaments since it would be difficult for them to prepare for a large number of tournaments in a year.[19] Generally, if they play a world championship match in a given year, they tend to play in fewer tournaments in that particular year to be able to better prepare for the world championship match.[20] In years without a world championship match, they typically pick a certain number of tournaments to participate in and make preperations. They may play in fewer tournaments in a given year if they believe their schedule does not allow for adequate preparation for each tournament. We control for the average ELO rating in a tournament to account for any selection

[19] In our sample with elite tournaments, a tournament with a superstar on average has 50 points higher average ELO score compared to the tournaments without a superstar. This shows that chess superstars indeed play in the strongest tournaments.

[20] We indeed document a negative correlation between the number of tournaments a superstar plays and world championship years. (results available upon request)

issues.[21]

5. Results

Table 3 shows the performance of non-superstar players playing against a superstar for each sample. There is a distinct pattern that is true for all superstars: playing against them is associated with a higher ACPL score, lower chances to win, and higher chances to lose. This finding verifies that the superstars considered in our study are indeed dominating and show greater performance compared to their peers. For instance, a player who plays against Fischer shows 5.76 points higher ACPL compared to his games against other players. His likelihood of win is 35.9% less; for a draw, 13.9% less; and for a loss 35.9% higher compared to his typical games. This implies that in terms of direct competition, these superstars had a strong dominance over their peers. The strongest domination appears to be with Rausis and Hou Yifan, followed by Fischer as the the magnitudes for ACPL, win, and loss probabilities are stronger compared to the rest of the samples.

The following set of tables, tables 3-10, show the effect of a superstar's presence on the performance of other competitors. It appears that the most dominant superstar according to Table 3, Rausis, had an adverse effect on the top players' performance. These players had a 7.23 higher ACPL score, 15 percentage points less winning chances, 31 percentage points less draws, and a 46 percentage points higher loss rate, although the coefficient on the ACPL and win rate is imprecise. A similar adverse effect is true for the second most dominant superstar, Hou Yifan. Her presence is associated with a 5.50 points of higher ACPL, 6.7 percentage points winning chances and a 10 percentage points higher loss rate for the top players in a tournament. For Fischer, the coefficient for ACPL is negative and imprecise. It appears that the top players did not make more mistakes when Fischer was present. However they indeed had fewer wins and more draws.

Another situation with intense competition is when two superstars, Kasparov and Karpov both participated in a tournament. This means that for a given player, he will have to face both Kasparov and Karpov and perform better than both of them in order to win a tournament. This tough competition appears to create an adverse effect on players. Top players had a 3.5 points higher ACPL, 10 percentage points less win rate, and a 16 percentage points higher loss rate.

[21] Linnemer and Visser (2016) document self-selection in chess tournaments with stronger players being more likely to play in tournaments with higher prizes. A central difference between their sample and ours is the level of tournaments. Their data comes from the World Open tournament, which is an open tournament with non-master participants with Elo ratings between 1400-2200. Our sample consists of players from a much restricted sample with only the most elite Grandmasters with Elo ratings often above 2700. Moreover, these high-level tournaments are invitation based, i.e., tournament organizers offer invitations to a select group of strong players. These restrictions work against any possible selection issues.

The next set of results shows that Kasparov and Karpov's presence separately does not appear to create an adverse effect for the top players. For Kasparov, the effect on the top players appears to be positive, although the coefficients are again imprecise. However, bottom players were negatively affected by his presence. They had 2.29 higher ACPL points, 8 percentage points less win rate, and a 6 percentage points higher loss rate. For Karpov, top players appear to show a slight worse performance, however the coefficients are not significant. Lastly, Carlsen had the least dominance compared to the rest of the superstars in our study according to Table 3. His presence appears to create a slight positive effect on performance. Players played more accurately and made fewer mistakes. For instance, top players had on average 2 points lower ACPL score. The positive effect appears to apply for all the tournament participants.[22]

Table 11 shows the superstar presence for all samples aggregated. It appears indeed the top quantile players show responses to a superstar being present. They commit more mistakes, have less win and draw chances, and experience more losses. Table 12 and Figure 15 show the aggregate superstar effect broken down to each sub-sample for the top quantile players. Moving from Carlsen to Rausis, we observe an increase in the mistakes committed; a decrease in the win rates; and an increase in the loss rates. These results suggest that an increase in the intensity of the superstar is associated with stronger adverse responses from the top players. In other words, players know odds are against them playing against Carlsen; however they have higher odds to win than Rausis' opponents. Knowing this, their aggregate performance during the tournament is much less impacted.

6. Conclusion

Theory predicts an adverse effect to exist in tournaments where a highly skilled competitor is present. Considering their chances to win a tournament against a "superstar", the competitors are discouraged, thus their effort level goes down. On the other hand, if the superstar is only slightly better than the rest of the group, theory predicts that players will show higher effort, as they will have higher chances to win the tournament and win the prize.

Using evidence from chess, we empirically show an adverse effect to exist when a "super" superstar is present in a tournament. Players make more mistakes, win fewer games and lose more games when they compete in a tournament with an extremely highly skilled superstar. In terms of head-to-head competition, our findings are consistent with the theory. A superstar shows greater skill, has higher chances to win, and lower chances to lose against their opponents. However, when a superstar is not "super", there is suggestive evidence

[22] Carlsen's sample is the only sample in which the draw rates are higher and ACPL scores are smaller. Many chess fans criticize modern chess to have too many draws, which we document in our analyses.

for a slight positive effect, despite the superstar still show better performance in head-to-head competition. In these tournaments, players "step-up" their game and collectively show greater performance.

The literature analyzing the superstar effect shows mixed empirical evidence. In golf, the effort level decreases with superstar presence; in 100-metres running or swimming contests, the effort level appears to increase. In this paper, we show that the effect depends on the intensity of the superstar against the rest of the competitors. An intense superstar creates an adverse effect in tournaments; while a superstar who is only slightly more skilled than the rest of the competitors may have a positive impact on the effort level in a tournament.

The takeaway for firms seeking to hire a superstar employee is that hiring a superstar employee may create a positive or an adverse effect on the cohort's performance depending on the skill level gap. If the gap is too large, there may be negative side effects of hiring a superstar employee. In these settings, a highly skilled team member would destroy competition and create an adverse effect on the rest of the team members.

