Are the Official World Golf Rankings Biased?*

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Abstract

Golf is a global sport with professional golfers playing on many organized tours throughout the world. The largest and most important tours for male professionals include the PGA Tour, European Tour, Japanese Tour and Asian Tour. The Official World Golf Ranking, or OWGR, is a system for ranking male professional golfers on a single scale. We say a ranking system is unbiased if otherwise identical golfers who happen to play on different tours have the same (or very similar) ranks. In this paper, we investigate whether the OWGR system is biased for or against any of the tours, and if so, by how much. To investigate any potential bias, we compare the OWGR system with two unbiased methods for estimating golfer skill and performance. The first is a score-based skill estimation (SBSE) method, which uses scoring data to estimate golfer skill, taking into account the relative difficulty of the course in each tournament round. The second is the Sagarin method, which uses win-lose-tie and scoring differential results for golfers playing in the same tournaments, to rank golfers. Neither the score-based skill method nor the Sagarin method use tour information in calculating player ranks, and therefore neither method is biased for or against any tour. Using data from 2002 to 2010 and comparing the results ranks from the OWGR and score-based methods, we find that PGA Tour golfers are penalized by an average of 26 to 37 OWGR ranking positions compared to non-PGA Tour golfers. Qualitatively similar results are found when comparing OWGR and Sagarin ranks. In all cases, the bias is large and statistically significant. We find a persistent bias through time and also find that the bias tends to be the largest for golfers with SBSE ranks between 40 and 120.

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1. Introduction

The Official World Golf Ranking (OWGR) is a system for ranking male professional golfers who play on a number of tours worldwide, including the PGA Tour, European Tour, Japanese Tour, and others. The rankings, updated and published on a weekly basis, allow golfers who play in different tournaments on different tours and continents to be ranked against each other on a single scale. Although we have been unable to find an official statement of purpose for the OWGR, the following statement by John Paul Newport (2012) best summarizes what we believe to be its main purpose:

> "the first thing to know about the OWGR is that its primary purpose is not to identify the world's No. 1, or even the top 10. It is to set the fields for golf's major championships and other big tournaments in a fair, transparent manner."

Consistent with Newport's statement, with minor exceptions, golfers in the OWGR top 50 are automatically eligible to play in major tournaments and World Golf Championships (WGC) events.[1] As an example, thirteen players qualified for the 2012 Masters based on their top-50 OWGRs who would have otherwise been ineligible.[2] The rankings also affect golfers' endorsement income, carry bragging rights, and are important to tournament sponsors who seek to attract the best golfers to their events.

We consider a ranking system to be *unbiased* if two otherwise identical golfers who happen to play on different tours have the same (or very similar) world rankings. That is, a ranking system is unbiased if a golfer is neither rewarded nor penalized because of the tour affiliation of the tournaments he plays. We investigate whether the OWGR system produces unbiased rankings.

Anecdotal evidence of bias in the rankings is often mentioned in the popular press. Examples include:

> "Ryo Ishikawa and Charl Schwartzel know the secret to becoming one of the top 50 players in the world ahead of their time: play on a foreign circuit." (Capelle, 2010)

> "Asian Tour and European Tour players benefit from full field (especially co-sanctioned) tournaments that lure in world class players with appearance fees. Their world rankings are inflated drastically on a continual basis." (Ballengee, 2009a)

> "[The change] doesn't address the self-perpetuating gaming of the system by European and Asian Tour events, or the preposterous notion of 'home tour ranking points.'" (Ballengee, 2009b)

[1] Among golf's majors and WGC events, The WGC Accenture Match Play Championship is the only event that bases eligibility strictly on OWGRs; only the top 64 players in the OWGR are eligible to participate. The PGA Championship is the only major that does not explicitly use OWGRs as a condition for eligibility. The remaining majors and WGC events employ various conditions for eligibility and then include "catch-all" categories based on OWGRs for players who would otherwise be ineligible. The catch-all category includes the top 50 in the OWGR for the Masters tournament and the (British) Open Championship and the top 60 for the US Open. The catch-all category for The WGC HSBC is the top 25 in the OWGR, and The WGC Cadillac Championship and WGC Bridgestone Invitational employ top-50 catch-all categories.

[2] See `www.masters.com/enUS/players/invitees_2012.html?promo=espn`, accessed May 3, 2012.

To date, though, there has not been a rigorous study of the OWGR system to determine whether it is biased and how significant any bias might be. In order to investigate the question of bias, we compare the OWGR system with two measures of player performance that do not use tour information. A major issue in measuring golf performance is the need to compare, on a single scale, golfers who might not have played together in tournament competition. Because golf course difficulty and conditions can vary tremendously, simply comparing scores is not sufficient. The problem arises because the scoring average of one golfer can be lower (i.e., better) than another, not because of superior skill, but because of playing on easier courses. The first performance measure that we use to compare with the OWGR employs a standard fixed effects statistical model applied to 18-hole scores to estimate golfer skill while eliminating the effects of varying course and round difficulty. Golfers from one tour can be statistically connected to golfers on other tours because there is a significant subset of golfers playing tournaments on more than one tour. This approach, which we term score-based skill estimation (SBSE), does not favor one tour over another, because no tour information is used in the procedure.

