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by

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Fundamental comparative advantage versus random talent: An analysis using chess data*

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Abstract

This paper analyzes the contribution of fundamental comparative advantage and random talent to explain differences in the number of expert chess players across countries. I posit a model where the quality of a chess player is determined by her innate talent and the fundamental comparative advantage of the country she is born. Using data on chess players FIDE ratings for 2015, I find that fundamental comparative advantage explains between 65% and 97% of the variation in the number of expert chess players across countries. Despite the appearance of chess servers that allow playing on-line and offer tools to improve skills, I do not find convergence in comparative advantage over the period 2001-2015. I find that fundamental comparative advantage is highly positively correlated with the popularity of chess. These results highlight that a social preference might generate a more advanced technology which leads to a fundamental comparative advantage.

JEL: F1

Keywords: comparative advantage, preferences, chess, Internet, convergence.

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1 Introduction

Aggregate outcomes are the sum of individual outcomes. However, due to heterogeneity, the contribution of each economic agent to the aggregate outcome is not the same. In the presence of heterogeneity, two elements drive the differences in aggregate outcomes across countries. First, some countries might have characteristics that renders them an advantage over other countries. Second, since the number of firms and individuals is finite, luck might also contribute to differences across countries. For example, a country might have the luck to host an outstanding productive firm or an extremely talented individual. If country-level, or fundamental, comparative advantage and individual advantage play a role in explaining the differences in aggregate outcome across countries, it becomes very important to know what their relative contribution is.

In this paper I analyze an activity, chess, where differences in performance across countries are explained by fundamental comparative advantage and individual-level advantage. Fundamental comparative advantage captures the larger opportunities that some countries provide to play chess and improve chess skills, and the higher percentage of population that are drawn to this game. However, since there is a finite number of players, the realization of random innate talent might also determine countries' success at chess. Using data on chess players FIDE ratings for 2015, I find very large differences in fundamental comparative advantage at chess. I show that these differences explain between 65% and 97% of the variation in the number of expert chess players across countries. I find that fundamental comparative advantage is highly correlated with the popularity of chess, proxy by the relative number of federated players, tournaments played in the country, and the relative number of visits to Wikipedia biographies of chess masters. These results point out that a social preference might lead to a more advanced technology, which generates, in turn, a Ricardian comparative advantage. Finally, I conclude that there is not convergence in countries' productivity at chess over the period 2001-2015. This result suggests that the appearance of chess servers has not narrowed the differences in fundamental comparative advantage across countries.

Chess is a suitable activity to analyze the relative contributions of fundamental comparative advantage and player's comparative advantage to differences in performance across countries. First, it is possible to identify Ricardian comparative advantage in chess. The Ricardian model predicts that once countries open to trade they will specialize in the production of goods in which they have a comparative advantage, and cease to produce the goods in which they have a comparative disadvantage. As stressed by Costinot and Donaldson (2012), if some goods are not longer produced, it is very difficult to determine the differences in productivity between countries before trade. Since the rules of chess are easy to learn, and playing chess requires a minimum infrastructure,[1] chess is a game that is played in all countries.[2] Moreover, a country with an enormous comparative advantage in chess does not preclude other countries from playing. Second, the productivity (quality) of players at chess is measured worldwide by the same index: the FIDE (Elo) rating, which facilitates comparisons across countries. Third, as innate talent is equally distributed across countries, it is possible to get a precise mapping from variations in the number of expert chess players to differences in fundamental comparative advantage. Identification is neat even when we take into account the effect of random innate talent on countries' performance.

This paper contributes to the literature providing an example on the relative contribution of fundamental comparative advantage and innate talent to the differences in performance across countries. The paper also shows a case in which a social preference generates a more advanced technology, which leads to a Ricardian comparative advantage. The paper adds to the knowledge-diffusion literature showing that the spread of the Internet has not coincided with convergence in fundamental comparative advantage. Finally, the paper adds to the power-law literature showing that the quality of chess players also follows a Pareto distribution.

This paper is related with several strands of the literature. First, it is related to papers that have analyzed the granularity of trade. Freund and Pierola (2015) show that, on average, the top five firms explain around 30% of non-oil exports in a sample of 32 countries. To explain this concentration, Eaton et al. (2012) develop a trade model with a finite number of exporters. Gaubert and Itskhoki (2016) build upon this model to analyze to what extent differences in trade shares across sectors in France are explained by fundamental comparative advantage and granular comparative advantage. This paper also analyzes the role of fundamental comparative advantage and innate talent. However, its scope is much more modest, as it only analyzes one activity: chess. The advantage of focusing on chess is that differences in countries performance depend on few variables. Hence, estimations on the relative contribution of fundamental comparative advantage and innate talent need to introduce fewer assumptions and demand a lower number of parameters. In addition to that, chess allows the estimation of fundamental comparative advantage for a large number of countries.

Second, it is related to papers, such as Costinot and Donaldson (2012), that identify suitable scenarios to test the Ricardian model. The aim of the this paper is not to test the

[1]For example, Chess Without Frontiers, a Spanish Non Governmental Organization, uses laminated chess boards and recycled materials for chess pieces in their schools in very poor countries (Fronterad, 3rd June 2016. Available at http://www.fronterad.com/?q=14490)

[2]For example, the World Chess Federation (FIDE) had 187 member federations in June 2016, and it is estimated that around 605 million people play chess regularly (The Economist, 5th October 2013). The website http://www.chess.com has around 14.5 million members who have registered using 236 different country names.

Ricardian model. Rather, I argue that relative performance at chess can be explained by a Ricardian model and, under reasonable assumptions, map the differences in the number of expert chess players to countries' comparative advantage at chess. Third, this paper is also related with studies, such as Levchenko and Zhang (2011) and Hanson et al. (2015), that have analyzed the evolution of comparative advantage across countries. In contrast to these papers, I only analyze the performance at one activity, chess, and show that differences in comparative advantage have not narrowed over the period 2001-2015. This analysis links the paper to the literature that has analyzed the geographical barriers to the diffusion of knowledge (Jaffe et al., 1993), and whether the spread of the Internet has contributed to erode that barrier (Head et al., 2015). The paper is also related to the literature that has analyzed how differences in social values, such as trust, might lead to variations in economic outcomes (Guiso et al., 2006; Knack and Keefer, 1997; Nunn, 2008; Algan and Cahuc, 2010; Tabellini, 2010). I show another activity, chess, in which a social preference generates a more advanced technology, which leads to a Ricardian comparative advantage. Chess is an interesting case because preference is not endogenous to economic development. This paper is also related to studies, such as Nunn (2007), Costinot (2009) and Chor (2010), that have analyzed how country-level idiosyncrasies, such as the quality of institutions, shape comparative advantage. Finally, the paper is related with the literature that has analyzed the presence of power laws in different activities (Gabaix, 2016). I show that players' performance at chess also follows a Pareto distribution.

The paper is organized as follows. In the next section, I posit a very simple model to determine the number of expert chess players in a country. Section 3 presents FIDE's database and finds that players' ratings fit a Pareto distribution. This section also shows that population is not sufficient to explain the differences in the number of expert chess players across countries, suggesting a role for fundamental comparative advantage. Section 4 estimates countries' fundamental comparative advantage at chess for a continuous number of players and for a finite number of players. Section 5 measures the contribution of fundamental comparative advantage and innate talent to the differences in the number of expert chess players across countries. Section 6 analyzes the sources of differences in fundamental comparative advantage across countries. It shows that these differences are highly correlated with variables that proxy the popularity of chess. Section 7 analyzes whether the appearance of chess servers has coincided with a convergence in fundamental comparative advantage across countries. The last section concludes.