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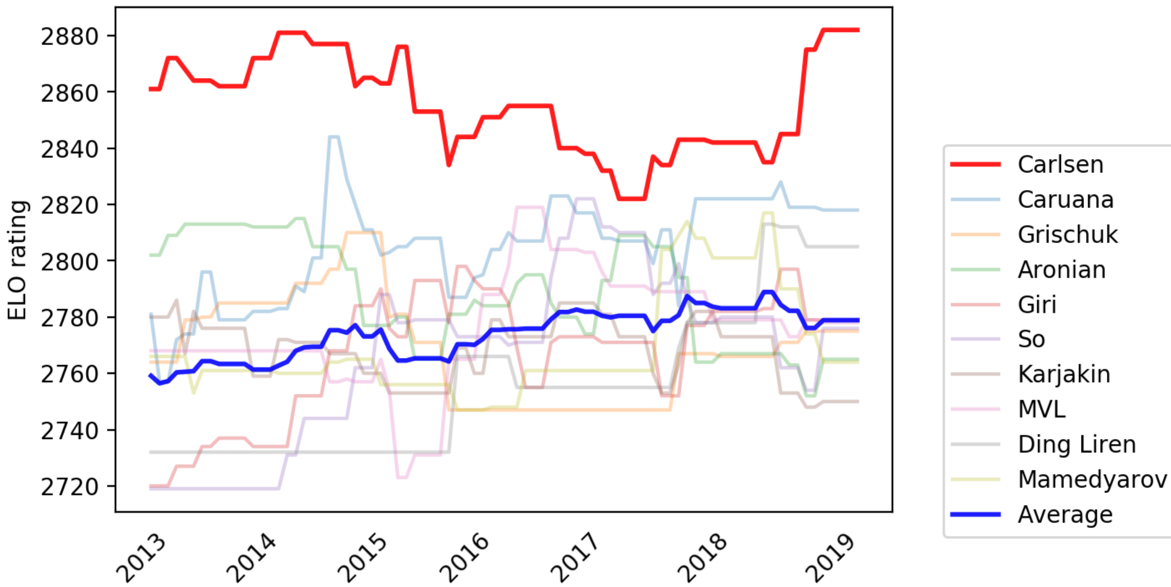
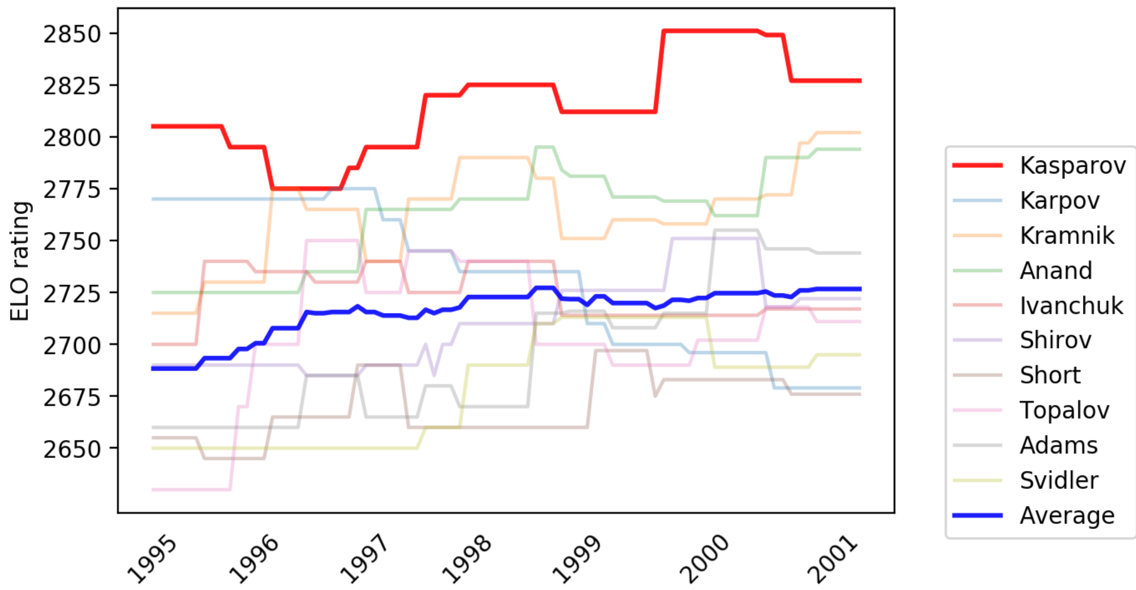
Tables & Figures

Figure 3: ELO ratings of top chess players between 2013-2019.



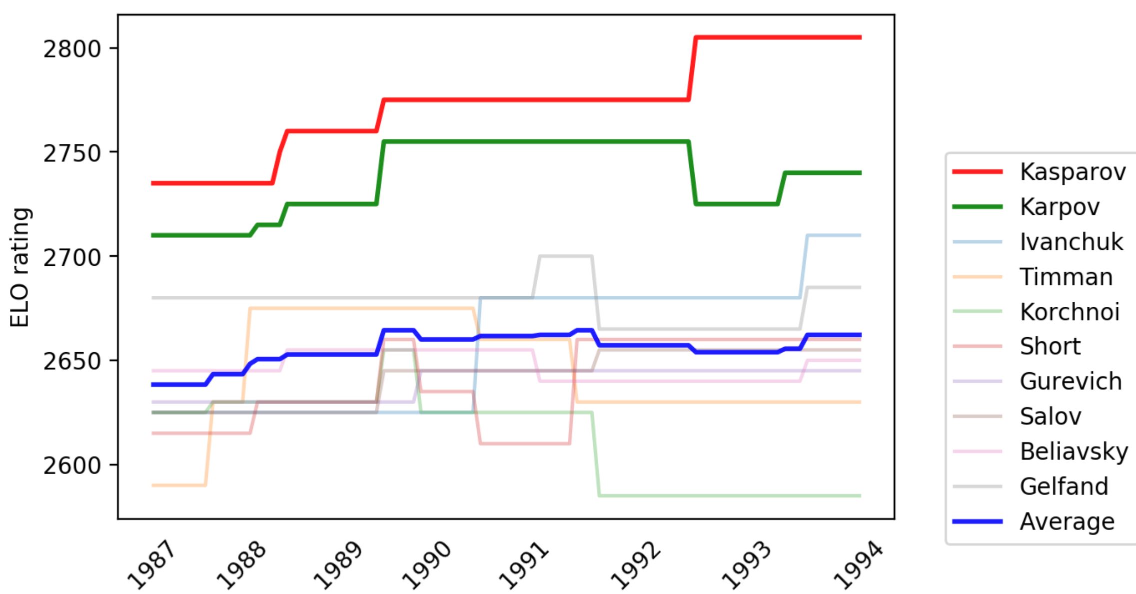
Note: The blue line shows the average ELO rating of top chess players other than Carlsen (World ranking 2–10). ELO rating data is obtained from Chessbase Mega Database 2020.

Figure 4: ELO ratings of top chess players between 1995-2001.



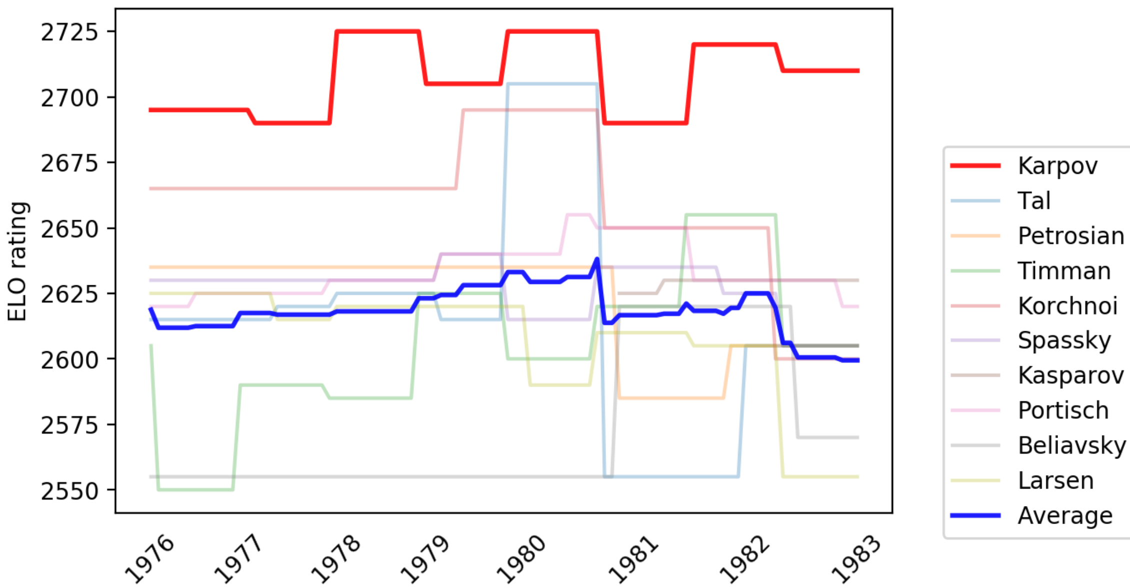
Note: ELO rating data is obtained from Chessbase Mega Database 2020.

Figure 5: ELO ratings of top chess players between 1987-1994.



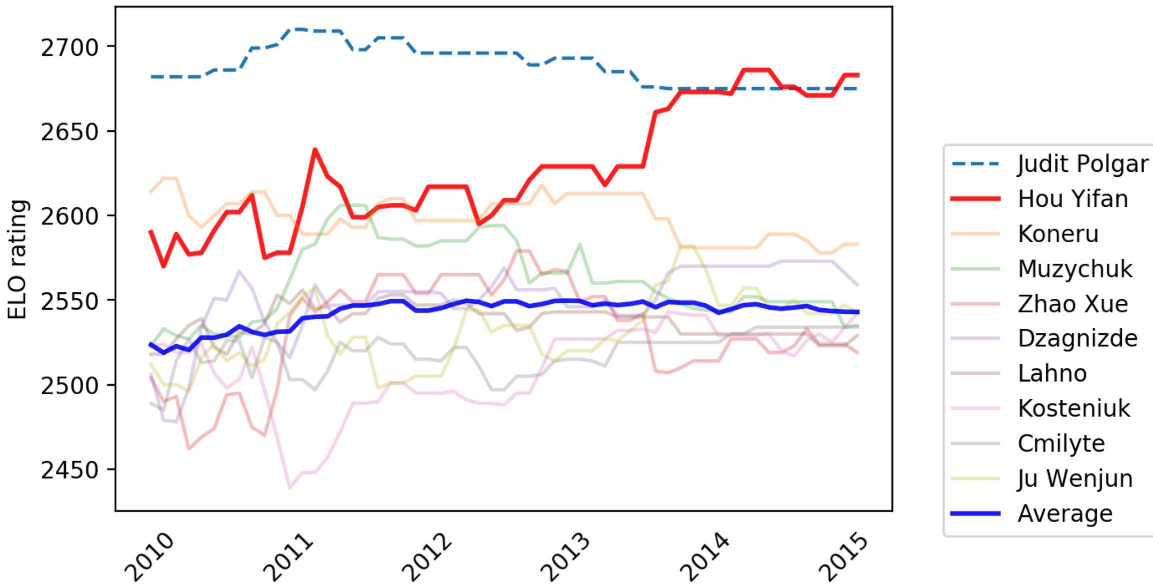
Note: ELO rating data is obtained from Chessbase Mega Database 2020.

