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**Wen-Jhan Jane**

Shih Hsin University,
Department of Economics,
Taiwan
✉ wjjane@cc.shu.edu.tw

# Pecuniary Incentive in Tournaments and Effects of Players' Heterogeneity on Efforts in the Association of Tennis Professionals

**Summary:** This article addresses the issues of players' heterogeneity in individual efforts and winning probability in the Association of Tennis Professionals (ATP) games. ATP players' personal characteristics and performance from 2011 to 2013 are collected. The results show that a negative impact of the matchup's heterogeneity on the intensity of the game is found. The evidence thus indicates that the two players play harder when the heterogeneity is smaller. Evidence also indicate that the pecuniary incentive in tournaments is supported, and appearance of a superstar makes his opponent exert less effort. In the odds ratio analysis for the players' heterogeneity, a rank differential increases a favorite player with 1.004% winning percentage in ATP matches. Younger, lower BMI, experienced, and right-hand players are more likely to win.

**Key words:** Competition, Heterogeneous contestants, Random-effects logistic model, Superstar effects, Tournament theory.

**JEL:** D01, L83, M52.

Tournament incentives are common in organizations, and the effectiveness of contestant heterogeneity between two players at motivating efforts is both of practical and theoretical importance. When tournament participants have homogeneous abilities, both theoretical and experimental researches in economics indicate that higher effort is obtained compared with tournament participants with heterogeneous abilities, holding constant the total financial compensation (Roman Sheremeta 2011).

We contribute to the existing literature by theoretically explaining the contamination hypothesis in a model of tournament theory with heterogeneous players, and by empirically investigating the impact of heterogeneity on behavior in tournaments. Although most of the existing literature investigates the pecuniary incentive of tournaments, this article adds new insights into the still small amount of studies about the relationship between the players' heterogeneity and their efforts. Furthermore, based on previous theoretical studies, it is still difficult to predict the overall performance when tournament participants have heterogeneous abilities. We investigate the behavior of *ex ante* favorites relative to *ex ante* underdogs in an uneven tournament. As we will show, the structure of a tennis game provides a good setting to investigate the impact of heterogeneity on individual efforts and game intensity.

The remainder of this article is organized as follows: the literature on tournament theory with heterogeneous contestants is reviewed, and a theoretical model is constructed in the first section. The empirical methodology and data description are presented in Section 2. The results are discussed in Section 3, and the article ends with a summary of the main conclusions.

## 1. Literature Review

Incentives to exert effort decrease if the competitors in a tournament become more heterogeneous. That is, competitors differ in their abilities, and hence, their *ex ante* winning chances are different. In heterogeneous tournaments, the underdog will shy away from a competition, because his chances of winning are comparably low. The opponent will anticipate this reduction in a costly effort and decide to hold back effort as well. As a result, overall performance and, hence, the intensity of the tournament decrease. This effect is referred to as the contamination hypothesis (Norbert Bach, Oliver Gürtler, and Joachim Prinz 2009; Gürtler and Matthias Kräkel 2010).

Because contestants are seldom completely homogeneous in practice, this prediction calls the frequent use and effectiveness of tournament schemes in firms and organization into question. Although the heterogeneous tournaments have been studied in the theoretical literature (see Kräkel and Dirk Sliwka 2004) and experimental studies (see Clive Bull, Andrew Schotter, and Keith Weigelt 1987; Schotter and Weigelt 1992), only recently, a growing body of articles test the theoretical predictions with non-experimental field data from sports contests (see Bach, Gürtler, and Prinz 2009).

As experimental studies have shown, underdogs often exert higher effort levels than theoretically predicted, whereas the behavior in symmetric settings is roughly in line with theory. Although Weigelt, Janet Dukerich, and Schotter (1989) find no significant differences when comparing effort levels of favorites and underdogs in unfair tournaments, Christine Harbring and Gabriele Lünser (2008) report that efforts of weak players are significantly higher than that in symmetric settings if the prize spread is high. In a real effort experiment of Frans van Dijk, Joep Sonnemans, and Frans van Winden (2001), players with lower ability try to win the tournament against a high-ability contestant, even though they lose in most cases and could avoid the tournament by playing a piece rate scheme. Wieland Müller and Schotter (2010) consider that the heterogeneity in contests depends on whether the cost-of-effort function is convex or not. The experimental results show that low-ability workers tend to “drop out” and provide little or no effort, whereas high-ability workers provide excessive levels of effort, so that there is a bifurcation of effort.

This article investigates whether tournaments between heterogeneous contestants are less intense. In this article, a theoretical model based on Edward Lazear and Sherwin Rosen (1981) and Kräkel and Sliwka (2004) is used to explain the contamination hypothesis (Bach, Gürtler, and Prinz 2009). To empirically test the hypothesis, professional tennis data from the Association of Tennis Professionals (ATP) were used. Based on world ranking system, the competing players’ heterogeneity is estimated. The evidence for a negative impact of the matchup’s heterogeneity on the intensity of the game is found. The effect of players' heterogeneity is significant not only at the match-level but also at the player-level analyses. All empirical evidence supports the theoretical hypothesis.

Following the seminal article of Lazear and Rosen (1981), a large literature investigating the effects of tournaments emerges (see, Kai Konrad 2009, for an overview). Lazear and Rosen (1981) show that effort levels in tournaments depend on a number of crucial design choices. Besides the size of the tournament prize that incentivizes contestants to exert effort, the set of respective contestants competing for a prize is likely to affect effort decisions. Therefore, for the past three decades, the effectiveness of the composition of the tournament has been discussed in many studies in the literature.

For instance, Kyung Hwan Baik (1994) uses Tullock-type contests and shows that total effort levels as well as individual effort levels are higher in contests with homogeneous contestants than in contests with heterogeneous contestants, with respect to their ability levels. If contestants are heterogeneous, it is rational for both to lower their effort which leads to a less-intense contest. For managers wishing to design highly intense tournaments between their employees - be it promotion tournaments, sales contests, or R&D competitions - it is a key insight that total effort levels are higher in setups with homogeneous contestants.

It is straightforward that sport organizers prefer close and intense matches to attract a large audience. A reduction in game intensity would be harmful for ticket sales, merchandising, and so on, and the organizers should therefore take action to make a contest as homogeneous as possible. Although the logic and effects of heterogeneous tournaments have been studied intensely in the theoretical literature (i.e. Baik 1994; William Stein 2002; Kräkel and Sliwka 2004; David Gill and Rebecca Stone 2010), articles offering an empirical test of the effectiveness of heterogeneous tournaments are sparse.

The existing empirical literature testing the contamination hypothesis can be classified into field studies focusing on actual firm-level data, studies using controlled laboratory experiments, and articles studying sports contests. Sports competitions usually have the structure of tournaments because relative comparison determines the best athletes in their respective fields. Therefore, sports are probably one of the best environments to test economic theories on incentives.

Indeed, professional sports are potential areas of empirical research on tournament models because performance and prize structure can be easily identified (see, Michael Maloney and Robert McCormick 2000; Bernd Frick, Joachim Prinz, and Karina Winkelmann 2003; Stefan Szymanski 2003; Thierry Lallemand, Robert Plasman, and François Rycx 2008). Armen A. Alchian (1988) argues that athletic competitions are the most promising area for empirical analyses of monetary incentives. Szymanski (2003) adds that individualistic sports (e.g. golf, tennis, foot races) represent an ideal setting to determine the prize structure that maximizes the agents' performance.

Tennis tournaments exhibit the key features that characterize all tournament models. First, the prize structure is fixed in advance, and the winner receives the same pay regardless of the margin of victory. Second, relative performance is critical, not absolute performance. Although all the competitors may have excellent ability, what matters is that a player performs well enough to win the match. Third, a competitor's effort depends on the size of the prize difference between winning and losing. The larger the spread, the greater the effort exerted by contestants (Lazear and Rosen 1981; Rosen 1986). Finally, the prize spreads increase significantly through successive rounds, concentrating much of the prize money in the top ranks.

Therefore, economists usually use the data of tennis matches to investigate the effects of players' heterogeneity and prize structure on level of effort (Keith Gilsdorf and Vasant Sukhatme 2008; Lallemand, Plasman, and Rycx 2008; Uwe Sunde 2009; David Malueg and Andrew Yates 2010). Gilsdorf and Sukhatme (2008) find that increased monetary prize differentials between the winner and the loser of a match have a positive effect on the winning probability of the higher-ranked player. Lallemand, Plasman, and Rycx (2008) describe the existence of a positive relationship between prize spreads and the number of games in women's tennis matches. They also find that the difference in the number of games won by the favorite and the underdog increases with the players' ranking differential. Sunde's (2009) data on professional tennis matches support the assumption that unevenly matched tournaments between heterogeneous players lead to the exertion of less effort. More recently, Malueg and Yates' (2010) empirical results support the theoretical predictions that tennis players adjust their efforts strategically during a best-of-three sets contest. Economic theory predicts best-of-three contests are more likely to end in two rounds than in three. If a contest reaches a third round, each player is equally likely to win.

Studies that use sports data do not provide unambiguous support for the contamination hypothesis. Among the first studies, Ronald Gordon Ehrenberg and Michael Bognanno (1990) analyze Professional Golfers' Association (PGA) tour golf tournaments and cannot clearly confirm the contamination hypothesis. They show that the stronger the opponent, the weaker the performance of a player. Although this is in line with the theory for participants performing below average, it violates the theory for participants performing above average, because they should be motivated by a higher quality opponent. Jennifer Brown (2011) also uses data from PGA golf tournaments from 1999 to 2006 and shows that effort declines if a superstar (Tiger Woods) participates in the tournament. However, her findings are only significant for higher-skilled players but not for lower-skilled ones. Ryuichi Tanaka and Kazutoshi Ishino (2012) indicate that the presence of a superstar adversely affects the scores of the other golfers in Japan Golf Tour. Furthermore, they find that the larger the size of the total prize, the better are the scores. The study of horse racing, by James Lynch (2005), supports the contamination hypothesis, as does the study of tennis by Sunde (2009). Sunde (2009) also conducts a separate analysis for favorites and underdogs and finds that only underdogs are sensitive toward heterogeneity and reduce effort accordingly.