Using scoring data from 2002-2010, we compare score-based skill ranks with OWGR ranks of the same golfers and investigate whether there are systematic discrepancies by tour. We find that PGA Tour golfers are penalized by an average of 26 to 37 OWGR ranking positions compared to non-PGA Tour golfers. The differences depend on whether the comparison is made at the end of the year or in the middle of the year. (Note that *we are not proposing* the score-based skill method as an alternative world golf ranking system, since there are many issues not addressed by this method, including, for example, how to weight more recent performance versus older results.)

We also compare the OWGR rankings to Sagarin golf rankings. The Sagarin method uses win-lose-tie and scoring differential results for golfers playing in the same tournaments to rank golfers. The exact algorithm for producing the Sagarin rankings is proprietary, but the method does not use tour information in calculating ranks and therefore does not favor one tour over another. We then compare OWGR and Sagarin ranks and find that PGA Tour golfers are penalized by an average of 16 to 20 OWGR ranking positions relative to non-PGA Tour golfers.

By comparing the OWGR results with those of two alternative methods that do not use tour information, we find that the OWGR method is biased against PGA Tour golfers and that the bias is statistically significant and large. In the remainder of the paper we provide details of our methodology and results.

2. How the OWGR Works

The OWGR awards points to participants in all majors, WGC events, and regular events on the tours of the six members of the International Federation of PGA Tours, which includes the PGA Tour, European Tour, Asian Tour, PGA Tour of Australasia, Japan Golf Tour, and Sunshine Tour (South Africa). In addition, points are awarded for high finishes on the Canadian Tour, OneAsia Tour, Nationwide Tour (developmental Tour of the PGA Tour), Challenge Tour (developmental

tour of the European Tour), Korean Tour and Tour de las Americas.

We begin with the majors. The winner of each major is awarded 100 OWGR points. All players who make the cut are awarded points, but on a declining basis, depending upon their finishing positions. For example, points for second through fifth place are 60, 40, 30, and 24, respectively. Those finishing near the bottom among the players who make the cut receive 1.5 points.

With two exceptions, all other events are awarded first-place points based on strength of field as measured by the OWGRs of its participating players and the money winnings of "home tour" players participating in the event. The first of two exceptions includes the "flagship events" of many, but not all, of the tours mentioned above. For example, the winner of the Players Championship, the flagship event of the PGA Tour, receives 80 OWGR points. The winner of the BMW PGA Championship, the flagship event of the European Tour, receives 64 points, while the winners of the South African Open, the Australian Open and the Japan Open Championship, the flagship events of the Sunshine, Australasian and Japan Tours, respectively, all receive 32 points. The second exception is that each tour is assigned a minimum number of OWGR points for its event winners, regardless of strength of field. For example, the winner of any PGA Tour or European Tour event receives at least 24 OWGR points. The minimum number of points awarded to the winner of a Japan Tour event is 16, the Nationwide and Asian Tours, 14, etc. In all tournaments where OWGR points are awarded, non-winners receive the same percentage points allocation relative to first-place points as in the majors. A player who would otherwise receive fewer than 1.2 points is awarded no points. Therefore, in full-field non-major events, some players who make the cut earn no OWGR points.

Points are accumulated over a rolling 104-week (two-year) period. Points awarded for the most recent 13 weeks are not adjusted. However, ranking points are reduced in equal decrements for the remaining 91 weeks of the two-year ranking period. Thus, recent performance is weighted more heavily than prior performance. Each player's total adjusted points are divided by the number of events in which he participated during the 104-week period, with a minimum divisor of 40 and maximum of 52. Each player is then ranked according to his average adjusted points. Details of the OWGR system can be found at: `www.officialworldgolfranking.com` (accessed May 3, 2012).

We note that the OWGR system does not directly use scoring information. For example, Tiger Woods was awarded the same number of OWGR points for winning the 2000 U.S. Open by 15 strokes as he received for winning the 2008 U.S. Open in a playoff. Moreover, all players who receive no OWGR points in a given tournament are treated the same, i.e., they receive zero points regardless of finishing position or total score.

3. Data

We obtained 18-hole scoring data for almost all stroke-play events over the period 2002-2010 for the following tours (courtesy PGA Tour): PGA Tour, European Tour, Asian Tour, Australasia

Tour, Sunshine Tour, Japan Tour, Nationwide Tour and Challenge Tour (2004-2010 only).[3] We also obtained end-of-December and end-of-June OWGR ranks and points for 2004, 2006, 2008 and 2010 from the PGA Tour. Each set of rankings reflects the rankings as of the last scheduled tournament of the month.[4] We obtained tournament-specific OWGR points allocation data from the PGA Tour and from the OWGR website.[5] Finally, we obtained Sagarin rankings and player ratings courtesy of *Golfweek*.[6] With these data, we built two data sets. The first covers the period January 2003-December 2010 and further sub-divides the data into four two-year sub-periods: Jan 2003-Dec 2004, Jan 2005-Dec 2006, etc. The second covers the period July 2002-June 2010 and further sub-divides the data into four two-year sub-periods: July 2002-June 2004, July 2004-June 2006, etc.