Figure 6: ELO ratings of top chess players between 1976-1983.



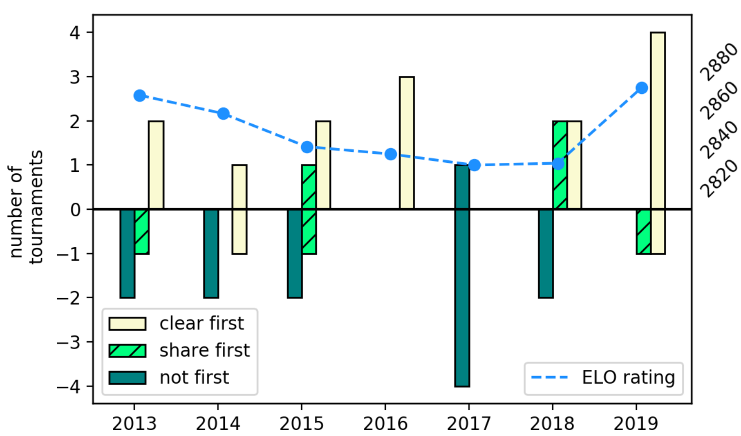
Note: ELO rating data is obtained from Chessbase Mega Database 2020.

Figure 7: ELO ratings of top female chess players between 2010-2015.



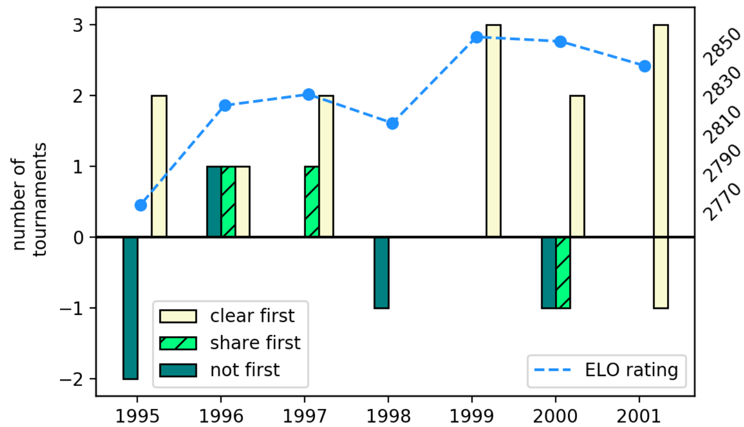
Note: Judit Polgar is considered the strongest female chess player of all time, however she stopped competing in female tournaments in 1990 when she was 14 years old. Hou Yifan stopped competing in female tournaments after 2015. ELO rating data is obtained from FIDE available online at https://ratings.fide.com

Figure 8: Carlsen's tournament performance (classical)



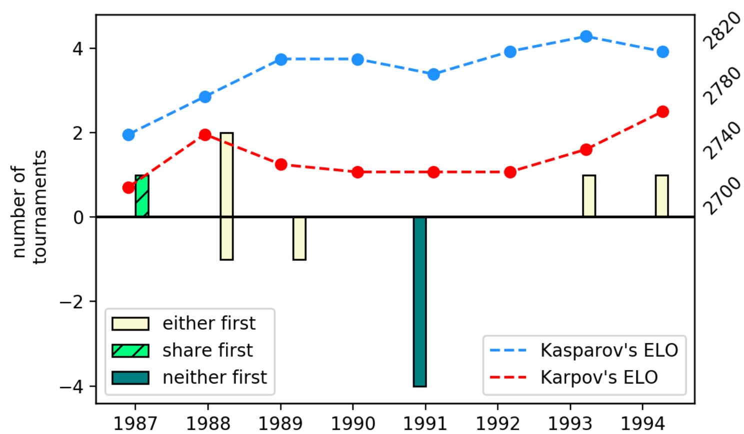
Note: Carlsen's ELO rating data is obtained from FIDE.

Figure 9: Kasparov's tournament performance (classical)



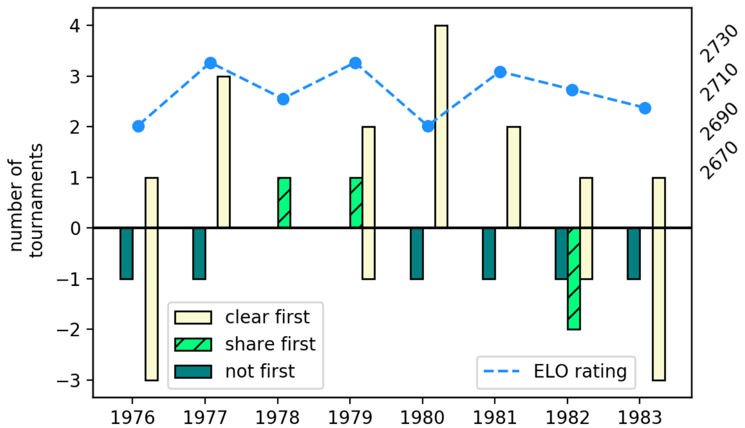
Note: Kasparov's ELO rating data is obtained from Chessbase Mega Database 2020.

Figure 10: Kasparov and Karpov's tournament performance (classical)



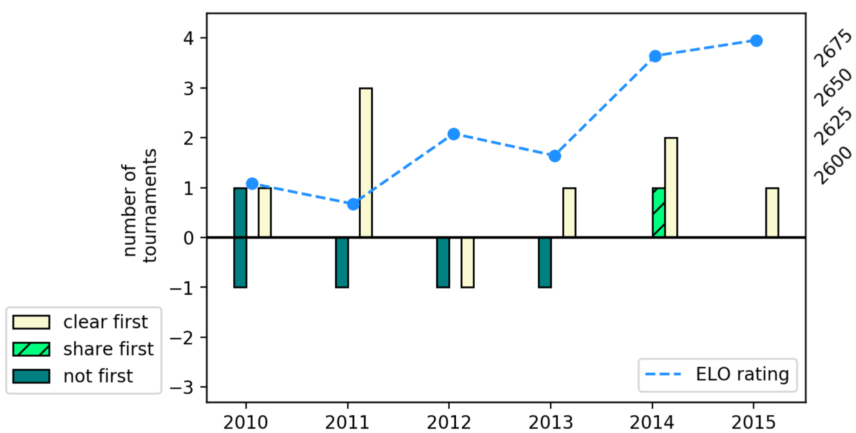
Note: Kasparov's and Karpov's ELO rating data is obtained from Chessbase Mega Database 2020.

Figure 11: Karpov's tournament performance (classical)



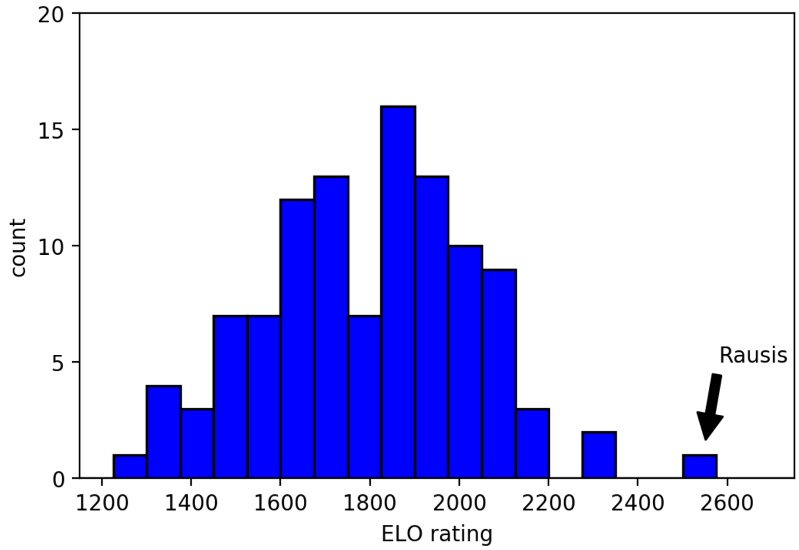
Note: Karpov's ELO rating data is obtained from Chessbase Mega Database 2020.