2 A very simple model to determine the number of expert chess players in a country

In this section I posit a very simple model to determine the number of expert chess players in a country. I assume that the quality of a chess player is determined by two variables: the innate talent of the player and the (chess) technology of the country where the player nurtures her chess skills:

$$q_{ic} = \varphi_i T_c \tag{1}$$

where q_{ic} is the quality of player i born at country c, φ_i is the innate talent of player i and T_c is country c technology at chess.

Countries will have a better technology if they provide players with more opportunities to play chess and improve their chess skills. First, countries that have chess as part of their school curriculum, allow children to learn chess rules and nurture their skills. Second, countries with a large number of chess clubs provide amateurs with more opportunities to play chess and learn from more experienced players. This learning will be specially significant if players have the opportunity to test their skills at chess tournaments. Third, countries with a larger number of chess trainers will provide more opportunities to improve chess tactics and strategies. Finally, countries with a high preference for chess, might offer financial means for high-talented players to pursue a career in chess.

According to (1), a player born in a country with an advanced technology will achieve a higher quality at chess than a player with the same innate talent, but born in a country that provides fewer opportunities to play chess and improve chess skills. Hence, players born in countries with a low technology need to have a very high innate talent to be internationally competitive.[3]

I assume that a player's innate talent is determined by a draw from a Pareto distribution function with a parameter θ, and a minimum value $\underline{\varphi}$. If there is a continuum of players, we can use the properties of the Pareto distribution function to determine the probability of a player having a quality level above or equal a given threshold. In particular,

$$Pr[q_{ic} \geq q] = P[\varphi_i T_c \geq q] = P[\varphi_i \geq q/T_c] = \left(\frac{q/T_c}{\underline{\varphi}}\right)^{-\theta} \tag{2}$$

The number of players with a chess-quality equal or higher than a certain threshold is

[3]For example, referring to the Spanish chess genius Arturo Pomar, who did not have the financial means to dedicate exclusively to chess during Franco's dictatorship, the famous Soviet chess manager Alexánder Kótov said that if Arturo had been born in the Soviet Union he would had been a contender for the World Chess Championship (from Leontxo García at El País, 27th May, 2016).

determined by the number of draws and the probability that a player has a quality equal or higher than the threshold:

$$N_c^q = D_c T_c^{\theta} (q/\underline{\varphi})^{-\theta} \tag{3}$$

where N_c^q is the number of players with a quality equal or higher than q in country c, and D_c is the number of draws in country c.

I assume that the number of draws depends on country c population, and the fraction of population that makes a draw at chess, μ_c. In countries where chess is popular a higher fraction of the population will make draws at chess; in contrast, countries with a lower preference for chess the fraction of population making draws will be lower.

Analytically,

$$D_c = \mu_c Pop_c \tag{4}$$

Substituting (4) in (3)

$$N_c^q = Pop_c \mu_c T_c^{\theta} (q/\underline{\varphi})^{-\theta} \tag{5}$$

Dividing the number of players with a quality $\geq q$ by population, we get the share of quality players in population,

$$\alpha_c^q = \frac{N_c^q}{Pop_c} = \mu_c T_c^{\theta} (q/\underline{\varphi})^{-\theta} = A_c (q/\underline{\varphi})^{-\theta} \tag{6}$$

where $A_c = \mu_c T_c^{\theta}$.

A_c captures the advantage of country c at chess. I will denote this variable as country c productivity at chess. This productivity stems from two different sources. The first is the fraction of population that makes a draw at chess (μ_c). If a higher number of potential players make a draw at chess, country c will have a larger number of quality players. This fraction will be related with the popularity of chess and the social recognition that quality players get in country c. The second source is country c chess technology. As explained above, this depends on the opportunities that country c provides to play chess and improve chess skills. I should stress that these two sources are highly correlated: countries with a larger fraction of population making draws at chess will also have a more advanced technology at chess. Finally, it is important to note that A_c does not capture an absolute productivity, but the productivity at chess relative to other activities individuals might pursue. Hence, A_c denotes a relative productivity.

A caveat of this model is that the number of expert chess players, specially the number of World Chess Champions, might also influence countries productivity at chess. For example, the winning of the World Chess Championship by Magnus Carlsen in 2013 might had increased the popularity of chess in Norway, raising the number of people making draws at chess. However, this concern is attenuated if we consider that there have only been eight countries which have had a World Chess Champion.[4] Moreover, since 1948, only four countries have had a World Chess Champion.

Up to now, I have assumed that despite differences in population and advantage across countries, the number of draws in each country is high enough, so players occupy all quality-levels. In the continuity scenario, the share of players in population with a quality equal of higher than a given threshold in country c, relative to country d, only depends on the ratio of advantages. I denote this ratio as fundamental comparative advantage.

$$\frac{\alpha_c^q}{\alpha_d^q} = \frac{A_c}{A_d} \tag{7}$$

Note that, according to (7), with a continuity of players fundamental comparative advantage ought to be the same regardless the quality-threshold we choose to compare relative performances at chess.

However, if the number of draws is finite, players will not occupy all quality levels. In this scenario, we can no longer apply the properties of the Pareto distribution to compare the number of expert chess players in a country.[5] Since not all quality levels are occupied, the realization of innate talent, or luck at draw, will start to play a role in determining the number of expert chess players in a country. Hence, it will be necessary to control for this effect when estimating countries' fundamental comparative advantage.

3 Data and some stylized facts

I measure the quality (productivity) of a chess player by her Elo rating. The Elo rating is represented by a number calculated from the games won, lost or drawn by a player. If a player wins a game against another player, she takes points from her opponent. She will take more points if her Elo rating is much lower than her opponents' rating, and fewer points if her rating is much higher than her opponent's rating. For the empirical analyses I use the Elo standard ratings calculated by the World Chess Federation (FIDE). As many organizations calculate variants of the Elo system, I will denote the Elo ratings calculated by FIDE as FIDE ratings. FIDE began the on-line publication of ratings in

[4] I cover all championships: Official, FIDE World Chess and Classical, and consider all countries belonging to the former Soviet Union as one country.

[5] As explained by Eaton et al. (2012), the expected number of players with a quality $\geq q$ will be the realization of a Poisson distributed random variable with parameter $A_c(q/\underline{\varphi})^{-\theta}$

January 2001. From 2001 to 2008 it published ratings 4 times per year (January, April, July and October). In 2009 the number of files per year rose to 5, in 2010 and 2011 to 6, in 2012 to 9, and from 2013 onwards FIDE publishes ratings every month. The database covers the ratings of players registered in a national chess federation which is a member of FIDE. It provides a numerical identifier of the player, the name of the player, birth year, gender, the federation in which the player is registered, the FIDE rating and whether the player is active or inactive.

I download all the data for the period 2001-2015.[6] I remove inactive players, without a birth year, with an age below 4, and without a federation. As country-level productivity aims to capture the higher opportunities that some countries provide to nurture chess skills, and this happens in the early career of a player, I always assign a player to her earliest federation. I calculate the year-average FIDE rating for each player.