In addition, there are some other features that can influence tennis matches. For example, Ruud Koning (2011) finds a significant home advantage in men's tennis matches. Rod Cross and Graham Pollard (2009) examine 20 years of men's serving data, showing that the height of the players plays a significant role in tennis. Peter O'Donoghue (2001) and Alex Krumer, Mosi Rosenboim, and Offer Moshe Shapir (2016) find the evidence of gender differences in serve dominance. Eric Gillet et al. (2009) find that the flat serve is significantly more effective than the topspin serve.

Krumer, Rosenboim, and Shapir (2016) show the crucial influence of physiological variables, such as body mass index (BMI), on the gender differences in the tightness of the final score in tennis.

In this article, we therefore concentrate on heterogeneous contests in tournament theory and test whether: (a) the intensity of the tournament is affected by the heterogeneity of contestants; (b) if so, whether both favorite and underdog behave according to this theorem.

In the theoretical literature, there is no consensus regarding the precise impact of heterogeneity in players' ability on individual performance. The contamination hypothesis suggests that both players are less performing in high uneven matches because they exert less effort when they have unequal chances of winning. Actually, in heavy uneven matches, the favorite player (i.e. the player with an *ex ante* advantage) can reduce his effort without threatening his success chances, whereas his weaker opponent knows he must produce extra effort to win the match. Because the probability for an underdog to win the match is lower, he may decide to exert less effort. On the other hand, the capability hypothesis stresses that larger heterogeneity leads *ceteris paribus* the favorite to perform better and the underdog to win fewer games since his inferior ability reduces his winning probability. The difference with the contamination hypothesis is that underdogs are less performing because of their weaker ability or talent, not because they are less motivated to put forth higher effort.

Player $i$'s production function can be described by $y_i = a_i + e_i + \varepsilon_i$, where $a_i$ denotes ability, $e_i$ denotes effort, and $\varepsilon_i$ denotes an error term. $\varepsilon_i$ is assumed to be identically independent with $\varepsilon_i \sim N(0, \sigma_\varepsilon^2)$, and its cumulative distribution function and probability distribution function are $F(\varepsilon)$ and $f(\varepsilon)$. The players' cost functions are $c(e_i) = (1/2)e_i^2$, and the function is increasing and strictly convex ($c' > 0$ and $c'' > 0$). The player's utility depends on whether the prize is won, less an effort cost which must be paid before the game:

$$U(e_i) = \begin{cases} V_j - c(e_i), & if \;\; i \;\; wins \\ \quad -c(e_i), & otherwise \end{cases}, \tag{1}$$

where the reward for winning this game is $V_j$. Let player $i$'s winning probability at round $j$ is $P_{ij}$. The $i^{th}$ player's expected utility conditional on ability and effort choice is:

$$E[U(e_i) \mid e_i, a_i] = \sum_j P_{ij} V_j - c(e_i). \tag{2}$$

The player's heterogeneity is simply assumed as the difference of ability $a_i$. All players' distributions of ability are known, but the players' actual ability cannot be measured before a contest is finished. Lower-ability players cannot win by effort, if the win is directly decided by ability. Therefore, the heterogeneity setting makes the discussions that "lower-ability players can count on efforts to win the games when the heterogeneity is small enough" possible. More specifically, the game organizers know every player's ability distribution, so the winning probability ($\hat{P}i$) and expected productivity ($\sum_i \hat{P}i\ \hat{a}i$) are computable. Therefore, in the perfect competition for these tournaments, the prize is determined as $V_i$ which is irrelevant with efforts.

In the case of two competitors in the model, players *A* and *B* competed in a tennis game. The former player has higher ability ($a_h$) and pays efforts ($e_h$) in a game. The latter one has lower ability ($a_l$ [$a_h > a_l$]) and pays efforts ($e_l$). Their corresponding chance are $\varepsilon_h$ and $\varepsilon_l$. When the player *A* wins ($y_h > y_l$), then $\varepsilon_l < (a_h - a_l) + (e_h - e_l) + \varepsilon_h$. The higher ability player's marginal winning probability is prob($\varepsilon_l < (a_h - a_l) +$ $+ (e_h - e_l) + \varepsilon_h$) = F($\Delta a + \Delta e + \varepsilon_h$), where $\Delta a \equiv a_h - a_l$ and $\Delta e \equiv e_h - e_l$. The player A's winning probability is:

$$P_h = prob(y_h > y_l) = \int_{-\infty}^{\infty} F(\Delta a + \Delta e + \varepsilon_h)\, f(\varepsilon_h)\, d\varepsilon_h = \Phi(\Delta a + \Delta e), \tag{3a}$$

where $\Phi$ is the cumulative distribution function of ($\varepsilon_l - \varepsilon_h$), and ($\varepsilon_l - \varepsilon_h$) ~ N(0, $2\sigma_\varepsilon^2$). It needs to be noted that $P_h > 0.5$ when $\Delta a + \Delta e > 0$. This represents a high-ability player would win even though their efforts are lower. $P_h < 0.5$ when $\Delta a + \Delta e < 0$, and it represents that a low-ability player would win by working hard enough.

Oppositely, when player *B* wins ($y_h < y_l$), the lower-ability player's winning probability is:

$$P_l = prob(y_l > y_h) = \int_{-\infty}^{\infty} F(-\Delta a - \Delta e + \varepsilon_l)\, f(\varepsilon_l)\, d\varepsilon_l = 1 - \Phi(\Delta a + \Delta e). \tag{3b}$$

Therefore, the player's winning probability is a function of the ability difference ($\Delta a$), the effort difference ($\Delta e$), and the parameters of *F* or $\Phi$ (*ex*: $\sigma_\varepsilon^2$), and so on.

Tournament organizers know every player's ability and equilibrium effort in advance, so the winning probability $\hat{P}$ and corresponding expected productivity are calculated. In the perfect competition for these tournaments, the prize is predetermined as $V_1$ and $V_2$ by the organizers, and it had been assumed irrelevant with efforts.

$$V_1 = \hat{P} a_H + (1 - \hat{P})\, a_L,\; V_2 = (1 - \hat{P}) a_H + \hat{P} a_L, \\ V_1 - V_2 = (2\hat{P} - 1)\Delta a. \tag{4}$$

$V_1$ is the winner's prize, and $V_2$ is the loser's prize. The prize gap is a function of winning probability and ability difference. The higher-ability (*A*) player's expected utility conditional on ability and effort choice is:

$$U_H = PV_1 + (1 - P)V_2 - (1/2)e_H^2,\; U_L = PV_1 + (1 - P)V_2 - (1/2)e_L^2. \tag{5}$$

Player's choice of effort ($u$) satisfies the first-order conditions:

$$\frac{\partial U_H}{\partial u_H} = (V_1 - V_2)\frac{\partial P}{\partial u_H} - e_H,\; \frac{\partial U_L}{\partial u_L} = -(V_1 - V_2)\frac{\partial P}{\partial u_L} - e_L. \tag{6}$$

The second-order conditions (f.o.c.) are as follows:

$$\frac{\partial^2 U_H}{\partial {u_H}^2} = (V_1 - V_2)\frac{\partial^2 P}{\partial {u_H}^2} - 1,\; \frac{\partial^2 U_L}{\partial {u_L}^2} = -(V_1 - V_2)\frac{\partial^2 P}{\partial {u_L}^2} - 1. \tag{7}$$

According to the definition of *P*, $\frac{\partial P}{\partial u_H}$ equals to $-\frac{\partial P}{\partial u_L}$. This represents that player *A*'s marginal effects of efforts on winning probability is the same as (minus) player *B*'s marginal effects of efforts:

$$\frac{\partial P}{\partial u_H} = \int_{-\infty}^{\infty} \mathrm{f}(\Delta a + \Delta e + \varepsilon)\, \mathrm{f}(\varepsilon)\, d\varepsilon = \Phi'(\Delta a + \Delta e) > 0. \tag{8}$$

Equation (8) represents that high-ability players can always increase their winning probability by their own efforts, but low-ability players cannot. Therefore, the high-ability players' advantage is proofed.

**Proposition 1.** The intensity of the tournament decreases when the ability difference increases.

$$\frac{\partial^2 P}{\partial {u_H}^2} = \frac{\partial^2 P}{\partial {u_L}^2} = \int_{-\infty}^{\infty} \mathrm{f}'(\Delta a + \Delta e + \varepsilon)\, \mathrm{f}(\varepsilon)\, \mathrm{d}\varepsilon = \Phi''(\Delta a + \Delta e) \begin{cases} > 0, \text{if } \ \Delta a + \Delta e < 0, \\ < 0, \text{if } \ \Delta a + \Delta e > 0. \end{cases} \tag{9}$$

Equation (9) implies that favorites' marginal effects of efforts on winning probability is decreasing, but the underdogs' marginal effects of efforts on winning probability is increasing.