Figure 12: Hou Yifan's tournament performance (classical)



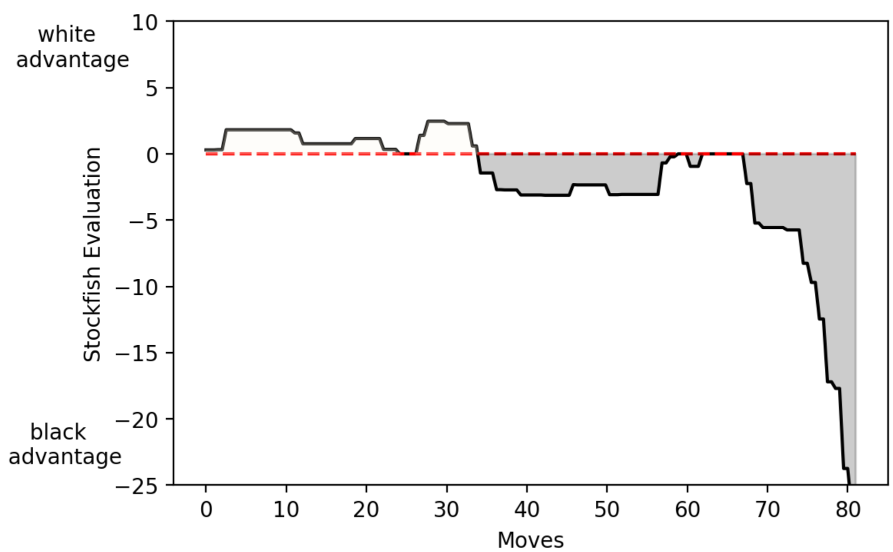
Note: Hou Yifan's ELO rating data is obtained from Chessbase Mega Database 2020.

Figure 13: Elo rating distribution of a tournament Rausis competed in 2012.



Note: The tournament is Tres Cantos Open played in June 2012 in Spain. Rausis had an ELO rating of 2514. His nine opponents had an average ELO rating of 2046. ELO rating information is obtained from Chessbase Mega Database 2020.

Figure 14: Computer evaluation of a game played by Carlsen in 2019.



Note: The game was played between Vincent Keymer (White) and Magnus Carlsen (Black) on April 20, 2019 during the first round of Grenke Chess Classic 2019. Keymer's Average Centipawn Loss (ACPL) was 21.82 and Carlsen's 5.77 using our algorithm. A higher ACPL means the player made more mistakes according to the chess engine. The chess engine used for evaluations is Stockfish 11 with a depth of 19 moves.

Table 2: Summary statistics for all samples.

	years: 2013-2019				*years: 1995-2001*			
	with Carlsen		*without Carlsen*		*with Kasparov*		*without Kasparov*	
variable	mean	sd	mean	sd	mean	sd	mean	sd
ACPL	7.337	14.635	8.033	14.659	8.927	12.416	9.625	17.833
win	.173	.378	.203	.402	.229	.420	.230	.420
draw	.652	.476	.592	.491	.548	.497	.539	.498
loss	.173	.378	.203	.402	.221	.415	.230	.420
ELO	2759	47.10	2714	80.46	2685	59.56	2644	64.73
Moves	43.56	15.68	45.75	17.64	39.03	16.01	39.48	15.74
#of tournaments	=35		=40		=22		=44	
#of games	=1,328		=1,762		=818		=1,970	
#of moves	=115,498		=160,776		=63,866		=154,852	
	years: 1987-1994				*years: 1976-1983*			
	with Kasparov & Karpov		*without Kasparov & Karpov*		*with Karpov*		*without Karpov*	
ACPL	9.722	16.448	9.614	16.805	8.540	13.613	9.370	17.913
win	.218	.413	.236	.424	.226	.418	.259	.438
draw	.563	.496	.527	.499	.566	.495	.505	.500
loss	.218	.413	.236	.424	.207	.405	.235	.424
ELO	2624	56.46	2586	55.68	2558	67.85	2530	76.21
Moves	39.90	16.84	40.20	16.77	37.17	17.65	38.04	17.20
#of tournaments	=11		=37		=32		=34	
#of games	=813		=1,787		=1,972		=3,114	
#of moves	=63,345		=143,164		=146,966		=236,392	
	years: 1962-1970				*years: 2014-2019*			
	with Fischer		*without Fischer*		*with Hou Yifan*		*without Hou Yifan*	
ACPL	9.987	19.134	10.238	17.402	8.581	21.582	9.144	23.095
win	.254	.435	.249	.432	.261	.439	.242	.429
draw	.490	.499	.500	.500	.477	.499	.514	.500
loss	.254	.435	.249	.432	.261	.439	.242	.429
ELO*	-	-	-	-	2492	67.88	2502	41.82
Moves	38.36	16.55	36.63	15.64	45.83	18.60	47.33	17.62
#of tournaments	=16		=81		=4		=6	
#of games	=1,762		=7,652		=276		=300	
#of moves	=134,430		=559,038		=25,168		=28,220	
	years: 2012-2019							
	with Rausis		*without Rausis*					
ACPL	15.390	28.487	14.731	27.857				
win	.405	.491	.365	.481				
draw	.213	.409	.275	.446				
loss	.380	.485	.359	.479				
ELO	1979	275.21	2052	259.98				
Moves	38.34	14.93	38.69	15.87				
#of tournaments	=8		=30					
#of games	=1,016		=2,818					
#of moves	=76,912		=216,046					

Notes: Superstar player observations are exluded in each sample. Data comes from Chessbase Mega Database 2020.
∗: ELO rating system was first adopted by FIDE beginning 1970.

Table 3: Performance against a superstar.

	Panel A. Classical					
	(1)	(2)	(3)	(4)		
	ACPL	*win*	*draw*	*loss*	*# of games*	*# of moves*
Against Carlsen	3.957***	-0.112***	-0.0618**	0.173***	1,722	153,283
2013-2019	(0.895)	(0.0159)	(0.0282)	(0.0251)		
Against Kasparov	3.083***	-0.171***	-0.0292	0.201***	1,058	82,130
1995-2001	(1.002)	(0.0201)	(0.0352)	(0.0338)		
Against Kasparov or Karpov	3.656***	-0.182***	-0.0424	0.224***	2,892	232,709
1987-1994	(0.722)	(0.0192)	(0.0292)	(0.0285)		
Against Karpov	3.704***	-0.179***	-0.0345	0.213***	5,025	412,618
1976-1983	(0.929)	(0.0155)	(0.0277)	(0.0275)		
Against Fischer	5.760***	-0.220***	-0.139***	0.359***	9,395	712,324
1962-1970	(1.120)	(0.0307)	(0.0308)	(0.0425)		
Against Hou Yifan	7.050**	-0.259***	-0.128***	0.387***	620	57,234
2014-2019	(2.340)	(0.0146)	(0.0351)	(0.0250)		
Against Rausis	11.136***	-0.670***	-0.015	0.585***	3,781	296,808
2012-2019	(1.299)	(0.0204)	(0.0688)	(0.0729)		

Notes: All regressions include player and year fixed effects, round fixed effects, event site fixed effects, average ELO in a tournament, player's side (white or black), and number of moves played. Clustered standard errors (clustered by tournament) are shown in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Performance in tournaments with and without Rausis.