Table 1: Summary statistics of FIDE ratings

Year	Federations	Players	Male	Female	Ave. FIDE rating	S.d. FIDE rating	Max. FIDE rating	Min. FIDE rating
2001	135	30,720	28,859	1,861	2,198	117	2,837	2,001
2002	133	31,646	29,752	1,894	2,191	121	2,838	1,802
2003	135	37,722	35,518	2,204	2,171	130	2,834	1,787
2004	135	43,338	40,686	2,652	2,147	141	2,820	1,603
2005	139	50,991	47,934	3,057	2,119	154	2,810	1,602
2006	146	55,074	52,068	3,006	2,090	171	2,812	1,401
2007	150	66,732	63,370	3,362	2,062	184	2,812	1,401
2008	152	73,729	68,790	4,939	2,028	201	2,796	1,401
2009	152	73,347	67,850	5,497	1,990	221	2,809	1,212
2010	160	86,333	79,764	6,569	1,960	232	2,815	1,201
2011	149	95,046	87,419	7,627	1,926	246	2,819	1,201
2012	161	105,371	96,419	8,952	1,893	261	2,840	1,003
2013	157	113,719	103,854	9,865	1,859	277	2,867	1,002
2014	171	129,257	117,405	11,852	1,808	302	2,873	1,001
2015	176	150,868	136,201	14,667	1,750	324	2,859	1,001

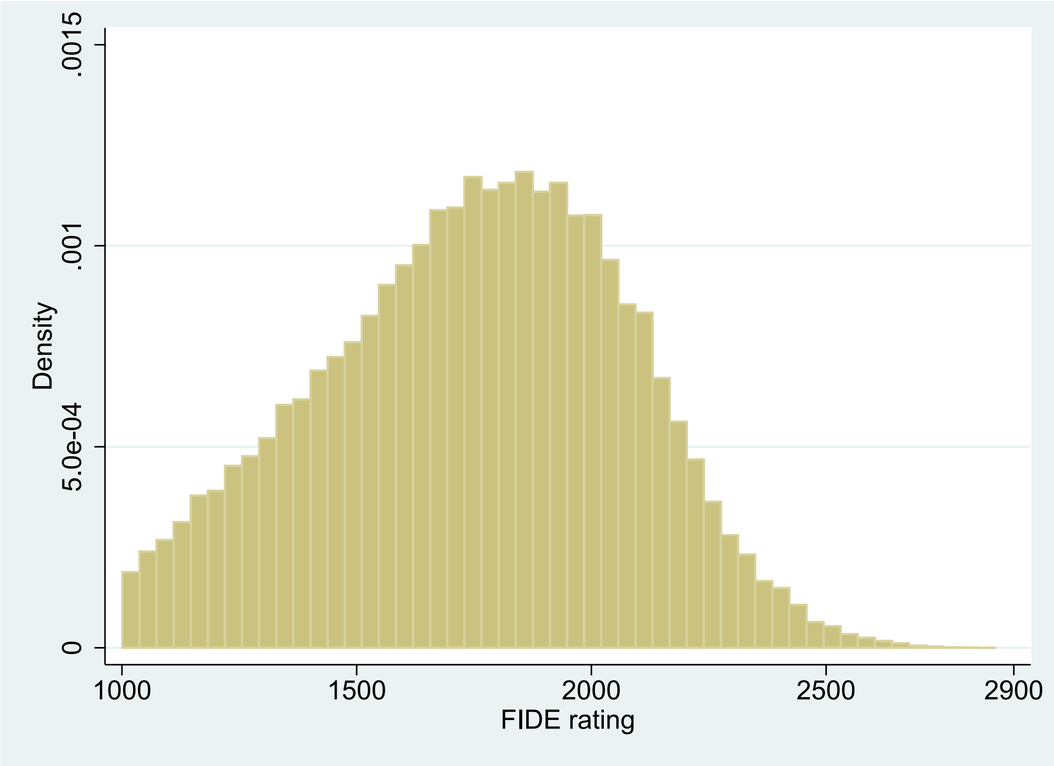
Ave.=Average; S.d.=Standard deviation; Max.=Maximum; Min.= Minimum

Table 1 presents some FIDE ratings' summary statistics. The number of federations that provide data to FIDE has increased from 135 in 2001 to 176 in 2015. The number of players covered in the database has multiplied almost by five over the 2001-2015 period. At the end of the period, 150,868 active players were registered in the database, of which 90% were men and 10% female. The percentage of females has risen in 4 percentage points since 2001. The average and minimum FIDE ratings have declined during the period, implying that the increase in the number of players has come from amateurs with low FIDE ratings. The maximum FIDE rating is 2,873 points. The player with the highest FIDE rating in December 2015 was the World Champion at that time, Magnus Carlsen.

Figure 1 presents the histogram of FIDE ratings for 2015. We can see that there is an increase in the density of players until 2,000 points and, then, there is a sharp reduction in the density of players. I test whether FIDE ratings follow a Pareto distribution for

[6]Data can be downloaded at: https://ratings.fide.com/download.phtml

Figure 1: Histogram of FIDE ratings, 2015



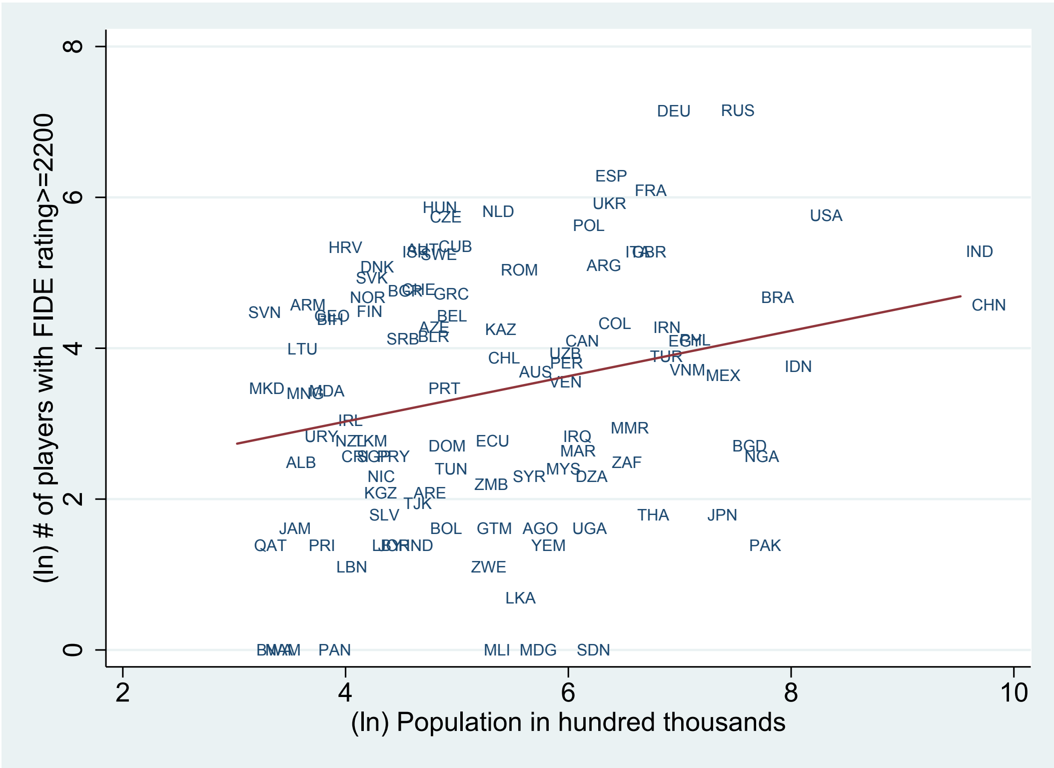
FIDE ratings over 2,000 points. Following Gabaix and Ibragimov (2011), I rank the 35,769 players with a FIDE rating $\geq 2,000$ in a descending order, and run the following regression:

$$\ln(Rank_i - 1/2) = \alpha + \beta \ln FIDE_i \tag{8}$$

According to the regression results, 96% of the differences in the (ln) rank of players is explained by the (ln) FIDE rating. This confirms that a Pareto distribution fits very well the distribution of FIDE ratings, for players with a FIDE rating$\geq 2,000$, and supports the assumption of the model regarding the distribution of players' innate talent. The regression yields a Pareto parameter equal to 16.67. Note that this parameter is much higher than those found in other economic phenomena such as city and firm size, or the distribution of income and wealth (Gabaix, 2009). It is also much higher that the parameter estimated by Gaubert and Itskhoki (2016) for the distribution of productivity across French firms. The large Pareto coefficient points out that quality at chess is extremely unequally distributed.