The 18-hole scoring data provides course identification information for each score recorded on the PGA Tour, which we use in connection with multiple-course events such as the AT&T Pebble Beach National Pro-Am. We refer to a particular round of play conducted on a given course in a particular event as a *course-round interaction*. Most tournaments are played on a single course and, therefore, four course-round interactions would be associated with such tournaments, one per round.[7]

For each two-year sub-period, we assign each player a *primary tour affiliation* based on the number of regular events in which he participates on the various tours covered in our data. Although it is often misunderstood by the public, none of golf's majors, including the three conducted in the U.S., are actual PGA Tour events. The same holds for WGC events, including the three held in the U.S. Instead, these events are "sanctioned" by each of the six member tours of the International Federation, which means that each player who participates in these events receives credit for winning official money on each Federation tour, which, in turn, determines the eligibility status of the player on each tour. For example, if Tiger Woods were to win $500,000 in a major or WGC event, he would not only receive official money credit on the PGA Tour but also on the

[3] A tiny fraction of the non-PGA scoring data is incomplete. Since the exclusions do not appear to be biased, and since a small amount of data is involved, the effect on our results is likely to be negligible.

[4] June OWGR dates are June 27, 2004, June 25, 2006, June 29, 2008 and June 27, 2010. December dates are December 12, 2004, December 17, 2006, December 21, 2008 and December 19, 2010. There was actually one event held after the December 12, 2004 date, which is reflected in our scoring data but not in the rankings, the Asia Japan Okinawa Open, an event on the Challenge Tour which finished on December 19, but we were unable to obtain OWGR data from the PGA Tour for the December 19 date. None of the players who participated in this event were in the top 200 of the OWGR, the group upon which we focus in this study; therefore, using December 12 OWGR data rather than December 19 data should have almost no effect on our results.

[5] OWGR website data was obtained at http://www.officialworldgolfranking.com/events/events_history.sps, accessed July 11, 2012.

[6] Our SBSE ranks are determined using sample sizes of approximately 1,300 golfers in each two-year period. We have Sagarin ranks of the top 1,000 golfers at the end of June and the end of December of each year. Our final results are restricted to the OWGR top 200 golfers in each two-year period.

[7] If a tournament is conducted on more than one course, course-round interactions identify the course and round in combination. For example, the AT&T Pebble Beach National Pro Am is conducted on three different courses for the first three rounds and on a single course (Pebble Beach) for the final round. Thus, there would be 10 course-round interactions for the AT&T Pebble Beach event, three for each of the first three rounds and one for the final round. Course IDs are not provided for non-PGA Tour events. Therefore, for events on these tours, we treat each round of a given event as being conducted on the same course. As such, there is only one course-round interaction per round for these events.

other Federation tours. As a result, we exclude participation in majors and WGC events when determining a player's primary tour affiliation.

Let t_1 represent the number of events played on the tour for which the player played the most in a two-year sub-period, excluding majors and WGC stroke-play events. Let t_2 represent the number of events played on the tour for which the player played the second-most in the same period, also excluding majors and WGC stroke-play events. If $t_1 - t_2 \leq 3$ and $t_2 > 0$, the player is designated as a *multiple tour* player. Otherwise, he is designated as a player of the tour on which he participated the most. The multiple tour category applies to a small number of golfers who play a nearly equal number of tournaments on two tours.[8]

4. Player Performance Benchmarks

In order to estimate any potential bias in the OWGR system, we use two methods for estimating golfer performance that do not use tour information. The first is a statistical measure, described in the next sub-section, which we refer to as the score-based skill estimate (SBSE). The second is the Sagarin ratings and associated ranks, published by *Golfweek*. A major obstacle to ranking golfers on a single scale is that professional golfers play in different tournaments on different courses against different competition. Tournament finishing positions are not necessarily comparable across tournaments. For example, winning a minor tournament against lesser competition is likely a less impressive accomplishment than finishing tenth at a major. Scores at different tournaments are not comparable because of differences in course difficulty. For example, many golfers on the Nationwide Tour, the developmental tour for the PGA Tour, have average scores that are lower (i.e., better) than the average scores of PGA Tour golfers. This happens not because the players are better but because the courses are easier. The two methods described next measure the performance of golfers relative to other golfers playing on the same course on the same day, and then tie the results together through the play of golfers who compete on multiple tours and those who participate in majors and WGC events. Both the score-based skill and Sagarin methods use 18-hole scores as input, while the OWGR method uses tournament finishing positions and does not use scoring information directly.

4.1. Score-Based Skill Estimate

A player's score-based skill estimate (SBSE) provides an estimate of his mean 18-hole score played on a "neutral" course in which the common effects of round-to-round variation in scoring due to differences in intrinsic course difficulty, course setup, weather, etc., have been (statistically)

[8] Our procedure for assigning a primary tour (or multiple tour) affiliation does not necessarily coincide with a golfer's official tour membership(s). There are two reasons for our procedure. First, we do not have official tour membership information. Second, the OWGR points that a golfer receives in a given event depends on the tournament itself, not on the golfer's official tour membership. Therefore, which tournaments a golfer plays is more important than whether he is officially a member of any particular tour. As such, official tour membership information would not be helpful for our analysis.

removed. The difference between two player's SBSEs predicts the mean difference in their scores under neutral playing conditions, which is possible because the method simultaneously estimates the relative scoring difficulty in each tournament round.