	Panel A. Classical			
	(1)	(2)	(3)	(4)
	ACPL	*win*	*draw*	*loss*
Superstar effect for				
All players	-0.646	-0.0105	0.0407	-0.0302
	(1.561)	(0.0516)	(0.0248)	(0.0494)
Top players^{+}	7.239	-0.153	-0.309**	0.463*
	(7.568)	(0.143)	(0.144)	(0.231)
Last 2 rounds	1.268	-0.377***	0.0534	0.324**
	(5.053)	(0.120)	(0.0651)	(0.135)
Number of moves	292,958	292,958	292,958	292,958
Number of games	3,729	3,729	3,729	3,729

Notes: Rausis' games are excluded. The sample consists of open tournaments in Swiss system as opposed to the previous tables in which the samples consist of invitation-based Round robin tournaments. All regressions include player fixed effects, year fixed effects, month fixed effects, event site fixed effects, player's side (white or black), and number of moves played. Clustered standard errors (clustered by tournament) are shown in parentheses.

$^{+}$: These are the players with the top 2 highest ELO rating in a given tournament following Rausis' ELO rating.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Performance in tournaments with and without Hou Yifan.

	Panel A. Classical			
	(1)	(2)	(3)	(4)
	ACPL	*win*	*draw*	*loss*
Superstar effect for				
Top 25% players	5.500**	-0.0671	-0.0336	0.101*
	(1.912)	(0.0691)	(0.0561)	(0.0470)
Mid 50% players	0.701	0.0121	0.00655	-0.0187
	(2.049)	(0.0562)	(0.0600)	(0.0474)
Bottom 25% players	3.908	0.0222	-0.0560	0.0338
	(3.077)	(0.0979)	(0.0616)	(0.0776)
Number of moves	53,388	53,388	53,388	53,388
Number of games	577	577	577	577

Notes: Hou Yifan's games are excluded. All regressions include player fixed effects, year fixed effects, player's side (white or black), and number of moves played. Clustered standard errors (clustered by tournament) are shown in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Performance in tournaments with and without Fischer.

	Panel A. Classical			
	(1)	(2)	(3)	(4)
	ACPL	*win*	*draw*	*loss*
Superstar effect for				
All players	-0.344	-0.0194	0.00753	0.0118
	(0.513)	(0.0153)	(0.0155)	(0.0180)
Top players	-0.0540	-0.123***	0.113***	0.00995
	(0.792)	(0.0311)	(0.0320)	(0.0248)
Number of moves	690,950	690,950	690,950	690,950
Number of games	9,395	9,395	9,395	9,395

Notes: Fischer's games are excluded. Top 10 players are the top chess players in the world from 1962-1970 other than Fischer.[+] All regressions include player fixed effects, year fixed effects, round fixed effects, event site fixed effects, player's side (white or black), and number of moves played. Clustered standard errors (clustered by tournament) are shown in parentheses.
[+]: These players are Tigran Petrosian, Viktor Korchnoi, Boris Spassky, Vasily Smyslov, Mikhail Tal, Mikhail Botvinnik, Paul Keres, Efim Geller, David Bronstein, and Samuel Reshevsky.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Performance in tournaments with and without Kasparov & Karpov.

	Panel A. Classical			
	(1)	(2)	(3)	(4)
	ACPL	*win*	*draw*	*loss*
Superstar effect *when both present*				
Top 25% players	3.554**	-0.106***	-0.0533	0.159***
	(1.374)	(0.0242)	(0.0416)	(0.0469)
Mid 50% players	1.884	-0.0184	-0.0298	0.0483
	(1.239)	(0.0331)	(0.0357)	(0.0315)
Bottom 25% players	1.998**	-0.0465*	0.0241	0.0224
	(0.875)	(0.0254)	(0.0360)	(0.0286)
Number of moves	156,507	156,507	156,507	156,507
Number of games	2,166	2,166	2,166	2,166

Notes: Kasparov and Karpov's games are excluded. Top 25% is defined as having an ELO rating in the top 25% among the competitors at the time of the tournament. Bottom 25% is defined as having an ELO in the bottom quartile. All regressions include player fixed effects, year fixed effects, round fixed effects, event site fixed effects, average ELO in a tournament, player's side (white or black), and number of moves played. Clustered standard errors (clustered by tournament) are shown in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Performance in tournaments with and without Kasparov.

	Panel A. Classical			
	(1)	(2)	(3)	(4)
	ACPL	*win*	*draw*	*loss*
Superstar effect for				
Top 25% players	-0.861	0.00970	-0.0140	0.00431
	(1.102)	(0.0385)	(0.0391)	(0.0299)
Mid 50% players	0.271	-0.0162	-0.0145	0.0307
	(0.879)	(0.0231)	(0.0328)	(0.0257)
Bottom 25% players	2.229*	-0.0805**	0.0133	0.0672**
	(1.239)	(0.0388)	(0.0385)	(0.0318)
Number of moves	218,718	218,718	218,718	218,718
Number of games	2,292	2,292	2,292	2,292

Notes: Kasparov's games are excluded. Top 25% is defined as having an ELO rating in the top 25% among the competitors at the time of the tournament. Bottom 25% is defined as having an ELO in the bottom quartile. All regressions include player by year fixed effects, round fixed effects, event site fixed effects, average ELO in a tournament, player's side (white or black), and number of moves played. Clustered standard errors (clustered by player-year) are shown in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Performance in tournaments with and without Karpov.

	Panel A. Classical			
	(1)	(2)	(3)	(4)
	ACPL	*win*	*draw*	*loss*
Superstar effect for				
Top 25% players	-0.109	-0.00403	-0.0151	0.0191
	(1.035)	(0.0408)	(0.0379)	(0.0313)
Med 50% players	0.867	0.00709	-0.00326	-0.00383
	(0.896)	(0.0269)	(0.0312)	(0.0270)
Bottom 25% players	0.713	-0.00470	0.0555	-0.0508
	(1.500)	(0.0466)	(0.0451)	(0.0428)
Number of moves	385,060	385,060	385,060	385,060
Number of games	5,106	5,106	5,106	5,106

Notes: Karpov's games are excluded. Top 25% is defined as having an ELO rating in the top 25% among the competitors at the time of the tournament. Bottom 25% is defined as having an ELO in the bottom quartile. All regressions include player by year fixed effects, round fixed effects, event site fixed effects, average ELO in a tournament, player's side (white or black), and number of moves played. Clustered standard errors (clustered by player-year) are shown in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 10: Performance in tournaments with and without Carlsen.

	Panel A. Classical			
	(1)	(2)	(3)	(4)
	ACPL	*win*	*draw*	*loss*
Superstar effect for				
Top 25% players	-2.043**	-0.0407	0.0777	-0.0370
	(0.999)	(0.0412)	(0.0531)	(0.0328)
Mid 50% players	-1.662**	-0.0273	0.0791**	-0.0518*
	(0.719)	(0.0341)	(0.0382)	(0.0291)
Bottom 25% players	-1.440	-0.0429	0.0825	-0.0396
	(1.053)	(0.0403)	(0.0556)	(0.0424)
Number of moves	276,272	276,272	276,272	276,272
Number of games	3,090	3,090	3,090	3,090

Notes: Carlsen's games are excluded. Top 25% is defined as having an ELO rating in the top 25% among the competitors at the time of the tournament. Bottom 25% is defined as having an ELO in the bottom quartile. All regressions include player by year fixed effects, month fixed effects, round fixed effects, event site fixed effects, average ELO in a tournament, player's side (white or black), and number of moves played. Clustered standard errors (clustered by player-year) are shown in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 11: Performance in tournaments with and without a Superstar (overall effect).