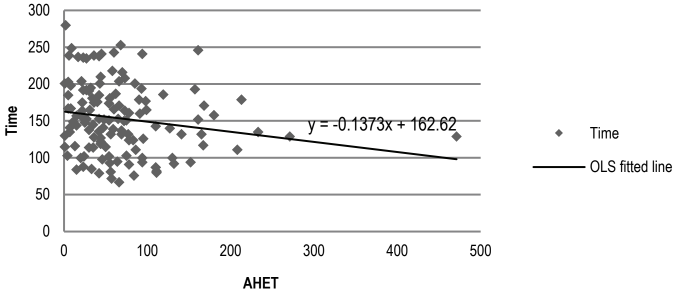
When the ability difference is larger than effort difference ($\Delta a > \Delta e$), high-ability players are more likely to win ($P_h > 0.5$). Underdogs will shy away from competition, because the chances of winning are comparably low. High-ability player will anticipate this reduction in costly effort and decide to hold back effort as well. As a result, overall performance and hence the intensity of the tournament decreases. Therefore, Proposition 1 is proofed.

## 2. ATP Tour, Grand Slams, and the Advantages of the ATP Data in Tournaments

In tournaments, the prize structure is set in advance, and the payouts depend on relative, not absolute, performance. Therefore, the data of competitions in professional tennis are suitable for investigating the incentive effects of tournament theory. As many firms organize their workers into teams who often compete against each other for a bonus pool or resources, studying tennis in tournaments is of particular interest. Measuring the relative performance of athletes in different events and keeping track of the differing compensation schemes inherently present in these events, we can make conclusions about the amount of effort agents will exert based on different marginal payoffs. These conclusions allow us to better construct ideal pay dispersion schemes in the labor market.

Contestant homogeneity and a large reward increase participants' motivation, because the greatest possible reward for winning creates a higher economic value and tournament participants with homogeneous abilities need to exert higher level of effort to increase the probability of winning the available reward. Taking the US Open tennis games in 2013 as an example, the rank difference of the longest match (280 minutes) which played by Miloš Raonić (ranking 11) and Richard Gasquet (ranking 9) was 2 and the rank difference of shortest match (67 minutes) which played by Gael Monfils (ranking 39) and Adrian Ungur (ranking 105) was 66. Incentives to exert effort increase in a homogenous tournament.

Figure 1 depicts the relationship between the contestants' heterogeneity and two ATP players' efforts. For the 127 US Open tennis games played in the 2013, the differences between favorites and underdogs in the current ATP standing (AHET) related to total time in a match are plotted. When total times in a game are used as a measure of effort, the graph clearly shows that the total time in ATP game decreases as the rank difference between the favorite and underdog increases. However, the graph fails to control for other important factors. This relationship thus needs further empirical work.




**Source:** Author's calculations.

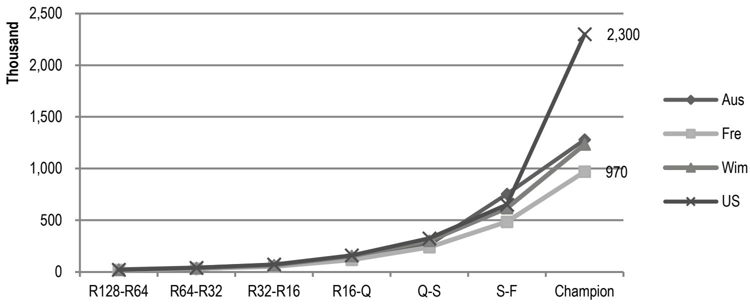
**Figure 1** The Relationship between Players' Heterogeneity and Total Efforts

A tennis match is composed of points, games, and sets. A set consists of a number of games, which in turn consist of points, with a tiebreak played if the set is tied at six games per player. A match is won when a player wins the majority of prescribed sets. Traditionally, matches are either a best-of-three sets or best-of-five sets format. The best-of-five set format is typically only played in the men's singles.

The Association of Tennis Professionals (ATP), formed in 1972, is the official organizer of the men's worldwide tennis tour. As of 2014, the ATP tour consists of 61 tournaments, in 31 countries, on 6 continents, around the world. Tournaments range in size from 32 to 128 competitors. In each tournament, players compete for both monetary prizes and for ATP points, which determine a player's ATP ranking. Higher-ranked players automatically qualify to participate in higher-profile (and higher paying) tournaments, and may even be given a seed, which gives them a preferable draw position and, thus, increased opportunities to win more money and points. Lower-ranked players must often succeed in a qualifier round if they wish to participate in ATP tournaments.

The four biggest ATP tournaments in terms of field size, total payout, and total points awarded are the Grand Slams - the Australian Open, Roland Garros (the French Open), Wimbledon, and the US Open. Each grand slam event consists of 128 total players, 32 of which are seeded. The payouts and total points awarded by each tournament are decided on a year-to-year basis. For example, in 2013, the US Open awarded a total of $34,300,000. Payouts are awarded on a sliding scale, where the prizes (and thus the marginal payouts) roughly double from round to round. Points are similarly awarded on a sliding scale, with marginal payouts increasing in each round. These reward schemes align with tournament theory and Rosen's claim that the higher someone's position, the larger his marginal rewards. Figure 2 shows prize structure and marginal gains for the Australian Open, Roland Garros (the French Open), Wimbledon, and US Open in 2013. In the 2013 season, the US Open prize money was the highest out of four grand slam tournaments, compared with $30 million at the

Australian Open, $29 million at French Open, and $34 million at the Wimbledon Championships.




**Source:** Author's calculations.

**Figure 2** Prize Structure and Marginal Gains for the Australian Open, Roland Garros (the French Open), Wimbledon, and US Open in 2013.

Given the difficulties of the available literature to clearly distinguish between the incentive and the selection effects of tournaments in competitions, the following analysis uses data from ATP tennis players' efforts in Grand Slam matches. The advantages of this kind of data are obvious. First, it comes from a natural setting somewhere between the simplicity of a laboratory experiment and the complexity and ambiguity of a particular labor market (see, e.g. Rodney Garratt, Catherine Weinberger, and Nick Johnson 2013). Second, the data are available for a number of consecutive years and not only for a cross-section of athletes. Our data contain extensive personal characteristics and yearly performance information on competitors from 2011 to 2013. Demographic data include age, height, and weight. Competition dates and locations, as well as athlete's world rank are also included in the data set. The data are obtained from the official website of ATP.

## 2.1 Empirical Model and Data Description

According to Ehrenberg and Bognanno's (1990) and Sunde's (2009) empirical settings, a direct way of testing for the existence of an incentive effect and the effect of player heterogeneity can be obtained by estimating the following empirical model:

$$Eff_{ijk} = \beta_0 + \beta_1\, AHET_{jk} + \beta_2\, PRIZES_{jk} + \beta_3\, Favorites + \beta_4\, Favorites\_rd + Char_i\, \Pi + X_{jk}\, \Psi + Y_k\, \Phi + \varepsilon_{ijk}, \quad (10)$$

where $Eff_{ijk}$ is $i^{th}$ player's efforts at match $j$ in tournament $k$, *AHET* is a measure of heterogeneity of the relative strength of the contestants at the outset of the match, *PRIZES* is the prize spread awarded at game $j$ between this and next rounds in the tournament $k$, *Favorites* is the dummy of players with a smaller rank number than their opponent, *Favorites_rd* is the intersection of *Favorites* and *AHET*, and $\varepsilon_{ijk}$ is a random error term. $Char_i$ is a vector of player $i$'s characteristics, it includes player's tenure (*tenure*), player's age (*age*), player's BMI (*bmi*), dummy of right-hand player (*play*), and dummy of star (*star*). The star is defined as the no. 1 player in ATP ranking before tournament. $X_{jk}$ contains information on the level of matches, such as the round of the match (*Round*). $Y_k$ is a vector of variables to control for the tournament course.

For the dependent variable (*Eff*), the total number of games (*IGames*) and total number of points (*IPoints*) won by a player *i* are used to proxy for player efforts. For the independent variable, the measure of *AHET* is the absolute value of difference between the player's own ATP rank and that of his opponent. Further investigations of *CH* effect on individual efforts can be provided by the author as needed. Note that favorites is players with a smaller rank number than their opponent, whereas underdogs exhibit a larger rank number.

The second part of our empirical model is used to investigate the relationship between players' heterogeneity on winning probability. Therefore, the second specification uses the probability that a player wins his match (*DWin*) as the dependent variable. Specifically, the empirical model is listed as follows:

$$Pr_{ijk}(DWin = 1) = \Phi(\gamma_1 Favorites_{ijk} + \gamma_2 PRIZES_{ijk} + \gamma_3 AHET_{jk} + \gamma_4 Favorites\_AHET_{ijk} + Z_{ijk}\Sigma + \varepsilon_{ijk}), \quad (11)$$

where $\Phi$ is the cumulative logistic function, *Favorites_AHE* is the intersection of *Favorites* and absolute value of rank differential (*AHET*), *Z* is a vector of other control variables. Other control variables (*Z*) include absolute value of tenure difference between players (*DiffTenure*), absolute value of height difference between players (*DiffHeight*), absolute value of weight difference between players (*DiffWeight*), absolute value of age difference between players (*DiffAge*), better-known opponents (*BP*) (Sunde 2009), intersection of *Favorites* and *IGames* (*Favorites_IGames*), and intersection of *Favorites* and *IPoints* (*Favorites_IPoints*), and prize awarded to loser (*LoserPrize*).

## 2.2 Data Description

The data contain information for four biggest ATP tournaments in over 3,048 individual's performance in 1,524 matches within the year 2011 to 2013. Formally, for each Grand Slam event each year, there were 127 matches and 254 individual's performance. So the full sample should be 1,016 matches each year, but some players hurt in the games, and missing values appeared. Our sample contains 1,014, 1,012, and 1,010 matches for the years of 2011, 2012, and 2013. Variable descriptions and corresponding statistics are listed in Table 1.