To parallel the two-year rolling window employed in the OWGRs, we estimate SBSEs over the same two years that would have been used in computing OWGRs. Thus, when examining potential bias in year-end OWGRs, we employ 18-hole scoring data starting in January of the previous year and going through December of the OWGR year. When estimating potential bias in mid-year OWGRs, we employ scoring data starting in July two years prior and going through June of the OWGR mid-year. We require that a player record at least 30 18-hole scores worldwide within a given two-year estimation period to be included in the SBSE.

For each two-year period, we estimate the following ordinary least squares fixed effects regression, where players are indexed $i = 1, \ldots, n$ and course-round interactions are indexed $j = 1, \ldots, m$:

$$s_{i,j} = \mu_i + \delta_j + \epsilon_{i,j} \tag{1}$$

In equation (1), $s_{i,j}$ is the score of player i in connection with course-round interaction j, μ_i is the estimate of the mean score of player i on a "neutral" course, δ_j is the estimate of the course-round effect j, and $\epsilon_{i,j}$ is the error term. Note that the equality in (1) holds if all μ_i are increased by a constant and all δ_j are decreased by the same constant. To remove this arbitrary degree of freedom, we set $\delta_1 = 0$; therefore the mean neutral scores are in connection with the first course-round interaction and δ_j is the estimated course-round effect relative to course-round effect 1. Although we do not take specific information about course setup and weather conditions into account in estimating (1), their mean effect on scoring is reflected in the δ_j estimates. In equation (1), the μ_i and δ_j are estimated simultaneously using zero-one indicator variables for the players and course-round interaction terms. Note that equation (1) can be re-arranged as $\mu_i = s_{i,j} - \delta_j - \epsilon_{i,j}$, which indicates that μ_i is the estimated average score of player i after the estimated difficulty of each course-round interaction, relative to the first interaction, has been removed.

Example. Suppose there are three golfers who play two courses. Their 18-hole scores are $s_{1,1} = 70$, $s_{2,2} = 68$, $s_{3,1} = 71$ and $s_{3,2} = 67$. Golfers 1 and 3 play course 1 on the same day (with course-round index 1). Golfers 2 and 3 play course 2 on the same day (with course-round index 2). Because golfers 1 and 2 play on different courses, it is not possible to determine who played better; the score of golfer 1 could be higher than golfer 2 because he is less skilled or because he is playing on a more difficult course. However, since golfer 3 plays on both courses, the SBSE method can simultaneously estimate the relative difficulty of the two courses and the skills of the three golfers. That is, the SBSE procedure uses golfer 3 to statistically connect all three golfers and rank them on a single scale. The parameter estimates from equation (1) are: $\mu_1 = 70$, $\mu_2 = 72$, $\mu_3 = 71$, $\delta_1 = 0$ and $\delta_2 = -4$. The score-based skill estimates indicate that golfer 1 is the best golfer, golfer 3 the next best, golfer 2 the worst and that course 2 played four strokes easier than course 1.

As shown in the example, equation (1) allows golfers who never play on the same course to be

ranked on a single scale as long as there are other golfers to link them together. In practice, the SBSE method is able to handle many golfers and many course-round interactions in the presence of noisy 18-hole scores. The fixed effects statistical model is very common, with hundreds of applications in economics, marketing, finance, sociology, and elsewhere. Most statistical software packages have built-in routines for estimating fixed effects models. Variations of the fixed effects approach have been used in golf in Connolly and Rendleman (2008), Connolly and Rendleman (2011), and Broadie (2012), among others. In short, the SBSE method is a standard workhouse model in statistics that we apply here to estimate golfer skill. Next we discuss the Sagarin method, which does not directly estimate course-round difficulty, but does rely on 18-hole scoring information from golfers playing in the same tournament.

4.2. Sagarin Rankings and Ratings

According to *Golfweek*, the Sagarin rankings reflect the following:

> "Jeff Sagarin's rating system is based on a mathematical formula that uses a player's won-lost-tied record against other players when they play on the same course on the same day, and the stroke differential between those players, then links all players to one another based on common opponents. The ratings give an indication of who is playing well over the past 52 weeks."

The website `www.golfweekrankings.com/sagarin/explanation.asp` (accessed May 3, 2012) contains additional general information, but the details of the calculations are considered proprietary and are not given. We do know that the Sagarin ratings and rankings are computed over a 52-week rolling window, rather than a two-year window as with the OWGR, and that tour information is not used in the computation. Even though the Sagarin algorithm is effectively a "black box," we include the results in our analysis because the Sagarin ratings and rankings are published each week, are unbiased relative to tours, and offer another point of comparison with the OWGR.

5. Results: Tests for Bias

In this section we focus on the relationship between the OWGR, SBSE and Sagarin player performance ratings and rankings. We first show that the three performance measures lead to highly correlated rankings. When analyzed further, however, we find large differences that depend on tour affiliations. We then perform regression analyses to quantify the bias and determine its statistical significance. We also give several concrete examples of the bias.