If countries did not have any impact on players FIDE ratings, we would expect the number of players above a given FIDE rating to be proportional to the population of each country. Figure 2 shows the scatter diagram comparing the population of countries and the number of players with a FIDE rating $\geq 2,200$ in 2015.[7] I choose this rating as it grants players the lowest ranked FIDE title: Candidate Master.[8] I include in the figure countries with at least a player with FIDE rating $\geq 2,200$ in 2015 and a population higher than 2 million. There are 106 countries that meet these conditions.

Figure 2: Players with FIDE rating >=2,200 vs. total population, 2015



As expected, more populated countries have a larger number of players with a FIDE rating $\geq 2,200$. However, for a similar level of population there is ample variation in the number of players. For example, Hungary and Bolivia have a similar population, but the number of players with a FIDE rating $\geq 2,200$ is 70 times larger in the former than in the latter. This suggests that fundamental comparative advantage might play a role in explaining the differences in the percentage of expert chess players across countries. The next section estimates countries' fundamental comparative advantage at chess.

[7] Population data is obtained from World Bank's World Development Indicators Database.

[8] FIDE grants three higher-ranked titles: FIDE Master, for players with an indicative FIDE rating $\geq 2,300$; International Master, with an indicative FIDE rating $\geq 2,400$; and Grandmaster, with an indicative FIDE rating $\geq 2,500$. The FIDE ratings are only indicative because players should fulfill additional conditions to achieve these FIDE titles.

4 Estimation of fundamental comparative advantage at chess

In this section I estimate countries' fundamental comparative advantage at chess both for a continuum of players and a finite number of players.

Since it is easy to learn how to play chess, and it requires a minimum infrastructure, I perform the first estimation of fundamental comparative advantages assuming that many people play chess in all countries. If there is a continuity of players, we could use (7) to calculate comparative advantage at chess. I use the number of players with a FIDE rating $\geq 2,200$ and population for 2015, and select Romania as the numeraire country. Figure 3 presents the results of the calculations.

We can observe large differences in fundamental comparative advantage across countries. Productivity in the highest-ranked country, Croatia, is 27 times higher than in median country, Jamaica, and more than 2,000 times higher than in the lowest-ranked country: Pakistan.[9] The average country-productivity is 0.86 with a standard deviation of 1.30. In addition to Croatia, the countries with a high comparative advantage in chess are Slovenia, Hungary, Armenia, Czech Republic, Denmark and Slovakia. With the exceptions of Cuba, Israel and Mongolia, European countries dominate the group of countries with a comparative advantage in chess. It is interesting to observe that, according to this estimation, Germany and Spain have a higher comparative advantage than Russia, a country that is popularly assumed to be the leader in chess. African, Asian and American countries, on average, have a comparative disadvantage in chess. For example, Japan, China and India occupy bottom positions in the ranking.

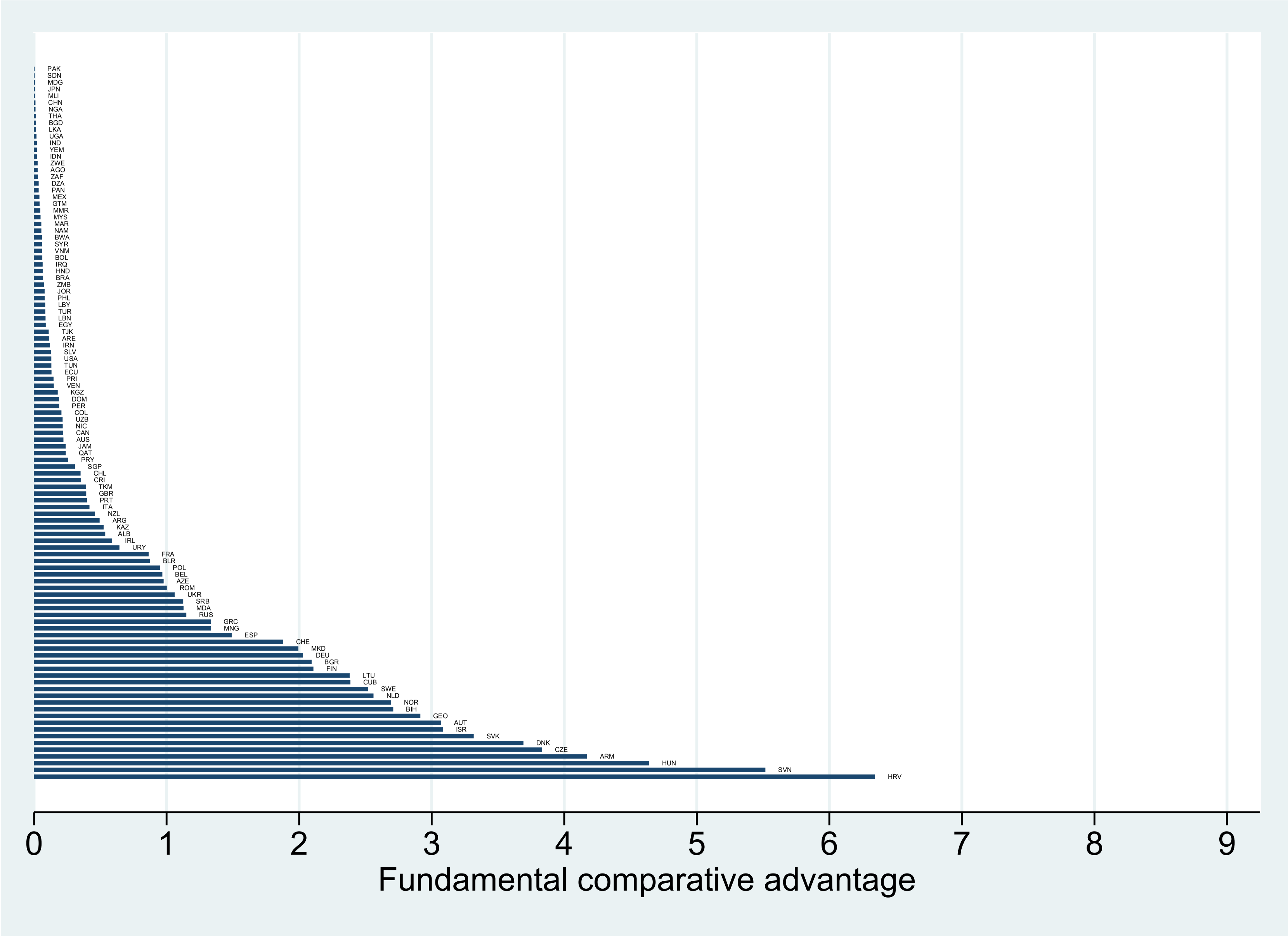
As explained before, according to (7), if there were a continuous number of players, it would not matter what FIDE rating is chosen to calculate fundamental comparative advantage. To test the validity of the continuity assumption, I estimate fundamental comparative advantage for a rating $\geq 2,300$ (FIDE Master), $\geq 2,400$ (FIDE International Master) and $\geq 2,500$ (FIDE Grand Master).

Figures A1 to A3 in the Appendix show countries' fundamental comparative advantage for these alternative rankings. We can see that there are changes in the countries productivity at chess relative to those presented in Figure 3, particularly for higher FIDE ratings. For example, Russia's fundamental comparative advantage at chess rises as we move to higher FIDE ratings, whereas it declines in Spain and in Germany. We also observe that for a large number of countries fundamental comparative advantage at chess is zero when Grandmaster FIDE ratings are used in (7).