In Table 1, the average number of games won by player *i* in a match was 17.55, with a range from 0 to 42. The average number of points won by player *i* in a match was 110.27, with a range from 4 to 254. The match which played by Marin Čilić and Sam Querrey in Wimbledon 2012 was the largest number of games (42) and the largest number of points (254) won by Čilić. His opponent Querrey lost it with 39 games and 245 points. The average time in a match for games in these tournaments during this period was 149.76 minutes. The longest time match was played by Novak Đoković and Rafael Nadal in the 2012 Australian Open Men's singles final, lasting 5 hours 53 minutes, Đoković defeated Nadal by the epic score of 5-7, 6-4, 6-2, 6-7, 7-5 in the match. The match is considered to be one of the greatest matches in tennis history.

**Table 1** Descriptive Statistics of the Data ($n$ = 3,036)

| Variable | Description | Mean | Std. dev. | Min. | Max. |
|---|---|---|---|---|---|
| Individual-level reg. | Dependent variables | | | | |
| IGames | Games won by player *i* in a match | 17.551 | 6.352 | 0 | 42 |
| IPoints | Points earned by player *i* in a match | 110.269 | 35.208 | 4 | 254 |
| Match-level reg. | Dependent variables | | | | |
| Time | Time in a match (min) | 149.759 | 50.186 | 15 | 353 |
| TGames | Total games in a match | 35.059 | 10.017 | 2 | 81 |
| Total points | Total points in a match | 220.464 | 66.593 | 10 | 499 |
| Binomial logistic reg. | Dependent variables | | | | |
| DWin | Player wins (yes 1; otherwise 0) | 0.5 | 0.50008 | 0 | 1 |
| Independent variables | | | | | |
| PRIZES* | Prize spread awarded between this and next round in a tournament | 54.253 | 132.668 | 11.894 | 2300 |
| AHET | Absolute value of difference between favorites and underdogs in ATP ranking | 68.593 | 84.108 | 1 | 1063 |
| Rank | Player's ATP ranking | 65.990 | 78.917 | 1 | 1098 |
| Favorites | Players with a smaller rank number than their opponent (yes 1; otherwise 0) | 0.500 | 0.500 | 0 | 1 |
| Favorite_rd | Intersection of Favorites and AHET | 34.161 | 67.835 | 0 | 1063 |
| Play | Right-hand player (yes 1; otherwise 0) | 0.869 | 0.337 | 0 | 1 |
| Tenure | Player's tenure | 10.129 | 3.218 | 0 | 18 |
| Age | Player's age | 26.594 | 3.325 | 17 | 36 |
| Height | Player's height (cm) | 186.309 | 7.005 | 156 | 211 |
| Weight | Player's weight (kg) | 80.424 | 7.457 | 64 | 108 |
| bmi | | 23.144 | 1.313 | 19.945 | 26.846 |
| bmi_2 | | 537.364 | 60.741 | 397.787 | 720.727 |
| Star | Dummy of no. 1 player in ATP ranking before the tournament (yes 1; otherwise 0) | 0.075 | 0.264 | 0 | 1 |
| Round | Round number | 6.055 | 1.27 | 1 | 7 |
| Rolandgarros | Dummy of Roland Garros (yes 1; otherwise 0) | 0.25 | 0 .433 | 0 | 1 |
| Wimbledon | Dummy of Wimbledon (yes 1; otherwise 0) | 0.25 | 0.433 | 0 | 1 |
| US | Dummy of US (yes 1; otherwise 0) | 0.25 | 0.433 | 0 | 1 |
| year_2012 | Dummy of year 2012 (yes 1; otherwise 0) | 0.333 | 0.471 | 0 | 1 |
| year_2013 | Dummy of 2013 (yes 1; otherwise 0) | 0.333 | 0.471 | 0 | 1 |
| DiffTenure | Absolute value of tenure difference between players | 3.676 | 2.815 | 0 | 16 |
| DiffHeight | Absolute value of height difference between players | 7.786 | 6.361 | 0 | 36 |
| DiffWeight | Absolute value of weight difference between players | 8.313 | 6.797 | 0 | 40 |
| DiffAge | Absolute value of age difference between players | 3.816 | 3.138 | 0 | 34 |
| BP | Better known opponents (Sunde 2009) | 0.542 | 0.498 | 0 | 1 |
| Favorites_IGames | Intersection of Favorites and IGames | 7.74 | 9.098 | 0 | 39 |
| Favorites_IPoints | Intersection of Favorites and IPoints | 52.087 | 58.384 | 0 | 233 |
| LoserPrize[a] | Prize awarded to loser | 61.739 | 115.535 | 18.615 | 1450 |

**Notes:** The unit is one thousand dollar.

**Source:** Author's calculations.

The largest relative strength of the contestants (i.e. rank differential) at the outset of the match was 1,063, and it took place at the second round of US Open 2012.

The 31st seeded Julien Benneteau (rank 35) was up against American wild-card entrant Dennis Novikov (rank 1,098). Novikov won 6-2, 7-6, 3-6, 6-3 to make it to the second round of his first ever Grand Slam, but lost the second round to Benneteau for 6-3, 4-6, 6-7, 5-7 with 170 minutes in the match.

Proposition 1 indicates that both underdogs and favorites try harder when the absolute value of rank difference is reduced, and less when it gets larger. Therefore, in Equation (10) the estimates of $\beta_1$ should be negative. As to the investigation of tournament theory, higher prize spread should lead to high scores; hence, estimates of $\beta_2$ should be positive.

Furthermore, the contamination hypothesis suggests that both players are less performing in highly uneven matches because they exert less effort when they have unequal chances of winning. However, the capability hypothesis stresses that larger heterogeneity leads *ceteris paribus* the favorite to perform better and to win more games, and the underdog to win fewer games since his inferior ability reduces his winning probability. Therefore, for the expectation of the intersection term *Favorites_rd*, the estimates of $\beta_4$ should be negative if the contamination hypothesis is supported, and it should be positive if the capability hypothesis is supported.

*Favorites* are high-ability players and they have higher winning probability. In Equation (11), the coefficient of *Favorites* ($\gamma_1$) is expected to have a positive relationship with winning probability. Players' heterogeneity increase a favorite's winning probability, so $\gamma_4$ is expected positively related to winning probability.

## 3. Empirical Results

The empirical results of Equation (10) for pooled ordinary least squares (OLS) and panel regressions are included in Table 2. In models 1 to 3, the $\chi^2$ values of the Breusch-Pagan (B-P) test (102.38 in model 1) reject the null hypothesis of homoscedasticity. Therefore, a robust regression using iteratively reweighted least squares (WLS) is employed in the following estimations. Moreover, in models 4 to 6, unobserved individual-specific heterogeneity for players is considered in the regressions. In model 4, the Breusch and Pagan Lagrangian multiplier (LM) test (6.03) rejects the null hypothesis of the absence of an unobserved effect, and the Jerry A. Hausman (1978) test (124.87) rejects the null hypothesis that the difference in coefficients is not systematic. The fixed effects (FE) model is supported.

The parameters of the *AHET* are of most interest for this study. In Table 2, all parameters on the *AHET* metrics are significant and correctly signed in the regressions. For example, in model 4, absolute value of difference between favorites and underdogs in ATP ranking (*AHET*) is significantly negatively related to number of games won by player *i* in a match. The evidence here indicates that players try harder when the absolute value of rank difference is reduced, and less when it gets larger. The finding confirms Proposition 1. The effects are consistent in the regressions of WLS and fixed-effects model.

As to testing the tournament theory, the coefficients of *PRIZES* are positively significant in the WLS and fixed-effects model regressions. The effect of the prize spread awarded between this and next round (*PRIZES*) is positively related to games won by players. Large prize spread incentives more players' efforts in a match, and this supports the tournament theory.