Throughout, we limit our analysis to the set of players in the top 200 of the OWGR at the end of each two-year sub-period.[9] Within each sub-period, our SBSE and Sagarin rankings are determined relative to the players in the OWGR top 200. We note that SBSEs are determined

[9]Consistent with typical usage, when we refer to a "high" ranking, we are referring to a low ranking number. For example, the highest ranking player would have ranking number 1.

using player sample sizes of approximately 1,300 in each two-year sub-period, not just the players in the top 200 of the OWGR. However, once we identify a player as a top-200 player, his SBSE ranking is determined relative to the group of top-200 OWGR players, not the approximately 1,300 players included in the SBSE. For example, at the end of 2010, Fabrizio Zanotti was ranked 200 in the OWGR. His SBSE ranking, relative to the 1,346 players included in the 2009-2010 SBSE regression was 256, but relative to the players in the top 200 of the OWGR, his SBSE ranking was 170. For the purposes of subsequent analyses, we use a 2010 SBSE ranking of 170 for Zanotti.

5.1. Rank Correlations

The OWGR method is based on tournament finishing positions, while the SBSE and Sagarin methods are based on 18-hole scores. The difference between OWGR points for finishing first versus second is much larger than the difference in points for finishing nineteenth versus twentieth. That is, OWGR points are awarded using a nonlinear scale. In the SBSE method, a one-stroke difference in scores carries the same weight regardless of the golfer's tournament finishing position, i.e., scores are used in a linear fashion. This is one of the reasons that we are not proposing the SBSE as an alternate world golf ranking method, but we are asserting that it provides a good estimate of golfer skill and, importantly, the SBSE rankings do not depend on tour affiliation. In spite of the algorithmic differences between the three methods, the rankings that they produce are highly correlated.

Table 1 shows average Spearman rank correlations for the three methods. The table entries represent the average of correlation values for the four two-year periods: Jan 2003-Dec 2004, ..., Jan 2009-Dec 2010. To save space, only averages are reported, since the results are similar in each of the four periods. Nearly identical results are obtained using the four July-to-June two-year subperiods. The table shows high rank correlations, between 0.72 and 0.87, for the three methods. The high correlations are not surprising, since low 18-hole scores and high tournament finishing positions are both reflections of superior performance. Even though the OWGR method uses nonlinear weights, OWGR rankings are highly correlated with SBSE and Sagarin rankings.

	OWGR	SBSE	Sagarin
OWGR	1.00	0.75	0.72
SBSE	0.75	1.00	0.87
Sagarin	0.72	0.87	1.00

Table 1: Average Spearman rank correlation during 2003-2010 among the OWGR top-200 ranked golfers. The rank correlations are computed for the four two-year periods Jan 2003-Dec 2004, ..., Jan 2009-Dec 2010, and then averaged. The results show that OWGR rankings, which are based on tournament finishing position, and the SBSE and Sagarin rankings, which are based on 18-hole scores, are highly correlated.

5.2. Impact of Tour Affiliation on OWGRs

Next we analyze the impact of tour affiliation on OWGR rankings. Figure 1 shows plots of end-of-year OWGRs vs. SBSE rankings and Sagarin rankings for PGA Tour and non-PGA Tour players over the Jan 2003-Dec 2010 period. Each plot includes rankings for each of the four sub-periods, Jan 2003-Dec 2004, ..., Jan 2009-Dec 2010. The top two plots within Figure 1 show the relationship between OWGRs and SBSE rankings, and the bottom two show the relationship between OWGRs and Sagarin rankings.

If there were no bias in OWGRs relative to either of the alternative rankings, the points within each plot would fall randomly and symmetrically around each respective 45-degree line. In fact, however, there is a clear tendency for OWGR/SBSE ranking pairs to fall below the 45-degree line for non-PGA Tour players and above the line for PGA Tour players, and likewise for the OWGR/Sagarin ranking pairs. For score-based skill positions 1-100, the OWGRs of almost all non-PGA Tour players fall below the 45-degree line. Although not quite as pronounced, this same tendency is evident for Sagarin rankings.

For concreteness, Table A.1 in Appendix A shows the top 100 OWGR ranked players at the end of December 2010, together with their SBSE ranks estimated using scoring data from Jan 2009-Dec 2010. Each OWGR/SBSE pair of ranks is one of the data points displayed in the top row of Figure 1.

The general bias illustrated in Figure 1 and Table A.1 can be illustrated vividly with a specific example. At the end of 2010, PGA Tour player Nick Watney and Yuta Ikeda of the Japan Tour had roughly the same OWGR rankings: Watney ranked 35 in the OWGR while Ikeda was ranked 41. But according to our SBSEs, Watney's mean neutral score was estimated to be 0.98 strokes lower (better) than Ikeda's. Watney was ranked 11 on the basis of SBSE while Ikeda was ranked 75, a difference of 64 ranking positions. These two golfers had similar OWGRs but very different SBSE ranks based on their performances in the Jan 2009-Dec 2010 period. Similarly, Watney's Sagarin ranking of 11 was 138 positions better than Ikeda's Sagarin ranking of 149 (where all ranks are relative to the top 200 players in the OWGR). Further insight can be gained by looking at their performances in some specific tournaments.