The variation in countries' fundamental comparative advantage at chess for different FIDE ratings points out that there are limitations to the continuity of players' assumption.

[9]Interestingly, the highest ranked country, Croatia, has a chessboard in its flag, to celebrate that a Croatian king gained the freedom of the country in a chess game.

Figure 3: Countries fundamental comparative advantage at chess, 2015. Continuous number of players for FIDE ratings $\geq 2,220$



As explained before, when there is a finite number of players, only some quality levels will be drawn. In this scenario, luck at draw begins to contribute to the differences in the number of expert chess players across countries.

To estimate fundamental comparative advantage at chess, controlling for the effect of luck at draw, as in Figure 2, first, I select countries with at least a player with a FIDE rating $\geq 2,200$ and a population of at least 2 million in 2015. Second, I use the Pareto coefficient estimated in Section 3 as the initial parameter for the distribution of innate talent. I use the figures presented in Figure 3 as initial values for countries' fundamental comparative advantage at chess .Third, I multiply countries' fundamental comparative advantage by their population to get the number of draws. Note that by this procedure I am assuming that a country's advantage at chess leads to a higher number of players through a higher number of draws.[10] Fourth, I get the random draws from the Pareto distribution, and count the number of players with a FIDE rating $\geq 2,200$, $\geq 2,300$, $\geq 2,400$ and $\geq 2,500$. Fifth, for each of the four FIDE ratings threshold I calculate the square of the difference between the estimated number of players with a FIDE rating equal or above the threshold and the actual number of players; then, I transform the square of the difference into natural logarithms and add the four terms (one per each FIDE threshold). This is the objective function I try to minimize.[11] To do so, in each iteration I introduce a 5% random shock to the previous iteration's country-level productivity. If the shock yields a lower figure for the objective function, I update country-level productivities. If not, I recover the previous country-level productivities. For each θ parameter, I iterate the model 100 times. After these iterations, I introduce a 5% random shock to the initial θ parameter. At the end of the iterations I compare the value of the objective function, and update the θ parameter if the value of the objective function is lower. I iterate this second loop 100 times.[12]

Figure 4 presents countries' fundamental comparative advantage at chess in 2015 assuming a finite number of players. We still observe large differences in productivity at chess across countries. The average comparative advantage is 0.94 with a standard deviation of 1.45; the country in the top of the ranking, Croatia, has 35 times higher productivity than the median country (Nicaragua), and a 2,673 times higher productivity than the country in the bottom of the list, Pakistan. In addition to Croatia, the countries with a high comparative advantage in chess are Slovenia, Hungary, Armenia, Denmark, Czech Republic and Slovakia. In addition to Pakistan, the bottom positions in the ranking are occupied by Sudan, Madagascar, Japan, Mali, Nigeria and China.

[10]Since I cannot estimate separately T_c and μ_c, I assume that the first variable also leads to a higher number of quality players raising the number of draws.

[11]I take logs to avoid the $2,200$ rating dominating the objective function.

[12]The objective function is minimized within each θ before reaching the limit of iterations. The objective function is also minimized before the 100th iteration across θ.

Figure 4: Countries fundamental comparative advantage at chess. Discrete number of players, 2015

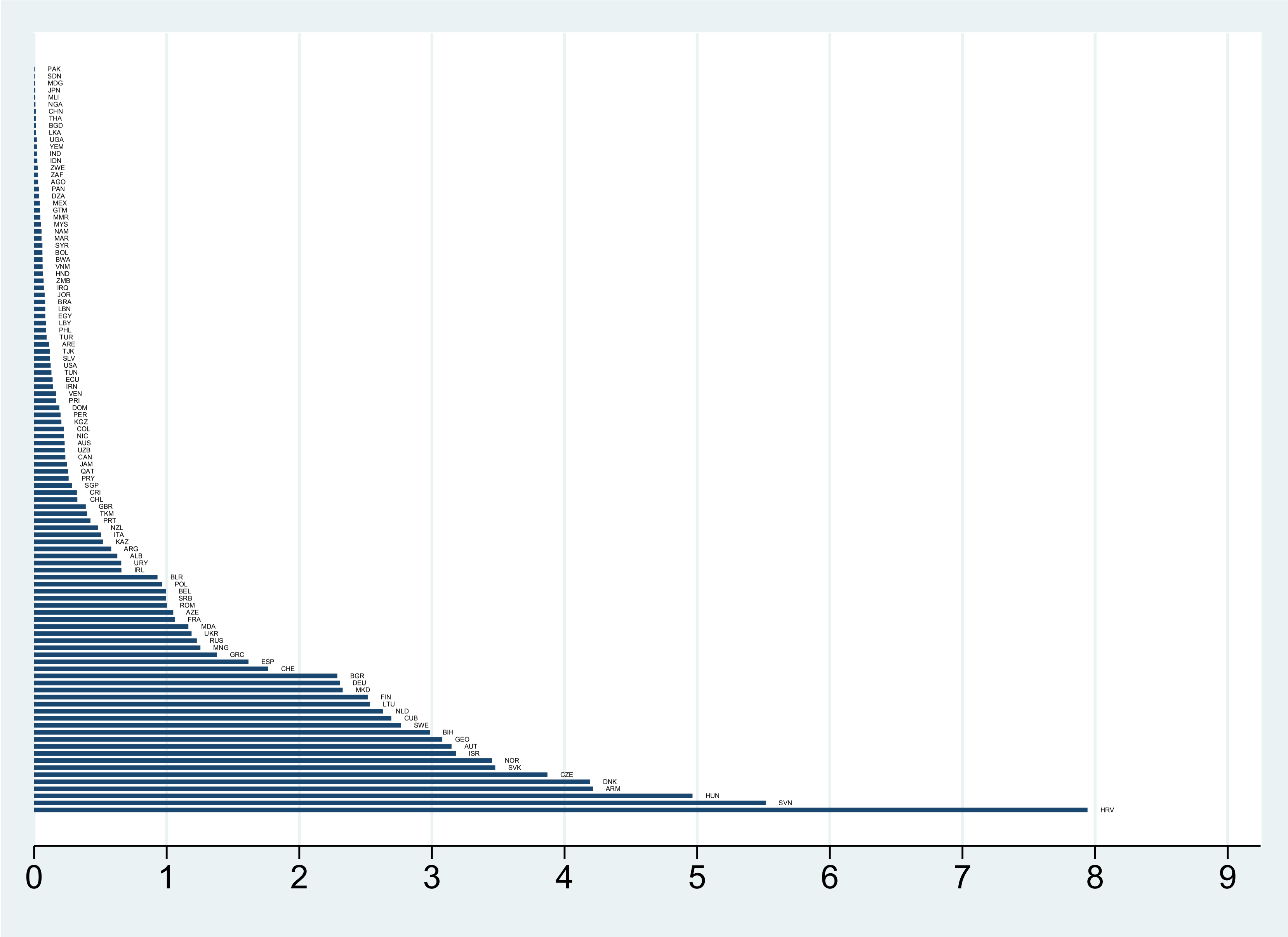


Table 2 presents the correlations between the estimations with the finite assumption and the four estimations with the continuity assumption. There is an almost perfect correlation with the country-level productivity calculated with data on the number of players with a FIDE rating $\geq 2,200$. However, the correlation declines as we move to continuous estimations based on higher FIDE ratings data. These result point out that for a FIDE rating threshold $\geq 2,200$ there is still a high number of players, so countries still occupy a large number of innate talent levels in the distribution. In this situation the fundamental comparative advantage at chess estimated using the continuity assumption is similar to the estimation controlling for the luck at draw. However, for higher FIDE rating thresholds continuity is not longer a valid assumption, leading to a lower correlation between the comparative advantages estimated controlling for luck at draw and those calculated under the continuity assumption.