**Table 2** Estimation Results of OLS and Panel Analyses

| Dependent variable: games won by an individual player | | | | | | |
|---|---|---|---|---|---|---|
| | **Model 1** | **Model 2** | **Model 3** | **Model 4** | **Model 5** | **Model 6** |
| PRIZES/1,000 | 2.07* | 2.00* | 1.96 | 3.56*** | 3.52*** | 3.67*** |
| | (1.20) | (1.20) | (1.19) | (1.19) | (1.19) | (1.19) |
| AHET | -0.0064** | -0.0064** | -0.0061** | -0.0085*** | -0.0084*** | -0.0084*** |
| | (0.0025) | (0.0025) | (0.0025) | (0.0026) | (0.0026) | (0.0026) |
| Favorites | 3.64*** | 3.64*** | 3.64*** | 2.91*** | 2.90*** | 2.90*** |
| | (0.30) | (0.30) | (0.30) | (0.33) | (0.33) | (0.33) |
| Favorite_rd | 0.0055* | 0.0055* | 0.0054* | 0.0071** | 0.0068** | 0.0067** |
| | (0.0029) | (0.0029) | (0.0029) | (0.0032) | (0.0032) | (0.0032) |
| Play | 0.59* | 0.61* | 0.58* | - | - | - [b] |
| | (0.35) | (0.35) | (0.35) | | | |
| Tenure | 0.039 | 0.065 | 0.062 | 0.15 | 0.46 | 1.07** |
| | (0.080) | (0.081) | (0.081) | (0.27) | (0.30) | (0.49) |
| Age | -0.093 | -0.12 | -0.12 | -0.043 | -0.37 | -0.12 |
| | (0.074) | (0.076) | (0.076) | (0.24) | (0.29) | (0.32) |
| bmi | -5.93** | -5.93** | -5.81** | 9.07 | 10.3 | 5.53 |
| | (2.65) | (2.65) | (2.64) | (19.2) | (19.2) | (19.5) |
| bmi_2 | 0.13** | 0.13** | 0.13** | -0.23 | -0.25 | -0.15 |
| | (0.057) | (0.057) | (0.057) | (0.41) | (0.41) | (0.42) |
| Star | 0.52 | 0.49 | 0.48 | -0.26 | -0.34 | -0.37 |
| | (0.40) | (0.41) | (0.41) | (1.32) | (1.32) | (1.32) |
| Round | 0.19 | 0.19 | 0.19 | 0.68*** | 0.69*** | 0.70*** |
| | (0.13) | (0.13) | (0.13) | (0.14) | (0.14) | (0.14) |
| Rolandgarros | | 0.25 | 0.25 | | 0.35 | 0.25 |
| | | (0.31) | (0.31) | | (0.33) | (0.34) |
| Wimbledon | | 0.58* | 0.58* | | 0.69* | 0.54 |
| | | (0.31) | (0.31) | | (0.37) | (0.38) |
| US | | 0.86*** | 0.85*** | | 0.95*** | 0.84** |
| | | (0.31) | (0.31) | | (0.34) | (0.34) |
| Constant | 82.3*** | 82.3*** | 80.5*** | -77.1 | -84.5 | -43.4 |
| | (30.6) | (30.6) | (30.5) | (222) | (222) | (224) |
| Tournament dummies | No | Yes | Yes | No | Yes | Yes |
| Year dummies | No | No | Yes | No | No | Yes |
| *N* | 3,017 | 3,017 | 3,017 | 2,998 | 2,998 | 2,998 |
| $R^2$ | 0.115 | 0.118 | 0.121 | 0.1160 | 0.1190 | 0.1220 |
| Breusch-Pagan test | 102.38*** | 96.97*** | 91.74*** | | | |
| LM test | | | | 6.03*** | 6.23*** | 5.88*** |
| Hausman test | | | | 124.87*** | 155.08*** | 178.43*** |
| Number of id | | | | 238 | 238 | 238 |

**Notes:** Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Time-invariant variables are dropped in the regressions of fixed-effects model.

**Source:** Author's calculations.

As for the coefficients of *Favorites_rd*, it is significant and positively related to the games won by the players, and the effects are consistent in all regressions. Favorite players perform better and win more games as the rank differential increases *ceteris paribus*, and the capability hypothesis is supported. However, the effects are not significantly related to the points won by the players in Table 3.

Concerning the effects of the player's characteristics and information of matches, the coefficients of *Play* (+), *bmi* (-), *Round* (+), *Star* (-), *Wimbledon* (+), and *US* (+) are significant. A right-hand player wins additional 0.58 to 0.61 games, and a lower-BMI player wins more games in a match. A match near final rounds induces more games, and a player, on average, won additional 0.68 to 0.70 games when he gets into the next round. Compared with Australian Open tournaments, a player, on average, won additional 0.69 games in Wimbledon tournaments and won additional 0.84 to 0.95 games in US Open tournaments. Finally, the results show that the presence of a superstar (the no. 1 player in the world) makes his opponent performance worse. In line with the evidence of a negative superstar effect on his opponent performance as found by Brown (2011) and Tanaka and Ishino (2012), this article found evidence for a negative superstar effect on individual performance.

**Table 3** Estimation Results of OLS and Panel Analyses

| Dependent variable: points won by an individual player | | | | | | |
|---|---|---|---|---|---|---|
| | **Model 1** | **Model 2** | **Model 3** | **Model 4** | **Model 5** | **Model 6** |
| PRIZES/1,000 | 21.3*** | 21.2*** | 20.6*** | 27.9*** | 27.9*** | 28.8*** |
| | (6.91) | (6.97) | (6.91) | (6.93) | (6.94) | (6.94) |
| AHET | -0.031** | -0.032** | -0.030** | -0.040*** | -0.039** | -0.039*** |
| | (0.014) | (0.014) | (0.014) | (0.015) | (0.015) | (0.015) |
| Favorites | 11.4*** | 11.4*** | 11.4*** | 10.9*** | 10.9*** | 10.9*** |
| | (1.75) | (1.75) | (1.74) | (1.90) | (1.90) | (1.90) |
| Favorite_rd | 0.020 | 0.020 | 0.019 | 0.028 | 0.027 | 0.027 |
| | (0.017) | (0.017) | (0.017) | (0.019) | (0.019) | (0.019) |
| Play | 1.36 | 1.43 | 1.27 | - | - | -[b] |
| | (2.03) | (2.02) | (2.02) | | | |
| Tenure | -0.32 | -0.23 | -0.26 | 1.23 | 2.27 | 5.34* |
| | (0.46) | (0.46) | (0.46) | (1.55) | (1.75) | (2.88) |
| Age | 0.042 | -0.048 | -0.062 | -0.097 | -1.19 | 0.093 |
| | (0.42) | (0.43) | (0.43) | (1.42) | (1.66) | (1.89) |
| bmi | -20.2 | -20.3 | -19.5 | 96.3 | 98.8 | 74.8 |
| | (15.3) | (15.3) | (15.3) | (112) | (112) | (113) |
| bmi_2 | 0.45 | 0.45 | 0.43 | -2.21 | -2.27 | -1.74 |
| | (0.33) | (0.33) | (0.33) | (2.41) | (2.41) | (2.45) |
| Star | -4.14 | -4.34* | -4.32* | -2.82 | -3.34 | -3.55 |
| | (2.52) | (2.53) | (2.53) | (7.68) | (7.70) | (7.70) |
| Round | 1.08 | 1.10 | 1.04 | 1.58* | 1.60* | 1.66** |
| | (0.73) | (0.73) | (0.74) | (0.83) | (0.83) | (0.83) |
| Rolandgarros | | 1.57 | 1.53 | | 1.96 | 1.43 |
| | | (1.80) | (1.80) | | (1.95) | (1.98) |
| Wimbledon | | 2.09 | 2.07 | | 2.52 | 1.74 |
| | | (1.82) | (1.82) | | (2.13) | (2.20) |
| US | | 1.55 | 1.55 | | 2.12 | 1.55 |
| | | (1.79) | (1.79) | | (1.97) | (2.01) |
| Constant | 328* | 329* | 317* | -995 | -962 | -757 |
| | (177) | (177) | (177) | (1,293) | (1,293) | (1,304) |
| Tournament dummies | No | Yes | Yes | No | Yes | Yes |
| Year dummies | No | No | Yes | No | No | Yes |
| *N* | 3,017 | 3,017 | 3,017 | 2,998 | 2,998 | 2,998 |
| $R^2$ | 0.039 | 0.039 | 0.043 | 0.038 | 0.039 | 0.0427 |
| Breusch-Pagan test | 26.64*** | 26.75*** | 19.39*** | | | |
| LM test | | | | 5.12** | 5.19** | 5.05** |
| Hausman test | | | | 40.01*** | 43.76*** | 50.12*** |
| Number of id | | | | 238 | 238 | 238 |

**Notes:** Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Time-invariant variables are dropped in the regressions of fixed-effects model.

**Source:** Author's calculations.

To check the robustness of the evidence, total number of points (*IPoints*) won by player *i*, which is used to proxy for player efforts is used in the regressions. The results for the WLS and fixed-effects regressions are presented in Table 3. All of the signs of the *PRIZES*, *AHET*, and *Favorites* are consistent with the results in Table 2. All of these results reinforce previous findings. Proposition 1 and tournament theory are fully supported.

In addition to use total number of games (*IGames*) and total number of points (*IPoints*) won by a player *i* as the proxy of efforts in the individual-level analysis, the match-level analysis uses time in a match (*Time*), total games in a match (*TGames*), and total points in a match (*TPoints*) as the proxy of efforts. The results of prize spread and heterogeneity effects on match-level efforts are presented in Table 4.

**Table 4** Estimation Results of OLS and Panel Analyses

| Dependent variable: total time (min) played during a match | | | | | | |
|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
| PRIZES/1,000 | 53.5*** | 53.6*** | 57.0*** | 45.0*** | 44.2*** | 46.8*** |
| | (16.7) | (17.0) | (16.8) | (13.4) | (13.4) | (13.3) |
| AHET | -0.030* | -0.033* | -0.032* | -0.058*** | -0.061*** | -0.059*** |
| | (0.017) | (0.017) | (0.017) | (0.019) | (0.019) | (0.019) |
| DTenure | 0.60 | 0.33 | 0.46 | 0.75 | 0.62 | 0.66 |
| | (0.83) | (0.84) | (0.83) | (0.89) | (0.89) | (0.88) |
| DiffAge | -0.44 | -0.40 | -0.41 | -0.27 | -0.32 | -0.27 |
| | (0.65) | (0.63) | (0.61) | (0.65) | (0.65) | (0.64) |
| DiffHeight | -0.094 | -0.095 | -0.090 | -0.19 | -0.16 | -0.15 |
| | (0.25) | (0.25) | (0.25) | (0.30) | (0.30) | (0.30) |
| DiffWeight | 0.022 | 0.021 | 0.0044 | 0.28 | 0.26 | 0.26 |
| | (0.25) | (0.25) | (0.24) | (0.28) | (0.28) | (0.28) |
| BP | -1.22 | -2.88 | -2.42 | - | - | -[b] |
| | (4.25) | (4.28) | (4.27) | | | |
| Star | -20.8*** | -22.0*** | -22.5*** | -2.80 | -4.65 | -4.85 |
| | (4.12) | (4.11) | (4.11) | (11.4) | (11.4) | (11.4) |
| Round | -2.87* | -2.93* | -2.77* | - | - | -[b] |
| | (1.57) | (1.56) | (1.56) | | | |
| Rolandgarros | | 2.57 | 2.58 | -7.16*** | -7.25*** | -7.16*** |
| | | (3.68) | (3.66) | (1.59) | (1.58) | (1.57) |
| Wimbledon | | 5.12 | 5.20 | | -2.29 | -2.41 |
| | | (3.67) | (3.65) | | (3.68) | (3.65) |
| US | | -10.1*** | -10.1*** | | 2.47 | 2.49 |
| | | (3.49) | (3.46) | | (3.70) | (3.67) |
| Constant | 169*** | 172*** | 168*** | 194*** | 199*** | 194*** |
| | (11.3) | (11.6) | (11.6) | (11.5) | (11.7) | (11.8) |
| Tournament dummies | No | Yes | Yes | No | Yes | Yes |
| Year dummies | No | No | Yes | No | No | Yes |
| *N* | 1,501 | 1,501 | 1,501 | 1498 | 1498 | 1498 |
| $R^2$ | 0.047 | 0.060 | 0.074 | 0.0385 | 0.0515 | 0.0647 |
| Breusch-Pagan test | 3.12* | 5.56** | 8.61*** | | | |
| LM test | | | | 30.73*** | 27.72*** | 32.22*** |
| Hausman test | | | | 24.90*** | 29.22*** | 30.71*** |
| Number of id | | | | 180 | 180 | 180 |

**Notes:** Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Time-invariant variables are dropped in the regressions of fixed-effects model.