	Panel A. Classical			
	(1)	(2)	(3)	(4)
	ACPL	*win*	*draw*	*loss*
Superstar effect for				
Top 25% players	0.766**	-0.0311**	-0.0102	0.0413***
	(0.377)	(0.0140)	(0.0148)	(0.0139)
Mid 50% players	0.107	0.00495	-0.0164	0.0115
	(0.300)	(0.00986)	(0.0125)	(0.0101)
Bottom 25% players	0.305	-0.0124	0.0218	-0.00946
	(0.459)	(0.0110)	(0.0148)	(0.0144)
Number of moves	1,149,398	1,149,398	1,149,398	1,149,398
Number of games	13,228	13,228	13,228	13,228

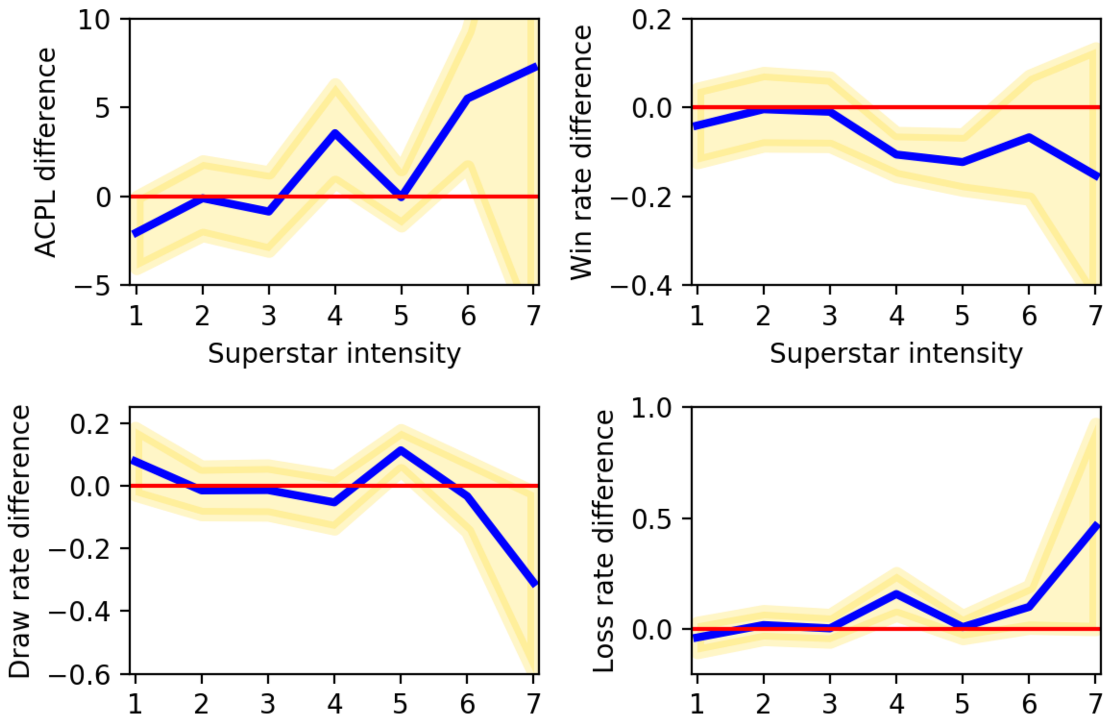
Notes: Superstars' games, and Rausis' and Fischer's samples are excluded. Top 25% is defined as having an ELO rating in the top 25% among the competitors at the time of the tournament. Bottom 25% is defined as having an ELO in the bottom quartile. All regressions include player and year fixed effects, month fixed effects, round fixed effects, event site fixed effects, average ELO in a tournament, player's side (white or black), and number of moves played. Clustered standard errors (clustered by tournament) are shown in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 12: Performance in tournaments with and without a superstar for top players.

	(1) *ACPL*	(2) *win*	(3) *draw*	(4) *loss*	*# of games*	*# of moves*
Rausis present^{+}	7.239	-0.153	-0.309**	0.463*	3,729	292,958
2012-2019	(7.568)	(0.143)	(0.144)	(0.231)		
Hou Yifan present	5.500**	-0.0671	-0.0336	0.101*	577	53,388
2014-2019	(1.912)	(0.0691)	(0.0561)	(0.0470)		
Fischer present^{++}	-0.0540	-0.123***	0.113***	0.00995	9,395	690,950
1962-1970	(0.792)	(0.0311)	(0.0320)	(0.0248)		
Kasparov & Karpov present	3.554**	-0.106***	-0.0533	0.159***	2,166	156,507
1987-1994	(1.374)	(0.0242)	(0.0416)	(0.0469)		
Kasparov present	-0.861	0.00970	-0.0140	0.00431	2,292	218,718
1995-2001	(1.102)	(0.0385)	(0.0391)	(0.0299)		
Karpov present	-0.109	-0.00403	-0.0151	0.0191	5,106	385,060
1976-1983	(1.035)	(0.0408)	(0.0379)	(0.0313)		
Carlsen present	-2.043**	-0.0407	0.0777	-0.0370	3,090	276,272
2013-2019	(0.999)	(0.0412)	(0.0531)	(0.0328)		
Aggregate effect^{+++}	0.766**	-0.0311**	-0.0102	0.0413***	13,228	1,149,398
	(0.377)	(0.0140)	(0.0148)	(0.0139)		

Notes: Superstars' games are excluded. A top player is defined as having an ELO rating in the top 25% among the competitors at the time of the tournament. All regressions include player and year fixed effects, round fixed effects, event site fixed effects, average ELO in a tournament (except Fischer's sample), player's side (white or black), and number of moves played. Clustered standard errors (clustered by tournament) are shown in parentheses.
$^{+}$: These are the players with the top 2 highest ELO rating in a given tournament following Rausis' ELO rating. In a Swiss type open tournament, only the very top players have a chance to win the tournament.
$^{++}$: Since no ELO rating information was available in Fischer's era, we define the top players as the top chess players in the world from 1962-1970 other than Fischer. These players are Tigran Petrosian, Viktor Korchnoi, Boris Spassky, Vasily Smyslov, Mikhail Tal, Mikhail Botvinnik, Paul Keres, Efim Geller, David Bronstein, and Samuel Reshevsky.
$^{+++}$: The sample restricted to Round-robin tournaments with average ELO information available.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Figure 15: Superstar presence coefficients for top players over different superstar intensity levels.



Note: The figure presents the coefficients in Table 11 with confidence intervals over different superstar intensity levels. Using magnitudes for dominance in terms of head-to-head competition presented in Table 2, we construct the superstar intensity scale as follows: 1=Carlsen, 2=Karpov, 3=Kasparov, 4=Kasparov & Karpov, 5=Fischer, 6=Hou Yifan, 7=Rausis.

Appendix

Table A.1: Variables list.

Variable Name	**Variable Meaning**
Superstar Present	=1 if a superstar is present in a tournament.
Against Superstar	=1 if a game is played against a superstar.
ELO	ELO rating of a player.
ACPL	Average Centipawn Loss of a player in a game.
win	=1 if a player wins his game.
draw	=1 if a games ends in a draw.
loss	=1 if a player loses his game.
white	=1 if a player's side is white.
moves	number of moves played in a game.

Table A.2: An example pgn file.

[Event "GRENKE Chess Classic"]
[Site "Karlsruhe GER"]
[Date "2019.04.20"]
[EventDate "2019.04.20"]
[Round "1"]
[Result "0-1"]
[White "Vincent Keymer"]
[Black "Magnus Carlsen"]
[ECO "A56"]
[WhiteElo "2516"]
[BlackElo "2845"]
[PlyCount "162"]

1 d4 ♘f6 2 c4 c5 3 d5 g6 4 ♘c3 d6 5 e4 ♗g7 6 ♘f3 O-O 7 ♗e2 e5 8 O-O ♘e8 9 ♘e1 f5 10 e×f5 g×f5 11 f4 ♘d7 12 ♘d3 e4 13 ♘f2 ♗×c3 14 b×c3 ♘df6 15 ♗e3 ♘g7 16 ♕e1 ♗d7 17 ♘d1 ♗a4 18 h3 ♗×d1 19 ♕×d1 ♕e8 20 ♔f2 ♕g6 21 ♖g1 ♔h8 22 a4 ♖g8 23 ♕f1 ♘fh5 24 g3 ♖af8 25 ♕g2 ♕f6 26 ♖ac1 ♕d8 27 ♕h2 ♘f6 28 g4 ♘d7 29 g5 ♕a5 30 g6 h6 31 ♖b1 ♖b8 32 ♕g3 ♕d8 33 ♔e1 ♘e8 34 ♔d2 ♘f8 35 ♗f2 ♕e7 36 ♔e3 ♕f6 37 ♔d2 ♘×g6 38 h4 ♘e7 39 ♕h3 ♖×g1 40 ♖×g1 ♕f7 41 h5 ♘f6 42 ♗h4 b6 43 ♖b1 ♕f8 44 ♖g1 ♕f7 45 ♖b1 ♕g7 46 ♖g1 ♕f8 47 ♔c2 ♘fg8 48 ♔d2 ♕f7 49 ♔c2 ♖f8 50 ♔d2 ♕e8 51 ♖a1 ♖f7 52 a5 b×a5 53 ♖×a5 ♘c8 54 ♖a1 ♕f8 55 ♖b1 ♘b6 56 ♖g1 ♖g7 57 ♖×g7 ♔×g7 58 ♕g3+ ♔h8 59 ♕g6 a5 60 ♗f1 a4 61 ♔c2 a3 62 ♔b3 ♘a4 63 ♗h3 ♕g7 64 ♕×g7+ ♔×g7 65 ♗×f5 ♘f6 66 ♔×a3 ♘×c3 67 ♗f2 ♘e2 68 ♔a4 ♘×h5 69 ♔a5 ♘f6 70 ♔b6 ♔f7 71 ♔c7 ♔e7 72 ♗e3 ♘d4 73 ♗g6 h5 74 ♗f2 ♘f3 75 ♗f5 ♘d2 76 ♗h4 e3 77 ♗d3 ♘f3 78 ♗×f6+ ♔×f6 79 ♔×d6 h4 80 ♔c7 ♘d4 81 ♔c8 e2 0-1

Figure A.1: An example tournament table.