Table 2: Correlation in country-level productivity estimations between finite and the four continuous estimations, 2015

$\geq 2,200$	$\geq 2,300$	$\geq 2,400$	$\geq 2,500$
0.99	0.96	0.85	0.76

5 The contribution of fundamental comparative advantage and innate talent to differences in the number of expert chess players across countries

To what extent fundamental comparative advantage explains the differences in the number of expert chess players across countries? To answer this question, I decompose the total variation in expert chess players into fundamental comparative advantage at chess and luck at draw. Following Gaubert and Itskhoki (2016), I calculate a variance-based decomposition and a regression-based decomposition. In the first calculation, the total variance in the log number of expert players across countries is decomposed into a fundamental comparative advantage term, a luck-at-draw term, and a covariance term:

$$var(N) = var(A) + var(N - A) + 2cov(A, N - A) \tag{9}$$

where N is the log number of expert chess players and A the log of country fundamental comparative advantage at chess. To assess the contribution of each component, I divide the right-hand side components by the left-hand side component.

In the regression-based decomposition, I regress each component on the log number of expert chess players and a constant. Specifically,

$$
\begin{aligned}
ln(A_c) &= \alpha + ln(N_c) \\
ln(N_c - A_c) &= \alpha + ln(N_c)
\end{aligned} \tag{10}
$$

If the covariance term in (9) is small, the two decompositions give similar results.

Table 3 presents the results of the decomposition for different thresholds of expert chess players. It is very interesting to observe that the contribution of fundamental comparative advantage declines as the threshold for expert players is set into a higher FIDE rating. Taking the regression-based decomposition as reference, for expert players defined as those with a FIDE rating $\geq 2,200$, fundamental comparative advantage explains 97% of the variation across countries, and luck at draw only explains 3% of the differences. However, the contribution of fundamental comparative advantage declines to 90%, 82% and 65% as I define expert players with a FIDE rating $\geq 2,300$, $\geq 2,400$ and $\geq 2,500$ respectively. These results confirm that with a finite number of players, luck at draw plays a higher role in explaining the differences in the number of expert players across countries. The contribution is higher for more stringent definitions of expert chess players.

These results show that fundamental comparative advantage is the main driver of the differences in performance across countries. It is interesting to observe that the contribution of fundamental comparative advantage and innate talent to the differences in the number of expert players across countries for FIDE ratings $\geq 2,500$, is very similar to the contribution of fundamental comparative advantage and granular comparative advantage to the differences in export shares across sectors in France found by Gaubert and Itskhoki (2016).

Table 3: Decomposition of variation in the number of expert chess players

	Fundamental comparative advantage	Luck at draw	Covariance
Elo$\geq 2,200$			
Variance-based	0.95	0.01	0.04
Regression-based	0.97	0.03	
Elo$\geq 2,300$			
Variance-based	0.91	0.07	0.02
Regression-based	0.90	0.10	
Elo$\geq 2,400$			
Variance-based	0.81	0.15	0.04
Regression-based	0.82	0.18	
Elo$\geq 2,500$			
Variance-based	0.60	0.34	0.06
Regression-based	0.65	0.35	

6 Explaining the differences in fundamental comparative advantage across countries

What explains the differences in fundamental comparative advantage across countries? In this section I show that they are explained by the popularity of chess.

To do so, I calculate the correlation between fundamental comparative advantage and three variables that proxy the popularity of chess: the number of federated chess players, the number of chess tournaments that take place in a country, and the relative number of visits to chess masters' Wikipedia pages. The number of federated players is obtained from the FIDE ratings database. I divide this number by population to get the share of federated chess players in total population in 2015. The number of tournaments in each country is calculated from the list of tournaments published in FIDE's web page.[13] I use data for the year 2015. To normalize this figure I divide it by population. Finally, I use Pantheon project data to calculate the relative number of visits to chess masters' Wikipedia pages (Yu et al., 2016). This dataset contains information on 11,341 biographies classified in 88 different occupations. Chess master is an occupation included in the database, and covers 30 biographies. The dataset also gives the number of visits to each biography's Wikipedia page for the period 2008-2013. Moreover, the dataset provides the number of visits for the language-specific biography page.[14] I take advantage of this information to link Wikipedia visits to countries. In particular, I select the languages that are mainly spoken in one country. This reduces the sample of countries from 106 to 40. I calculate the preference for chess dividing, for each language, the visits to chess masters' pages by the visits to all Wikipedia pages included in the database.

Figure 5 presents the scatter diagrams for fundamental comparative advantage and the three chess-popularity proxies. We observe that there is a strong positive correlation between fundamental comparative advantage and the three chess-popularity variables. In particular, the correlation with the share of federated chess players in population is 0.90; the correlation with the per capita number of chess tournaments is 0.74; and the correlation with the relative visits to chess masters' Wikipedia pages is 0.55.

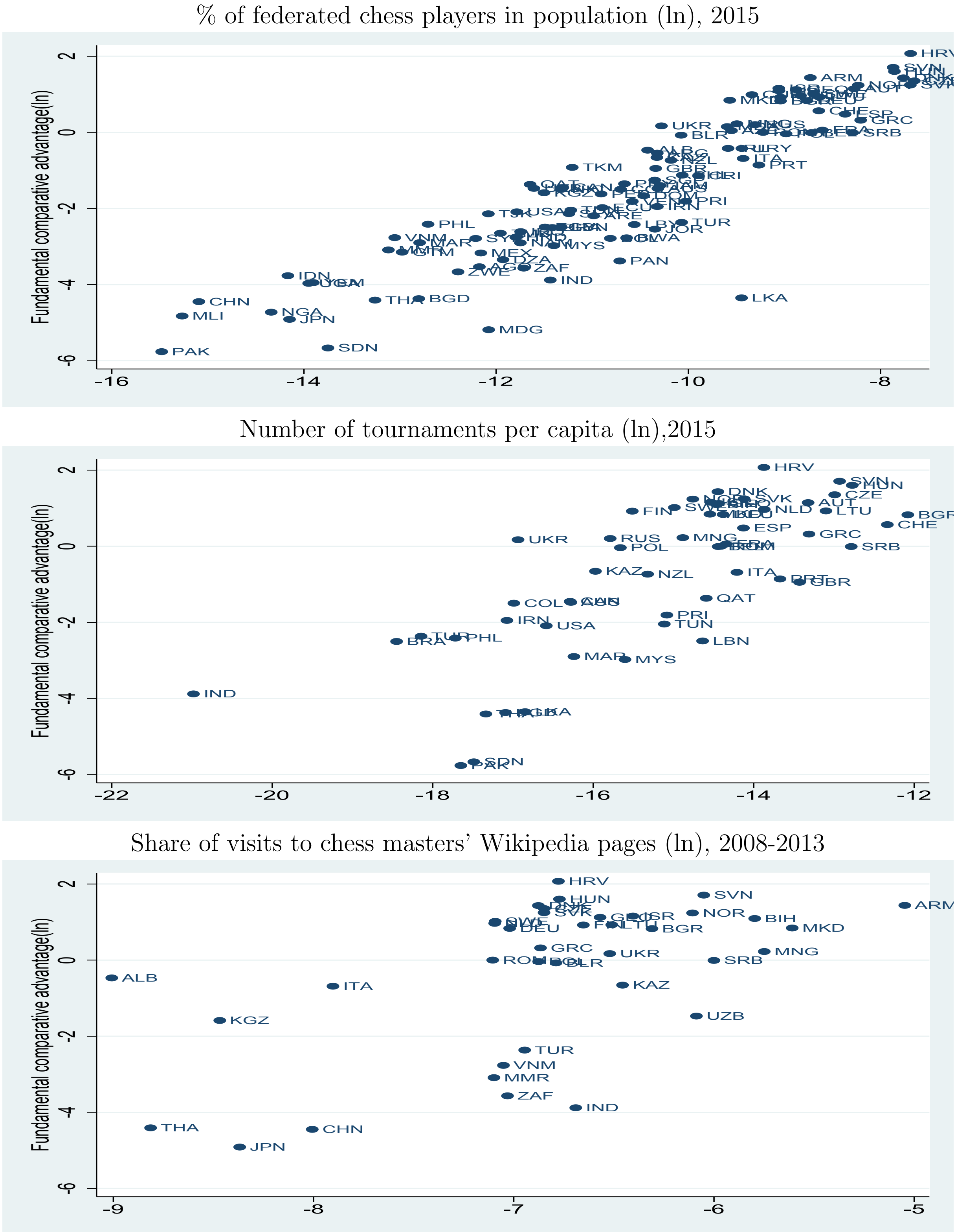
7 Is there a converge in fundamental comparative advantage?