**Source:** Author's calculations.

In models 1 to 3, the $\chi^2$ values of the B-P test (3.12 in model 1) rejects the null hypothesis of homoscedasticity. Therefore, a robust regression using iteratively WLS is used in the estimations. Moreover, in models 4 to 6, unobserved individual-specific heterogeneity for players is considered in the regressions. For example, in model 4, the Breusch and Pagan LM test (30.73) rejects the null hypothesis of the absence of an unobserved effect, and the Hausman (1978) test (24.90) rejects the null hypothesis that the difference in coefficients is not systematic. The fixed effects (FE) model is supported.

In Table 4, all parameters on the *AHET* metrics are significant and negatively signed in the regressions. The evidence here indicates that players try harder when the absolute value of rank difference is reduced, and less when it gets larger. The finding reinforces Proposition 1. The results of estimations for total games in a match (*TGames*) and total points in a match (*TPoints*) are included in Tables A and B of the Appendix. These findings reinforce Proposition 1 and tournament theory. As to testing the tournament theory, all coefficients of *PRIZES* are positively significant in the WLS and fixed-effects model regressions. The effect of the prize spread awarded between this and next round (*PRIZES*) is positively related to time in a match, and this supports the tournament theory. Take model 6 as an example, one million increases in *PRIZES* induces additional 46.8 minutes in a match, and one decrease in rank difference (*AHET*) increases additional 0.06 minutes. These effects are consistent in the regressions of WLS and fixed-effects model. Finally, the results show that the presence of a superstar (the no. 1 player in the world) makes his opponent less effort, whereas Brown (2011) documents that the presence of a high-ability player (Tiger Woods) is associated with reduced efforts. This part of the evidence echoes Brown's (2011) findings.

## 3.1 Odds of Winning in Random-Effects Logistic Model

In the second part of the empirical analysis, the estimation results of Equation (11) for player's heterogeneity on performance in the Grand Slam matches are presented in Tables 5 and 6. Table 5 reports binomial logistic estimates in which the dependent variable *DWin* takes the value 1 when a player wins match *j* in tournament *k*. Moreover, in Table 6, unobserved individual-specific heterogeneity for players is considered in the regressions. Take model 1 as an example, the likelihood-ratio (LR) test (517.49) rejects the null hypothesis of panel-level variance component is unimportant. The random-effects logistic model is supported.

The parameters of the *Favorite_rd* are of most interest for this part of empirical investigation. In Table 6, all coefficients on the *Favorites* and *Favorite_rd* are significant and positively signed in the regressions. The evidence here indicates that favorite players increase their winning probability in the match, and the favorites' winning probability increases when the rank differential increases. For example, in model 1, on average, a favorite player gets 5.001% more than an underdog. Moreover, a one ATP rank difference increases, a favorite player additional 1.004% winning possibility *ceteris paribus*. The effects are consistent in the regressions of pooled logistic and random-effects logistic models.

Concerning to the effects of the other control variables, the coefficients of *Play* (+), *Tenure* (+), *Age* (-), *bmi* (-), *Star* (+), and *Round* (+) are significant. A young, experienced, low-bmi, and right-hand player is more likely to win. Finally, a star player increases additional 3.804% winning probability in a match, and getting into next round games increases 1.34% winning probability, *ceteris paribus*.

**Table 5** Binomial Logistic Regressions: Odds of Winning

| Dependent variable: dummy of win (win 1; otherwise 0) | Model 1 | Odds ratio | Model 2 | Odds ratio | Model 3 | Odds ratio |
|---|---|---|---|---|---|---|
| Favorites | 1.78*** (0.11) | 5.950 | 1.78*** (0.11) | 5.949 | 1.78*** (0.11) | 5.948 |
| PRIZES/1,000 | -0.33 (0.96) | .722 | -0.31 (0.96) | .731 | -0.28 (0.96) | .753 |
| LoserPrize | -0.000075 (0.0012) | 1 | -0.000098 (0.0012) | 1 | -0.00017 (0.0012) | 1 |
| AHET | -0.0021** (0.00093) | .998 | -0.0021** (0.00093) | .998 | -0.0021** (0.00093) | .998 |
| Favorite_rd | 0.0037*** (0.0012) | 1.004 | 0.0037*** (0.0012) | 1.004 | 0.0037*** (0.0012) | 1.004 |
| Play | 0.30** (0.13) | 1.345 | 0.30** (0.13) | 1.347 | 0.30** (0.13) | 1.345 |
| Tenure | 0.096*** (0.030) | 1.101 | 0.099*** (0.031) | 1.104 | 0.098*** (0.031) | 1.103 |
| Age | -0.11*** (0.028) | .892 | -0.12*** (0.029) | .889 | -0.12*** (0.029) | .889 |
| bmi | -1.51 (1.01) | .221 | -1.51 (1.01) | .221 | -1.50 (1.01) | .222 |
| bmi_2 | 0.034 (0.022) | 1.035 | 0.034 (0.022) | 1.035 | 0.034 (0.022) | 1.034 |
| Star | 1.11*** (0.21) | 3.022 | 1.10*** (0.21) | 3.007 | 1.11*** (0.21) | 3.028 |
| Round | 0.080 (0.052) | 1.083 | 0.080 (0.052) | 1.083 | 0.077 (0.052) | 1.080 |
| Rolandgarros | | | 0.045 (0.12) | 1.046 | 0.044 (0.12) | 1.045 |
| Wimbledon | | | 0.061 (0.12) | 1.063 | 0.061 (0.12) | 1.062 |
| US | | | 0.063 (0.12) | 1.065 | 0.063 (0.12) | 1.065 |
| Constant | 17.1 (11.6) | | 17.1 (11.6) | | 17.1 (11.7) | |
| Tournament dummies | No | | Yes | | Yes | |
| Year dummies | No | | No | | Yes | |
| *N* | 3,029 | | 3,029 | | 3,029 | |
| Pseudo $R^2$ | 0.1974 | | 0.1975 | | 0.1975 | |
| Log likelihood | -1685.083 | | -1684.9051 | | -1684.7936 | |
| LR chi2 test | 828.88*** | | 829.24 *** | | 829.46*** | |

**Notes:** Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

**Source:** Author's calculations.

In this study, the policy implications of heterogeneous tournaments are twofold. First, for the impact of heterogeneity on behavior in tournaments, taking the estimation result in model 4 of Table 2 as an example, a one rank differential decreases the number of games by 0.0085. The change in efforts from the largest rank differential to the smallest rank differential in advance in our sample would result in a loss of over 9 games (-0.0085*1,062) in a match. That is, underdogs will shy away from competition, as the chances of winning are comparably low. Favorite players will anticipate this reduction in costly effort and decide to hold back effort as well. As a result, overall efforts fall and hence the intensity of the tournament decreases. This suggests that an administrator could have a basis for imposing rules which seek to achieve balanced competition between two players in a match.