Grenke Chess Classic 6th 2019

			1	2	3	4	5	6	7	8	9	10		TB	Perf.	+/-
1	**Carlsen,Magnus**	2845	*	½	½	1	½	1	1	1	1	1	7.5 / 9		2990	+14
2	**Caruana,Fabiano**	2819	½	*	1	½	½	½	½	½	1	1	6.0 / 9		2833	+3
3	**Naiditsch,Arkadij**	2695	½	0	*	½	1	½	0	½	1	1	5.0 / 9	19.00	2766	+9
4	**Vachier Lagrave,Maxime**	2773	0	½	½	*	½	½	½	½	1	1	5.0 / 9	18.25	2758	-1
5	**Anand,Viswanathan**	2774	½	½	0	½	*	½	½	1	0	1	4.5 / 9	19.75	2719	-6
6	**Aronian,Levon**	2763	0	½	½	½	½	*	1	½	½	½	4.5 / 9	18.75	2720	-5
7	**Svidler,Peter**	2735	0	½	1	½	½	0	*	½	1	½	4.5 / 9	17.75	2723	-1
8	**Vallejo Pons,Francisco**	2693	0	½	½	½	0	½	½	*	½	1	4.0 / 9		2689	-1
9	**Meier,Georg**	2628	0	0	0	0	1	½	0	½	*	0	2.0 / 9	8.75	2518	-12
10	**Keymer,Vincent**	2516	0	0	0	0	0	½	½	0	1	*	2.0 / 9	6.50	2529	+1

Average Elo: 2724 <=> Cat: 19

gm = 3.24 m = 1.44

(45 Games)

Note: The tournament table is obtained from Chessbase Mega Database 2020.

Table A.3: List of tournaments (classical)

Year	*Tournament Name*
	Panel A. Carlsen Present
2019	GCT Croatia 2019, Grenke Chess Classic 2019, Gashimov Memorial 2019, Norway Chess 2019, Sinquefield 2019, Tata Steel 2019
2018	Gashimov Memorial 2018, Sinquefield 2018, Biel 2018, Norway Chess 2018, Grenke Chess Classic 2018, Tata Steel 2018
2017	London Classic 2017, Norway Chess 2017, Sinquefield 2017, Grenke Chess Classic 2017, Tata Steel 2017
2016	Norway Chess 2016, Tata Steel 2016, Bilbao Masters 2016
2015	London Classic 2015, Sinquefield 2015, Norway Chess 2015, Gashimov Memorial 2015, Grenke Chess Classic 2015, Tata Steel 2015
2014	Norway Chess 2014, Zuerich Chess Challange 2014, Sinquefield 2014, Gashimov Memorial 2014
2013	Moscow Tal Memorial 2013, Norway Chess 2013, Candidates Tournament 2013, Tata Steel 2013, Sinquefield 2013
	Panel B. Carlsen Not Present
2019	U.S. Championship 2019, Dortmund 2019
2018	Candidates Tournament 2018, U.S. Championship 2018, Dortmund 2018
2017	U.S. Championship 2017, Dortmund 2017, Gashimov Memorial 2017
2016	London Classic 2016, Sinquefield 2016, Gashimov Memorial 2016, Candidates Tournament 2016, Moscow Tal Memorial 2016, U.S. Championship 2016, Dortmund 2016
2015	Dortmund 2015, Zuerich Chess Challenge 2015, Tbilisi FIDE GP 2015, Khanty-Mansiysk FIDE GP 2015, Capablanca Memorial 2015, U.S. Championship 2015
2014	Beijing Sportaccord Basque 2014, London Classic 2014, Tashkent FIDE GP 2014, Dortmund 2014, Tata Steel 2014, U.S. Championship 2014, Candidates Tournament 2014, Baku FIDE GP, Capablanca Memorial 2014, Bergomo ACP Golden Classic 2014
2013	Paris FIDE GP 2013, Dortmund 2013, Thessaloniki FIDE GP 2013, Zug FIDE GP 2013, Beijing FIDE GP 2013, Zuerich Chess Challenge 2013, Grenke Chess Classic 2013, Capablanca Memorial 2013, U.S. Championship 2013

Table A.4: List of tournaments (classical)

Year	*Tournament Name*
	Panel A. Kasparov Present
2001	Astana 2001, Zuerich 2001, Linares 2001, Corus Wijk aan Zee 2001
2000	Fujitsu Siemens Giants 2000, Sarajevo Bosnia 2000, Linares 2000, Corus Wijk aan Zee 2000
1999	Sarajevo Bosnia 1999, Linares 1999, Hoogovens Wijk aan Zee 1999
1998	Linares 1998
1997	Tilburg 1997, Novgorod 1997, Linares 1997
1996	Las Palmas 1996, Dos Hermanas 1996, Amsterdam Euwe Memorial 1996
1995	Horgen 1995, Amsterdam Euwe Memorial 1995, Novgorod 1995
	Riga Tal Memorial 1995
	Panel B. Kasparov Not Present
2001	Sigeman & Co 2001, Biel 2001, Dortmund 2001, Pamplona 2001, Dos Hermanas 2001
2000	Japfa Classic 2000, Dortmund 2000, Sigeman & Co 2000, Biel 2000
1999	Pamplona 1999, Lost Boys Amsterdam 1999, Dortmund 1999, Sigeman & Co 1999
	Dos Hermanas 1999, Biel 1999
1998	Hoogovens Wijk aan Zee 1998, Tilburg 1998, Dortmund 1998, Madrid 1998, Pamplona 1998
1997	Hoogovens Merrillville 1997, Sigeman & Co 1997, Ubeda 1997, Hoogovens Wijk aan Zee 1997
	Dos Hermanas 1997, Lost Boys 1997, Dortmund 1997, Madrid 1997, Belgrade Investbank 1997
1996	Koop Tjuchem 1996, Donner Memorial 1996, Hoogovens Wijk aan Zee 1996,
	Tilburg 1996, Dortmund 1996, Dos Hermanas 1996, Madrid 1996
1995	Belgrade Investbank 1995, Horgen 1995, Donner Memorial 1995, Biel 1995, Madrid 1995,
	Dos Hermanas 1995, Groningen 1995, Dortmund 1995

Table A.5: List of tournaments (classical)

Year	*Tournament Name*
	Panel A. Kasparov & Karpov Both Present
1994	Linares 1994
1993	Linares 1993
1992	
1991	Reggio Emilia 1991, Tilburg 1991, Amsterdam Euwe Memorial 1991, Linares 1991
1990	
1989	World Cup Skelleftea 1989
1988	USSR Championship 1988, World Cup Belfort 1988, Optiebeurs Amsterdam 1988
1987	Brussels 1987
	Panel A. Kasparov & Karpov Neither Present
1994	Donner Memorial 1994, Dortmund 1994, Hoogovens Wijk aan Zee 1994, Groningen 1994, Munich 1994
1993	Antwerp 1993, Amsterdam VSB 1993, Madrid 1993, Las Palmas 1993, Munich 1993
1992	Alekhine Memorial 1992, Amsterdam Euwe Memorial 1992, Hoogovens Wijk aan Zee 1992, Groningen 1992, Munich 1992
1991	World Cup Reykjavik 1991, Hoogovens Wijk aan Zee 1991, Groningen 1991, Munich 1991
1990	Tilburg 1990, Hoogovens Wijk aan Zee 1990, Prague 1990, Groningen 1990, Munich 1990
1989	Hoogovens Wijk aan Zee 1989, Groningen 1989, Munich 1989, Amsterdam Euwe Memorial 1989
1988	Amsterdam Euwe Memorial 1988, OHRA Amsterdam 1988, Linares 1988, Hastings 1988
1987	Belgrade Investbanka 1987, Hoogovens Wijk aan Zee 1987, Interpolis 1987, OHRA Amsterdam 1987, Reykjavik 1987