I have argued that comparative advantage in chess is related with the opportunities to practice and improve chess skills and the fraction of the population that are drawn to chess. These two sources of fundamental comparative advantage are highly correlated,

[13]Available at `https://www.fide.com/calendar/tournaments.html`

[14]For example, the dataset provides the number of visits to the Wikipedia page of Gary Kasparov in Russian, in Spanish and in other 68 languages.

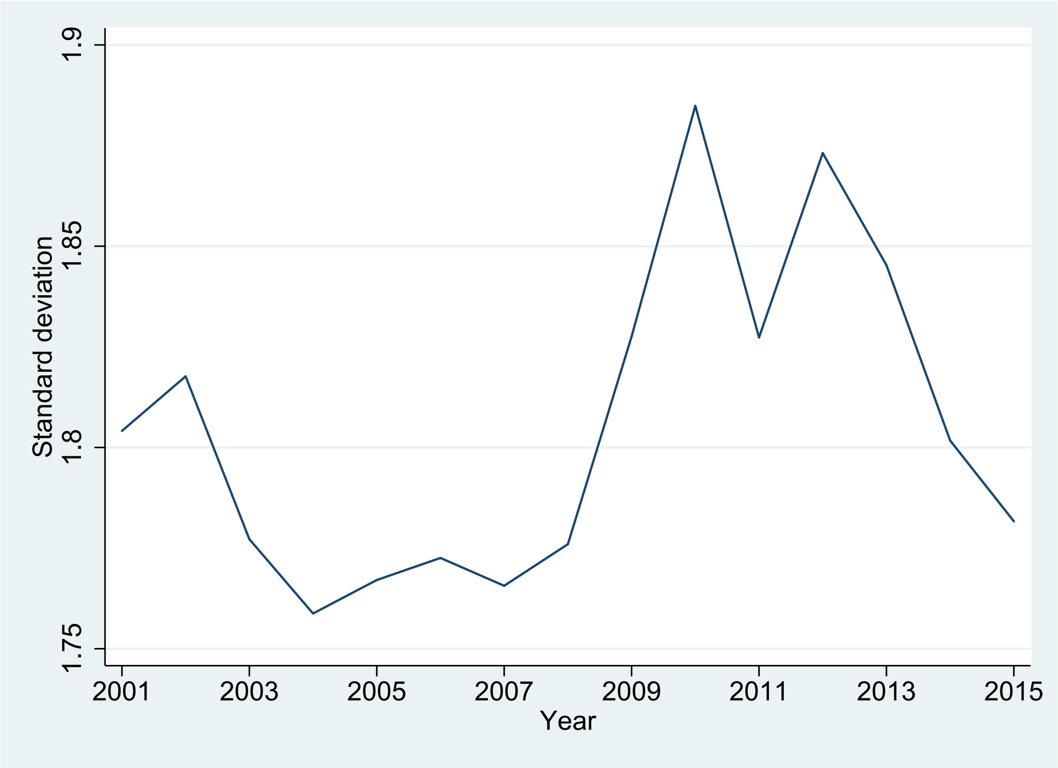
Figure 5: Correlation between fundamental comparative advantage and popularity of chess



which precludes the estimation of their individual contributions. However, a dynamic analysis might help us to get a tentative, and rough, estimate of their relative contributions.

With the spread of the Internet, different chess servers offer the possibility to play chess on-line, provide free tutorials on chess tactics, and access to an enormous database of games. Most of these chess servers were launched over the period covered by our database: 2001-2015.[15] If fundamental comparative advantage is explained by the higher opportunities to play and learn chess skills, the availability of free chess servers might narrow the differences across countries. In contrast, if fundamental comparative advantage is explained by a preference for chess, and a high recognition for expert chess players, drawing more players to this game, free chess servers might not narrow the differences across countries.

Figure 6: Standard deviation in countries fundamental comparative advantage, 2001-2015



To test these hypotheses, I estimate countries' fundamental comparative advantage at chess for each year over the period 2001-2015, and calculate the standard deviation.[16] Figure 6 shows the evolution of the standard deviation of countries (log) fundamental

[15]For example, chesscube.com was launched as a chess server in 2006, chess.com in 2007, and chess24.com in 2014.

[16]To estimate the year-specific countries' fundamental comparative advantage at chess I assume that the θ parameter that governs the distribution of innate talent across players does not change over the period. To perform the estimations I take the θ parameter that minimizes the objective function in the estimation with a discrete number of players: 17.48

comparative advantage at chess over the period 2001-2015. As shown in the figure, there is no clear trend in the evolution of the standard deviation of fundamental comparative advantages. At the beginning of the period there is some convergence, followed by divergence, and then by convergence again. If we compare the standard deviation at the end of the period with the standard deviation at the beginning of the period, there is only a 2.2% difference between them.[17]

These figures point out that, despite of the spread of the Internet, and the appearance of chess servers that allow amateurs to play and learn chess skills, differences in fundamental comparative advantages have not narrowed. This result gives a rough indication that social preference and recognition, drawing more players to chess, might play a more important role in explaining countries fundamental comparative advantage. However, this conclusion is highly tentative. For example, it might be the case that on-line mechanisms are only effective to reinforce the skills that are learned through off-line mechanisms. In this situation off-line opportunities to play and develop chess skills would still play a very important role in explaining the differences in fundamental comparative advantage across countries.

8 Conclusion

There are many situations in which the aggregate performance of a country combines country-level advantages and individual-level advantages. This paper analyzes an activity, chess, which is amenable to test the contribution of country-level advantages and individual-level advantages to differences across countries. Using players FIDE ratings, I show that fundamental comparative advantage explains between 65% and 97% of the variation in the number of expert chess players across countries. This result points out that country-level advantage is the main driver of the differences across countries. I find that differences in fundamental comparative advantage are highly correlated with the popularity of chess. This result shows that a social preference leads to a more advanced technology, which generates a Ricardian comparative advantage. I also show that over the period 2001-2015, despite the spread of the Internet, and the appearance of chess servers, there has not been a convergence in comparative advantage in chess.

[17]Using trade data Levchenko and Zhang (2011) and Hanson et al. (2015) find a reversion to the mean in comparative advantage for a sample of developed and developing countries during the second half of the 20th century. Using data on citations to mathematics papers, Head et al. (2015) find that the spread of the Internet has reduced the geography barrier to the diffusion of knowledge.