**Table 6** Random-Effects Logistic Regressions: Odds of Winning

| Dependent variable: dummy of win (win 1; otherwise 0) | | | | | | |
|---|---|---|---|---|---|---|
| | **Model1** | **Odds ratio** | **Model2** | **Odds ratio** | **Model3** | **Odds ratio** |
| Favorites | 1.61*** (0.43) | 5.001 | 1.61*** (0.13) | 4.994 | 1.61*** (0.13) | 4.992 |
| PRIZES/1,000 | -0.32 (0.94) | 0.723 | -0.30 (0.94) | 0.737 | -0.29 (0.95) | 0.748 |
| LoserPrize | -0.00027 (0.0012) | 1 | -0.00031 (0.0012) | 1 | -0.00035 (0.0012) | 1 |
| AHET | -0.0025** (0.00099) | 0.997 | -0.0025** (0.00099) | 0.997 | -0.0025** (0.00099) | 0.997 |
| Favorite_rd | 0.0039*** (0.0013) | 1.004 | 0.0039*** (0.0013) | 1.004 | 0.0039*** (0.0013) | 1.004 |
| Play | 0.29 (0.19) | 1.336 | 0.29 (0.19) | 1.339 | 0.29 (0.19) | 1.337 |
| Tenure | 0.11*** (0.041) | 1.120 | 0.12*** (0.043) | 1.128 | 0.12*** (0.043) | 1.127 |
| Age | -0.12*** (0.039) | 0.889 | -0.12*** (0.040) | 0.883 | -0.12*** (0.040) | 0.883 |
| bmi | -2.63* (1.52) | 0.072 | -2.61* (1.52) | 0.073 | -2.61* (1.52) | 0.074 |
| bmi_2 | 0.058* (0.033) | 1.060 | 0.057* (0.033) | 1.059 | 0.057 (0.033) | 1.059 |
| Star | 1.34*** (0.33) | 3.804 | 1.32*** (0.33) | 3.754 | 1.33*** (0.33) | 3.783 |
| Round | 0.29*** (0.064) | 1.340 | 0.29*** (0.064) | 1.342 | 0.29*** (0.065) | 1.339 |
| Rolandgarros | | | 0.057 (0.13) | 1.059 | 0.057 (0.13) | 1.059 |
| Wimbledon | | | 0.097 (0.13) | 1.102 | 0.097 (0.13) | 1.101 |
| US | | | 0.10 (0.13) | 1.107 | 0.10 (0.13) | 1.107 |
| Constant | 28.7* (17.4) | | 28.6 (17.4) | | 28.6 (17.4) | |
| Tournament dummies | No | | Yes | | Yes | |
| Year dummies | No | | No | | Yes | |
| *N* | 3,010 | | 3,010 | | 3,010 | |
| Number of id | 238 | | 238 | | 238 | |
| Log likelihood | -1649.2129 | | -1648.8046 | | -1648.7001 | |
| LR chi2 test ($H_0$: $\rho = 0$) | 517.49*** | | 517.53*** | | 517.77*** | |

**Notes:** Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

**Source:** Author's calculations.

Second, for the incentive effects in tournament theory, taking the estimation result in model 4 of Table 2 as an example, a one million US dollar increase in prize spread increases the number of games by 3.56. This shows that the prize is the best incentives for the professional tennis players. In sum, our findings have significant practical implications for designing a tournament reward structure. Organizations should consider not only the prize spread, but also actual level of heterogeneity in abilities of tournament participants.

## 4. Conclusions

This study incorporated a theoretical model which is based on the study of Lazear and Rosen (1981) and Kräkel and Sliwka (2004) which explain the contamination hypothesis. We contribute to the existing literature by empirically investigating the impact of heterogeneity on behavior in tournaments. Overall, the empirical results are in line with the theory. The contamination hypothesis (i.e. Proposition 1) and tournament theory are fully supported in both player-level and matches-level analyses. Players try harder when their heterogeneity degree gets smaller, and when prize spread awarded between this and next round gets larger. In the second part of the empirical analysis, we found that favorites have higher winning probability, and a favorite player gets additional 1.004% winning possibility as ATP ranking difference increases, *ceteris paribus*. The evidence provides better understanding of the effects of heterogeneity in the players' ability on individual efforts and performance for professional sporting competition.

In sports, the main purpose of tournaments is to find out the best player or team in the respective field. Besides inducing incentives for the athletes to give their best, organizers of sports events desire to attract spectators. The outcome uncertainty hypothesis (Simon Rottenberg 1956) had indicated that attendance is usually high if the match is close and intense, which can be expected if the contestants are homogeneous. Therefore, the policy implication indicates that handicapping helps to ensure a game uncertainty and the better box office receipts. Besides, an employer can, for example, match employees with equal tenure, educational background, job profiles, or position. If matching employees is impossible, you can consider handicapping the more able contestant at least (Lazear and Rosen 1981).

Our study has a limitation which presents opportunity for future research. We only examine one type of contestant heterogeneity (CH) which measured by player's ATP ranking. Someone may concern that the difference in quality may not be correctly accounted *via* ranking difference. Future research could try other measures of CH and examine the effect. Despite the limitation, we believe our study makes a contribution to the literature on tournament incentives and factors that correlated with tournament incentive design choices.

## References

**Alchian, Armen A.** 1988. "Promotions, Elections and Other Contests: Comment." *Journal of Institutional and Theoretical Economics*, 144(1): 91-93.

**Bach, Norbert, Oliver Gürtler, and Joachim Prinz.** 2009. "Incentive Effects in Tournaments with Heterogeneous Competitors - An Analysis of the Olympic Rowing Regatta in Sydney 2000." *Management Revue*, 20(3): 239-253. http://dx.doi.org/10.5771/0935-9915-2009-3-239

**Baik, Kyung Hwan.** 1994. "Effort Levels in Contests with Two Asymmetric Players." *Southern Economic Journal*, 61(2): 367-378. http://dx.doi.org/10.2307/1059984

**Brown, Jennifer.** 2011. "Quitters Never Win: The (Adverse) Incentive Effects of Competing with Super Stars." *Journal of Political Economy*, 119(5): 928-1013. http://dx.doi.org/10.1086/663306

**Bull, Clive, Andrew Schotter, and Keith Weigelt.** 1987. "Tournaments and Piece Rates: An Experimental Study." *Journal of Political Economy*, 95(1): 1-33. http://dx.doi.org/10.1086/261439

**Cross, Rod, and Graham Pollard.** 2009. "Grand Slam Men's Single Tennis 1991-2009: Serve Speeds and Other Related Data." *International Tennis Federation Coaching and Sport Science Review*, 16: 8-10.

**Ehrenberg, Ronald Gordon, and Michael Bognanno.** 1990. "Do Tournaments Have Incentive Effects?" *Journal of Political Economy*, 98(6): 1307-1324. http://dx.doi.org/10.1086/261736

**Frick, Bernd, Joachim Prinz, and Karina Winkelmann.** 2003. "Pay Inequalities and Team Performance: Empirical Evidence from the North American Major Leagues." *International Journal of Manpower*, 24(4): 472-488. http://dx.doi.org/10.1108/01437720310485942

**Garratt, Rodney, Catherine Weinberger, and Nick Johnson.** 2013. "The State Street Mile: Age and Gender Differences in Competition Aversion in the Field." *Economic Inquiry*, 51(1): 806-815. http://dx.doi.org/10.1111/j.1465-7295.2011.00370.x

**Gill, David, and Rebecca Stone.** 2010. "Fairness and Desert in Tournaments." *Games and Economic Behavior*, 69(2): 346-364. http://dx.doi.org/10.1016/j.geb.2010.01.002

**Gillet, Eric, David Leroy, Régis Thouvarecq, and Jean François Stein.** 2009. "A Notational Analysis of Elite Tennis Serve and Serve-Return Strategies on Slow Surface." *Journal of Strength and Conditioning Research*, 23(2): 532-539. http://dx.doi.org/10.1519/JSC.0b013e31818efe29

**Gilsdorf, Keith, and Vasant Sukhatme.** 2008. "Testing Rosen's Sequential Elimination Tournament Model Incentives and Player Performance in Professional Tennis." *Journal of Sports Economics*, 9(3): 287-303. http://dx.doi.org/10.1177/1527002507306790

**Gürtler, Oliver, and Matthias Kräkel.** 2010. "Optimal Tournament Contracts for Heterogeneous Workers." *Journal of Economic Behavior & Organization*, 75(2): 180-191. http://dx.doi.org/10.1016/j.jebo.2010.03.020

**Harbring, Christine, and Gabriele Lünser.** 2008. "On the Competition of Asymmetric Agents." *German Economic Review*, 9(3): 373-395. http://dx.doi.org/10.1111/j.1468-0475.2008.00438.x

**Hausman, Jerry A.** 1978. "Specification Tests in Econometrics." *Econometrica*, 46(6): 1251-1271. http://dx.doi.org/10.2307/1913827

**Koning, Ruud.** 2011. "Home Advantage in Professional Tennis." *Journal of Sports Sciences*, 29(1): 19-27. http://dx.doi.org/10.1080/02640414.2010.516762

**Konrad, Kai.** 2009. *Strategy and Dynamics in Contests*. Oxford: Oxford University Press. http://dx.doi.org/10.1111/j.1468-0335.2009.00841.x

**Kräkel, Matthias, and Dirk Sliwka.** 2004. "Risk Taking in Asymmetric Tournaments." *German Economic Review*, 5(1): 103-116. http://dx.doi.org/10.1111/j.1465-6485.2004.00096.x

**Krumer, Alex, Mosi Rosenboim, and Offer Moshe Shapir.** 2016. "Gender, Competitiveness, and Physical Characteristics Evidence from Professional Tennis." *Journal of Sports Economics*, 17(3): 234-259. http://dx.doi.org/10.1177/1527002514528516

**Lallemand, Thierry, Robert Plasman, and François Rycx.** 2008. "Women and Competition in Elimination Tournaments Evidence from Professional Tennis Data." *Journal of Sports Economics*, 9(1): 3-19. http://dx.doi.org/10.1177/1527002506296552

**Lazear, Edward, and Sherwin Rosen.** 1981. "Rank-Order Tournaments as Optimum Labor Contracts." *Journal of Political Economy*, 89(5): 841-864. http://dx.doi.org/10.3386/w0401

**Lynch, James.** 2005. "The Effort Effects of Prizes in the Second Half of Tournaments." *Journal of Economic Behavior & Organization*, 57(1): 115-129. http://dx.doi.org/10.1016/j.jebo.2003.10.005

**Maloney, Michael, and Robert McCormick.** 2000. "The Response of Workers to Wages in Tournaments: Evidence from Foot Races." *Journal of Sports Economics*, 1(2): 99-123. http://dx.doi.org/10.1177/152700250000100201

**Malueg, David, and Andrew Yates.** 2010. "Testing Contest Theory: Evidence from Best-of-Three Tennis Matches." *Review of Economics and Statistics*, 92(3): 689-692. http://dx.doi.org/10.1162/rest_a_00021

**Müller, Wieland, and Andrew Schotter.** 2010. "Workaholics and Dropouts in Organizations." *Journal of the European Economic Association*, 8(4): 717-743. http://dx.doi.org/10.1111/j.1542-4774.2010.tb00538.x

**O'Donoghue, Peter.** 2001. "The Most Important Points in Grand Slam Singles Tennis." *Research Quarterly for Exercise and Sport*, 72(2): 125-131. http://dx.doi.org/10.1080/02701367.2001.10608942

**Rosen, Sherwin.** 1986. "Prizes and Incentives in Elimination Tournaments." *American Economic Review*, 76(4): 701-715.