During the two years that comprised the OWGR ranking period, Ikeda won seven events and had 10 other top-10 finishes on the Japan Tour. Clearly, it was this stellar performance relative to other Japan Tour players that enabled Ikeda to achieve an OWGR of 40. With this high ranking, Ikeda was eligible to participate in four majors in 2010, one WGC event in 2009 and three more in 2010. During 2009 and 2010, Ikeda and Watney participated in twelve of the same tournaments and their performance in these common tournaments is summarized in Table 2. In these twelve events, Ikeda missed five cuts while Watney missed none. Watney had five top-10 finishes; Ikeda's best finish was T22 (a tie for 22nd) in the WGC-CA Championship. Overall, Watney performed better than Ikeda in ten of their twelve common events. Finally, Ikeda's finishing position of T33 and Watney's T9 in the WGC-Accenture Match Play Championship reflects that Watney beat Ikeda (four up with three holes to play) in head-to-head competition during the first round of play.

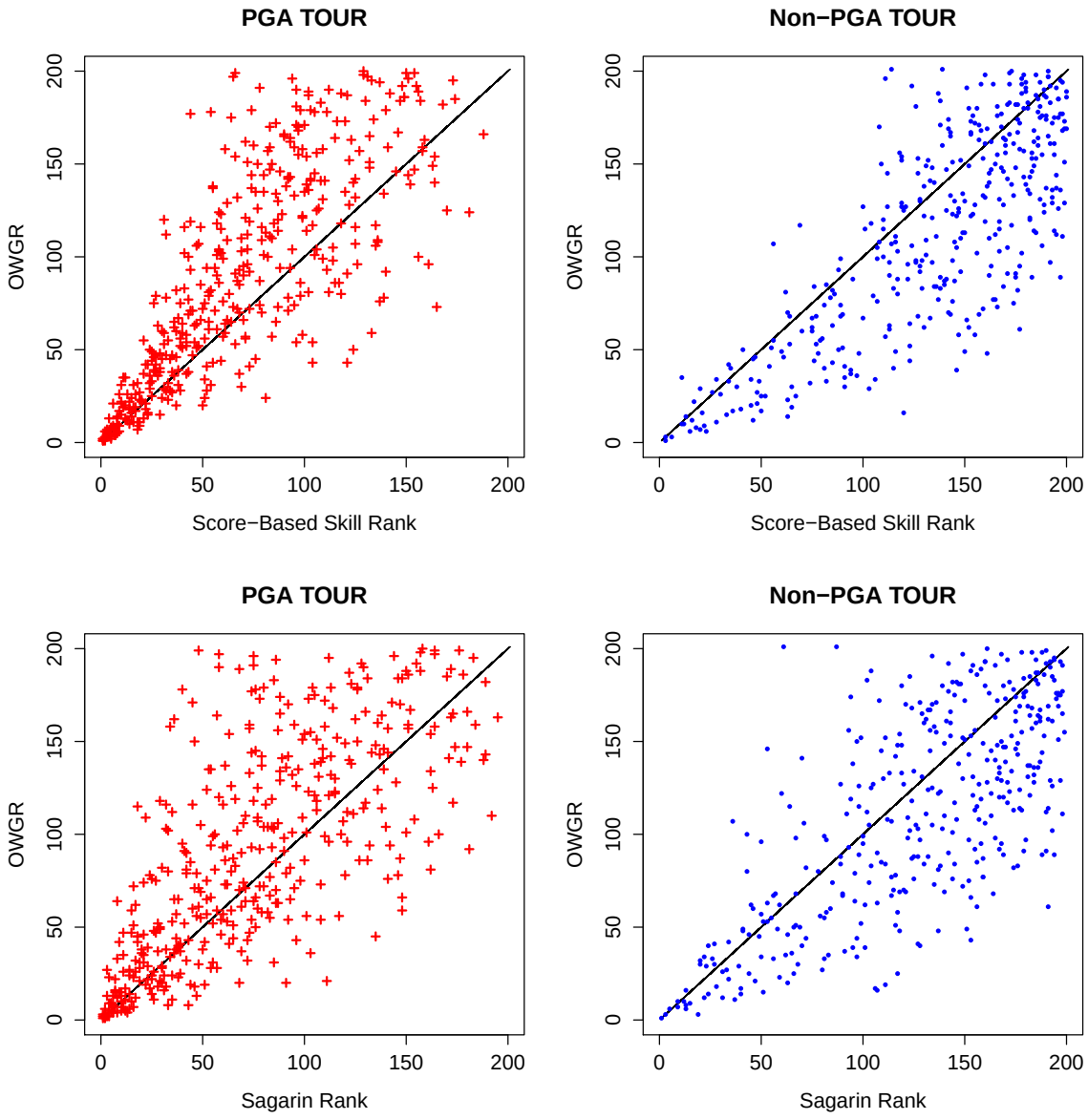

Figure 1: Top row: OWGR vs. score-based ranks. Bottom row: OWGR vs. Sagarin ranks. The left column contains results for golfers with the PGA Tour as their primary tour affiliation (red '+' markers). The right column contains results for all other non-PGA Tour affiliated golfers (blue circle markers). Each data point represents a single golfer in one of the four subperiods: Jan 2003-Dec 2004, ..., Jan 2009-Dec 2010. Casual visual inspection shows a preponderance of PGA Tour golfers above the 45-degree line, indicating that they are ranked worse in the OWGR method than the SBSE or Sagarin methods.