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Figure A1: Fundamental comparative advantage at chess. Continuous number of players. FIDE rating $\geq 2,300$, 2015

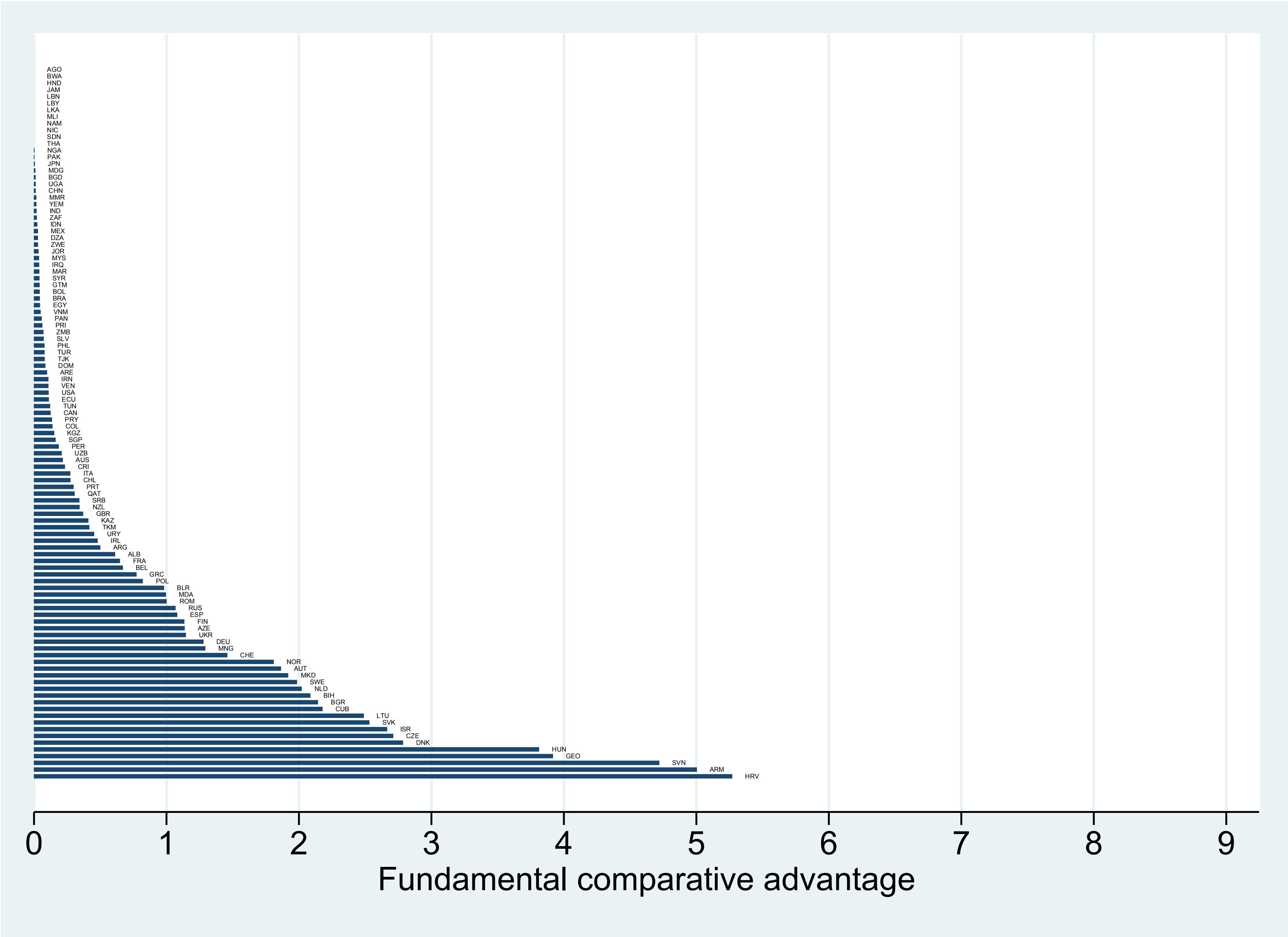

Figure A2: Fundamental comparative advantage at chess. Continuous number of players. FIDE rating $\geq 2,400$, 2015

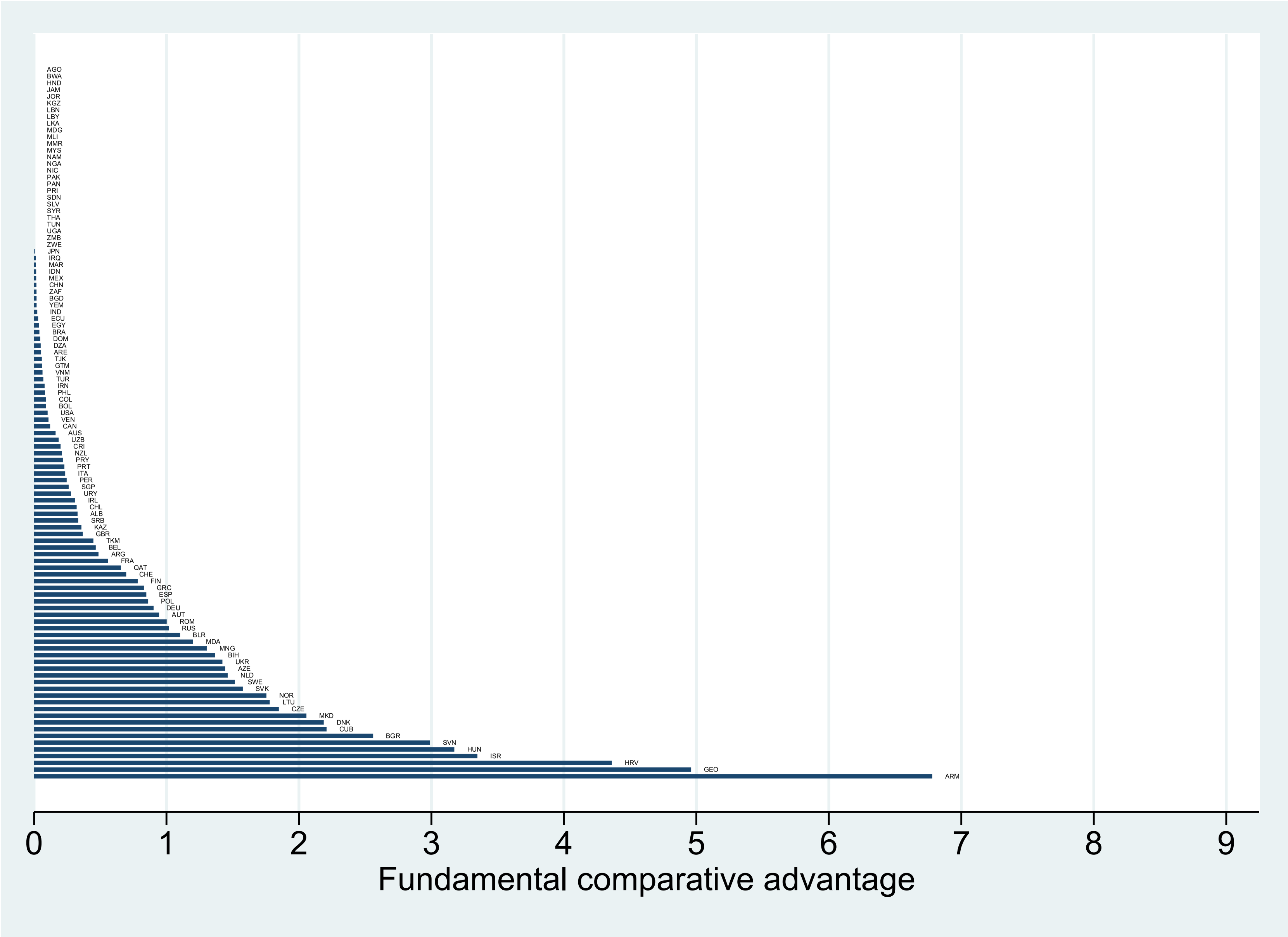

Figure A3: Fundamental comparative advantage at chess. Continuous number of players. FIDE rating $\geq 2,500$, 2015