**Rottenberg, Simon.** 1956. "The Baseball Players' Labor Market." *Journal of Political Economy*, 64(3): 242-258. http://dx.doi.org/10.1086/257790

**Schotter, Andrew, and Keith Weigelt.** 1992. "Asymmetric Tournaments, Equal Opportunity Laws, and Affirmative Action: Some Experimental Results." *The Quarterly Journal of Economics*, 107(2): 511-539. http://dx.doi.org/10.2307/2118480

**Sheremeta, Roman.** 2011. "Contest Design: An Experimental Investigation." *Economic Inquiry*, 49(2): 573-590. http://dx.doi.org/10.1111/j.1465-7295.2009.00274.x

**Stein, William.** 2002. "Asymmetric Rent-Seeking with More than Two Contestants." *Public Choice*, 113(4): 325-336. http://dx.doi.org/10.1023/A:1020877410243

**Sunde, Uwe.** 2009. "Heterogeneity and Performance in Tournaments: A Test for Incentive Effects Using Professional Tennis Data." *Applied Economics*, 41(25): 3199-3208. http://dx.doi.org/10.1080/00036840802243789

**Szymanski, Stefan.** 2003. "The Economic Design of Sporting Contests." *Journal of Economic Literature*, 41(4): 1137-1187. http://dx.doi.org/10.1257/002205103771800004

**Tanaka, Ryuichi, and Kazutoshi Ishino.** 2012. "Testing the Incentive Effects in Tournaments with a Superstar." *Journal of the Japanese and International Economies*, 26(3): 393-404. http://dx.doi.org/10.1016/j.jjie.2012.05.001

**Van Dijk, Frans, Joep Sonnemans, and Frans van Winden.** 2001. "Incentive Systems in a Real Effort Experiment." *European Economic Review*, 45(2): 187-214. http://dx.doi.org/10.1016/S0014-2921(00)00056-8

**Weigelt, Keith, Janet Dukerich, and Andrew Schotter.** 1989. "Reactions to Discrimination in an Incentive Pay Compensation Scheme: A Game-Theoretic Approach." *Organizational Behavior and Human Decision Processes*, 44(1): 26-44. http://dx.doi.org/10.1016/0749-5978(89)90033-2

# Appendix

**Table A** Estimation Results of OLS and Panel Analyses

| Dependent variable: total number of sets played during a match | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
|---|---|---|---|---|---|---|
| PRIZES/1,000 | 0.49** | 0.48** | 0.49** | 0.40* | 0.38* | 0.39* |
| | (0.19) | (0.20) | (0.19) | (0.22) | (0.23) | (0.23) |
| AHET | -0.00046 | -0.00049* | -0.00045 | -0.00072** | -0.00075** | -0.00072** |
| | (0.00028) | (0.00029) | (0.00029) | (0.00032) | (0.00032) | (0.00032) |
| DTenure | 0.015 | 0.013 | 0.014 | 0.020 | 0.020 | 0.020 |
| | (0.014) | (0.014) | (0.014) | (0.015) | (0.015) | (0.015) |
| DiffAge | -0.0061 | -0.0061 | -0.0064 | -0.0036 | -0.0044 | -0.0041 |
| | (0.0097) | (0.0097) | (0.0096) | (0.011) | (0.011) | (0.011) |
| DiffHeight | -0.0019 | -0.0020 | -0.0020 | -0.0033 | -0.0033 | -0.0029 |
| | (0.0042) | (0.0042) | (0.0043) | (0.0050) | (0.0050) | (0.0050) |
| DiffWeight | 0.000035 | -0.000018 | -0.00016 | 0.0053 | 0.0053 | 0.0052 |
| | (0.0040) | (0.0040) | (0.0040) | (0.0048) | (0.0048) | (0.0048) |
| BP | 0.0074 | -0.0021 | -0.00077 | - | - | -[b] |
| | (0.073) | (0.074) | (0.073) | | | |
| Star | -0.34*** | -0.34*** | -0.35*** | 0.0017 | -0.012 | -0.042 |
| | (0.060) | (0.059) | (0.059) | (0.19) | (0.19) | (0.19) |
| Round | -0.00072 | -0.0017 | -0.0020 | - | - | -[b] |
| | (0.023) | (0.023) | (0.023) | | | |
| Rolandgarros | | 0.00064 | -0.00049 | -0.076*** | -0.077*** | -0.077*** |
| | | (0.060) | (0.060) | (0.027) | (0.027) | (0.027) |
| Wimbledon | | 0.056 | 0.056 | | -0.053 | -0.054 |
| | | (0.060) | (0.060) | | (0.062) | (0.062) |
| US | | -0.051 | -0.051 | | 0.045 | 0.046 |
| | | (0.060) | (0.060) | | (0.062) | (0.062) |
| Constant | 3.64*** | 3.66*** | 3.60*** | 4.03*** | 4.06*** | 3.99*** |
| | (0.17) | (0.17) | (0.18) | (0.19) | (0.20) | (0.20) |
| Tournament dummies | No | Yes | Yes | No | Yes | Yes |
| Year dummies | No | No | Yes | No | No | Yes |
| *N* | 1,501 | 1,501 | 1,501 | 1498 | 1498 | 1498 |
| $R^2$ | 0.021 | 0.024 | 0.028 | 0.0125 | 0.0153 | 0.0204 |
| Breusch-Pagan test | 7.48*** | 6.78*** | 7.58*** | | | |
| LM test | | | | 13.62*** | 13.83*** | 15.62*** |
| Hausman test | | | | 20.79** | 24.11** | 24.47** |
| Number of id | | | | 180 | 180 | 180 |

**Notes:** Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Time-invariant variables are dropped in the regressions of fixed-effects model.

**Source:** Author's calculations.

**Table B** Estimation Results of OLS and Panel Analyses

| Dependent variable: total number of games played during a match | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
|---|---|---|---|---|---|---|
| PRIZES/1,000 | 5.55** | 5.38** | 5.40** | 4.56* | 4.28 | 4.32 |
| | (2.65) | (2.70) | (2.67) | (2.71) | (2.71) | (2.71) |
| AHET | -0.0071** | -0.0073** | -0.0068* | -0.011*** | -0.012*** | -0.011*** |
| | (0.0035) | (0.0035) | (0.0035) | (0.0039) | (0.0039) | (0.0039) |
| DTenure | 0.12 | 0.13 | 0.13 | 0.11 | 0.14 | 0.14 |
| | (0.16) | (0.16) | (0.16) | (0.18) | (0.18) | (0.18) |
| DiffAge | -0.056 | -0.056 | -0.060 | -0.041 | -0.046 | -0.043 |
| | (0.11) | (0.11) | (0.11) | (0.13) | (0.13) | (0.13) |
| DiffHeight | 0.0050 | 0.0029 | 0.0034 | 0.0077 | 0.0014 | 0.0059 |
| | (0.051) | (0.051) | (0.051) | (0.061) | (0.061) | (0.060) |
| DiffWeight | 0.035 | 0.034 | 0.032 | 0.058 | 0.061 | 0.060 |
| | (0.051) | (0.051) | (0.051) | (0.057) | (0.057) | (0.057) |
| BP | -0.48 | -0.40 | -0.39 | - | - | -[b] |
| | (0.86) | (0.87) | (0.87) | | | |
| Star | -4.93*** | -4.95*** | -4.96*** | -0.37 | -0.51 | -0.92 |
| | (0.78) | (0.78) | (0.78) | (2.30) | (2.31) | (2.33) |
| Round | -0.14 | -0.15 | -0.16 | - | - | -[b] |
| | (0.29) | (0.29) | (0.29) | | | |
| Rolandgarros | | 0.61 | 0.60 | -1.16*** | -1.16*** | -1.16*** |
| | | (0.72) | (0.72) | (0.32) | (0.32) | (0.32) |
| Wimbledon | | 1.32* | 1.32* | | -0.17 | -0.19 |
| | | (0.71) | (0.71) | | (0.75) | (0.74) |
| US | | 1.48** | 1.48** | | 1.06 | 1.08 |
| | | (0.72) | (0.72) | | (0.75) | (0.75) |
| Constant | 36.4*** | 35.5*** | 34.8*** | 42.3*** | 41.7*** | 40.9*** |
| | (2.11) | (2.17) | (2.20) | (2.33) | (2.38) | (2.40) |
| Tournament dummies | No | Yes | Yes | No | Yes | Yes |
| Year dummies | No | No | Yes | No | No | Yes |
| *N* | 1,501 | 1,501 | 1,501 | 1498 | 1498 | 1498 |
| $R^2$ | 0.031 | 0.035 | 0.039 | 0.0177 | 0.0219 | 0.0269 |
| Breusch-Pagan test | 3.65* | 3.77* | 5.30** | | | |
| LM test | | | | 34.80*** | 34.79*** | 37.60*** |
| Hausman test | | | | 23.70*** | 28.07*** | 28.59** |
| Number of id | | | | 180 | 180 | 180 |

**Notes:** Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Time-invariant variables are dropped in the regressions of fixed-effects model.

**Source:** Author's calculations.