Table A.6: List of tournaments (classical)

Year	*Tournament Name*
	Panel A. Karpov Present
1983	Interpolis 1983, International DSB Mephisto GM 1983, USSR Final 1983, Bath 1983, Linares 1983
1982	Interpolis 1982, Turin 1982, Hamburg 1982, London Phillips 1982, Mar del Plata Clarin Masters 1982
1981	IBM Herinnerungs Toernooi 1981, Moscow 1981, Linares 1981
1980	Buenos Aires 1980, Interpolis 1980, IBM Kroongroep 1980, Bugojno 1980, Bad Kissingen 1980
1979	Interpolis 1979, Waddinxveen KATS 1979, Montreal International 1979, GER International 1979
1978	Bugojno 1978
1977	Interpolis 1977, October Revolution 1977, Las Palmas 1977, GER International 1977
1976	USSR Final 1976, Montilla 1976, Manila Marlboro 1976, Amsterdam 1976, Skopje Solidarnost 1976
	Panel B. Karpov Not Present
1983	Jakarta International 1983, Hoogovens Wijk aan Zee 1983
1982	Interzonal 1982, Hoogovens Wijk aan Zee 1982
1981	Las Palmas 1981, IBM Herinnerungs Toernooi 1981, Interpolis 1981, Hoogovens Wijk aan Zee 1981
1980	Buenos Aires 1980, London Phillips 1980, Hoogovens Wijk aan Zee 1980, Las Palmas 1980, Reykjavik International 1980
1979	Buenos Aires Clarin 1979, Interzonal 1979, Vidmar Memorial 1979, IBM 1979 Hoogovens Wijk aan Zee 1979, Buenos Aires Konex 1979
1978	Interpolis 1978, Reykjavik International 1978, Hoogovens Wijk aan Zee 1978, Las Palmas 1978 IBM 1978, Clarin 1978
1977	Geneve 1977, Vidmar Memorial 1977, Hoogovens Wijk aan Zee 1977, IBM 1977
1976	Interzonal 1976, Las Palmas 1976, Reykjavik International 1976, Hoogovens Wijk aan Zee 1976, IBM 1976

Table A.7: List of tournaments (classical)

Year	*Tournament Name*
	Panel A. Fischer Present
1970	Interzonal 1970, Buenos Aires 1970, Rovinj Zagreb 1970
1969	
1968	Vinkovci 1968, Nathanya 1968,
1967	Skopje 1967, Monaco Grand Prix 1967, Interzonal 1967
1966	Piatigorsky Cup 1966, U.S. Championship 1966
1965	U.S. Championship 1965, Capablanca Memorial 1965
1964	
1963	U.S. Championship 1963
1962	U.S. Championship 1962, Candidates Tournament 1962, Interzonal 1962
	Panel B. Fischer Not Present
1970	Vinkovci 1970, IBM Amsterdam 1970, Budapest 1970, Sarajevo 1970, Caracas 1970, Hoogovens Wijk an Zee 1970, Costa del Sol 1970, Skopje 1970, Rubinstein Memorial 1970, Christmas Congress 1970
1969	Monaco Grand Prix 1969, Hoogovens Wijk an Zee 1969, Venice 1969 U.S. Championship 1969, Palma de Mallorca 1969, IBM Amsterdam 1969, Sarajevo 1969, Christmas Congress 1969, Rubinstein Memorial 1969, Capablanca Memorial 1969
1968	Rubinstein Memorial 1968, Christmas Congress 1968, Palma de Mallorca 1968, U.S. Championship 1968, Bamberg 1968, IBM Amsterdam 1968, Sarajevo 1968 Hoogovens Wijk an Zee 1968, Monaco Grand Prix 1968, Skopje 1968
1967	Winnipeg 1967, October Revolution Leningrad 1967, October Revolution Moscow 1967, Capablanca Memorial 1967, Palma de Mallorca 1967, Sarajevo 1967, Hoogovens Beverwijk 1967, Christmas Congress 1967, Rubinstein Memorial 1967, Venice 1967, IBM Amsterdam 1967
1966	IBM Amsterdam 1966, Sarajevo 1966, Palma de Mallorca 1966 Hoogovens Beverwijk 1966, Venice 1966, Rubinstein Memorial 1966, Christmas Congress 1966
1965	ZSK International 1965, Zagreb 1965, Mer del Plata 1965, IBM Amsterdam 1965, Sarajevo 1965, Hoogovens Beverwijk 1965, Christmas Congress 1965, Rubinstein Memorial 1965
1964	Buenos Aires 1964, Capablanca Memorial 1964, Rubinstein Memorial 1964, Interzonal 1964, IBM Amsterdam 1964, Sarajevo 1964, Hoogovens Beverwijk 1964, Christmas Congress 1964, ZSK International 1964
1963	Piatigorsky Cup 1963, Alekhine Memorial 1963, IBM Amsterdam 1963, Sarajevo 1963, Hoogovens Beverwijk 1963, Rubinstein Memorial 1963, Christmas Congress 1963, Capablanca Memorial 1963
1962	Mer del Plata 1962, IBM Amsterdam 1962, Sarajevo 1962, Hoogovens Beverwijk 1962, Rubinstein Memorial 1962, Christmas Congress 1962, Capablanca Memorial 1962

Table A.8: List of tournaments (classical)

Year	*Tournament Name*
	Panel A. Hou Yifan Present
2015	Monte Carlo FIDE GP 2015
2014	Lopota FIDE GP 2014, Khanty-Mansiysk FIDE GP 2014, Sharjah FIDE GP 2014
	Panel B. Hou Yifan Not Present
2019	Skolkovo FIDE GP 2019, Saint Louis Cairns Cup 2019
2016	Khanty-Mansiysk FIDE GP 2016, Chengdu FIDE GP 2016, Batumi FIDE GP 2016, Tehran FIDE GP 2016

Table A.9: List of tournaments (classical)

Year	*Tournament Name*
	Panel A. Rausis Present
2019	Lugano op 2019
2018	Sautron op 2018
2017	
2016	Salon de Provence op 2016
2015	
2014	Chemnitz op 2014, Biella op 2014
2013	Charleroi op 2013, Lueneburg op 2013
2012	Tres Cantos op 2012
	Panel B. Rausis Not Present
2019	Locarno op 2019, Ascona op 2019, Porto San Giorgio op 2019
2018	Erfurt op 2018, Pfarrkirchen Rottal op 2018, Locarno op 2018, Paderborn op 2018, Forchheim op 2018
2017	Pfarrkirchen Rottal op 2017, Porto San Giorgio op 2017 Lugano op 2017, Sautron op 2017
2016	Wasselonne op 2016, Heraklion op 2016
2015	Salon de Provence op 2015, Biella op 2015, Porto San Giorgio op 2015, Erfurt op 2015, Lugano op 2015, Ascona op 2015, Lugano op 2015, Forchheim op 2015
2014	Salon de Provence op 2014, Paderborn op 2014, Erfurt op 2014 Arco op 2014, Ascona op 2014, Forchheim op 2014
2013	Biella op 2013, Forchheim op 2013

Table A.10: Performance against Kasparov or Karpov.

	Panel A. Classical			
	(1)	(2)	(3)	(4)
	ACPL	*win*	*draw*	*loss*
Against Kasparov	4.043***	-0.204***	-0.0392	0.243***
	(0.703)	(0.0198)	(0.0318)	(0.0258)
Against Karpov	1.157	-0.157***	0.0432	0.114**
	(1.331)	(0.0264)	(0.0386)	(0.0441)
Against Kasparov or Karpov	3.656***	-0.182***	-0.0424	0.224***
	(0.722)	(0.0192)	(0.0292)	(0.0285)
Number of moves	232,709	232,709	232,709	232,709
Number of games	2,892	2,892	2,892	2,892

Notes: All regressions include player and year fixed effects, round fixed effects, event site fixed effects, average ELO in a tournament, player's side (white or black), and number of moves played. Clustered standard errors (clustered by tournament) are shown in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$