It appears to us that Watney was the superior player during the 2009-2010 period, yet the OWGR rankings of the two players were almost identical.

Tournament		Watney	Ikeda
2009	The Open Championship	T27	Cut
2009	WGC-HSBC Champions	5	T51
2010	WGC-Accenture Match Play Championship	T9	T33
2010	WGC-CA Championship	T26	T22
2010	Transitions Championship	4	T72
2010	Arnold Palmer Invitational	T64	Cut
2010	The Masters	7	29
2010	Crowne Plaza Invitational at Colonial	T27	Cut
2010	U.S. Open Championship	76	T58
2010	The Open Championship	T7	Cut
2010	WGC-Bridgestone Invitational	T16	T69
2010	PGA Championship	T18	Cut

Table 2: Finishing positions of Nick Watney and Yuta Ikeda in common tournaments, 2009-2010. The results show that Watney performed better than Ikeda in ten of the twelve events, even though they had similar OWGRs at the end of 2010. The "T" notation indicates a finishing position tie, e.g., T27 means a tie for 27th. "Cut" means the player missed the tournament cut, which means, roughly, that the golfer was in the bottom half after the first two rounds of the tournament. Note that some of the smaller-field WGC events do not have cuts.

5.3. Quantifying the Tour Bias in Rankings

The previous results strongly suggest a bias in the OWGR system. Next we use regression to quantify the tour bias, assess its statistical significance, and further refine the results by tour. We also address the question of whether the bias is uniform throughout the ranks, i.e., is there more or less bias for higher ranked golfers.

To quantify the bias, we first regress OWGR rankings on SBSE rankings and a PGA Tour affiliation indicator variable using data from the four end-of-year subperiods. The results are shown in panel A of Table 3. The regression results in panel A show that a golfer whose *primary tour affiliation is the PGA Tour is penalized an average of 37 OWGR rankings positions* relative to non-PGA Tour affiliated golfers. Consistent with the graphical evidence in Figure 1, the regression results show that the magnitude of the tour bias in the OWGR is large and statistically significant. Panel B of Table 3 shows a breakdown by individual tours, where the PGA Tour is the omitted tour. Results by each two-year subperiod are given in Table A.2 in Appendix A for both SBSE and Sagarin rankings. The OWGR bias, after controlling for SBSE rankings, varies from 30 to 48 OWGR positions. The OWGR bias, after controlling for Sagarin rankings, varies from 11 to 30 OWGR positions in the four two-year subperiods. In all cases, the estimate of the PGA Tour penalty is highly significant, with p-values less than 0.1%.

Next we investigate whether the bias varies by skill rank. If a player has an OWGR rank of 10, for example, then there cannot be a bias of more than 9 ranking positions against the player.

Panel A: PGA Tour vs. non-PGA Tour

Coefficient	Estimate	s.e.	p-value
Intercept	-11.4	3.9	0.00
SBSE Rank	0.9	0.0	0.00
PGA Tour	36.7	3.0	0.00

Panel B: Individual tours

Coefficient	Estimate	s.e.	p-value
Intercept	23.9	2.5	0.00
SBSE Rank	0.9	0.0	0.00
Multiple Tour	-21.1	6.8	0.00
European Tour	-36.3	3.2	0.00
Japan Tour	-50.2	4.7	0.00
Asian Tour	-38.9	9.7	0.00
Sunshine Tour	n/a	n/a	n/a
Nationwide Tour	-7.0	10.5	0.51
Challenge Tour	-47.4	11.1	0.00

Table 3: Regression estimates of OWGR bias using SBSE rankings based on end-of-year data for the four two-year periods in 2003-2010. The PGA Tour indicator coefficient estimate, 36.7, in panel A means that the OWGR rankings are biased an average of 37 OWGR rankings positions against PGA Tour-affiliated players relative to non-PGA Tour affiliated players. The panel A regression has an adjusted R^2 value of 0.63. Panel B shows the results using indicator variables for each tour, except the PGA Tour. The Asian Tour indicator coefficient estimate, -38.9, in panel B means that the OWGR rankings favor Asian-tour affiliated golfers by an average of 39 OWGR ranking positions relative to PGA Tour-affiliated golfers. The panel B regression has an adjusted R^2 value of 0.64.

Therefore, if the regression results indicate an average bias larger than 9 ranking positions against a particular tour, and if there are golfers affiliated with that tour in the OWGR top 10, then the bias cannot be uniform across OWGR ranks. A cursory examination of Figure 1 suggests that the bias against PGA Tour-affiliated golfers may be greater among less skilled players, i.e., those with the larger skill ranking position numbers. Values in Table 4 show how the bias varies by SBSE quintile. The bias is the largest for golfers in skill-based quintiles 2 and 3, i.e., skill-based ranking positions 41-120. Inasmuch as most majors and WGC events base eligibility, in part, on players being among the top 50 to 64 in OWGR rankings, bias in SBSE skill rankings in quintile 2 (positions 41-80) are critical to these golfers. A non-PGA Tour player whose SBSE ranking falls between 41 and 80 is more likely to gain eligibility into a major or WGC event based on his OWGR than a comparably-ranked PGA Tour player. More detailed results by subperiod and for Sagarin rankings are given in Table A.3 in Appendix A.

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
SBSE Rank	1-40	41-80	81-120	121-160	161-200
SBSE skill range	2.2	0.38	0.34	0.41	1.1
OWGR ranking difference	13.6*	46.4*	46.5*	29.9*	4.8

Table 4: Values in the OWGR ranking difference row represent the difference between the average OWGR rankings for PGA Tour and non-PGA Tour players by SBSE quintile. The bias is largest for golfers in SBSE quintiles 2 and 3, i.e., skill-based ranking positions 41-120. The SBSE skill range of 2.2 strokes for quintile 1 represents the average difference (over four two-year subperiods) between SBSE rank 40 and SBSE rank 1 golfer's skill estimates. * denotes that the difference is statistically significant at the 0.05 level using the Welch two-sample t-test.

Two-year subperiods from January of one year to December of the next year is a natural, though arbitrary choice. To investigate whether the estimated bias is sensitive to this choice, we compute regression coefficients using two-year periods from July of one year to June two years later. As Ballengee (2009a) points out, the OWGR's time factor, which places the highest weight on OWGR points earned over the most recent 13-week period, can work against players on the PGA Tour and Japan Tour: "This is because their seasons do not last a full calendar year, unlike the Asian and European Tours. Yes, the PGA Tour season lasts from January through November. But, the best players on the PGA Tour generally play from early February through September. When the new season rolls around in January – three months later – their Official World Golf Ranking is already depressed because they played sparsely or not at all during the winter months. The points that they earned during the summer in some of the biggest events are already losing value." Thus, the bias against PGA Tour players that we observe in end-of-year OWGRs may reflect the timing problem to which Ballengee refers. To investigate this timing issue, we also estimate the same regression using mid-year OWGRs and SBSE rankings. These results are given in panels B and D of Table A.2 in Appendix A. Using mid-year OWGRs and SBSE rankings, panel B shows that the PGA Tour penalty is approximately 26 OWGR ranking positions over the entire eight-year period, July 2002 through June 2010, approximately 10 positions less than with end-of-year rankings. Over the four two-year July-June periods, the PGA Tour penalty ranges from 21 to 43 ranking positions, and all estimates are highly statistically significant.

The magnitude of the estimated bias is large in all cases that we tested. Recall that the initial SBSE ranks are determined using player sample sizes of approximately 1,300 in each two-year subperiod (and Sagarin ranks cover the top 1,000 golfers), not just the players in the top 200 of the OWGR. The regression and quintile results are based on re-ranking golfers relative to the players in the OWGR top 200 in each sample period. For example, at the end of 2010, Gregory Havret had an OWGR rank of 115 with an original SBSE rank of 400, a difference of 285 ranking positions. In our analyses, Havret was re-assigned a rank of 192 out of the OWGR top 200, a difference of only 77 ranking positions. This re-ranking to include only golfers in the OWGR top 200 has the effect of reducing our bias estimates. A separate small simulation study confirms the intuition provided by this example. We intentionally chose this approach so that our reported bias estimates would, if anything, be conservative.

At the suggestion of a referee, we investigated the possible effect of travel on the bias. We re-estimated our equation 1 with a dummy variable for travel and found only slight changes in our estimated coefficients. Including this adjustment for travel would have no effect on our conclusions.

5.4. Bias in Implied Skill

Note that our previous analysis weights all ranking differences equally, regardless of the actual skill differences of the players who have different OWGR and SBSE (or Sagarin) ranks. The analysis that follows transforms rank differences to implied skill differences and, as such, does not weight all ranking differences the same.

Consider N players, $i = 1, 2, ..., N$, ordered by expected scores, $SBSE_i$, with $SBSE_1 < SBSE_2 < \ldots < SBSE_N$. Let $j(i)$ denote the OWGR of player i. For example, if the most highly-skilled player is ranked 3 in the OWGR, $j(1) = 3$. Then $SBSE_{j(i)}$ is the inverse transformation of SBSE implied by player i's OWGR, $j(i)$, which we refer to as "implied skill."

Table 5 illustrates implied skill.[10] In Table 5, player 1, with an expected neutral score (SBSE) of 67, is ranked 1 in skill but 3 in the OWGR. Therefore, player 1's SBSE as implied by his OWGR ranking of 3 is 69, that of the third most highly-skilled player.

Skill Rank	SBSE	OWGR	SBSE Implied by OWGR
1	67	3	69
2	68	1	67
3	69	5	71
4	70	2	68
5	71	6	72
6	72	4	70
7	73	7	73
8	74	10	76
9	75	8	74
10	76	9	75

Table 5: Hypothetical Player Skill Distribution

To test for potential bias in implied skill, we regress implied SBSE against SBSE along with a PGA tour indicator variable for the January 2003-December 2110 and July 2002-June 2010 periods. Table 6 summarizes estimated coefficients associated with the PGA Tour indicator variable for each two-year sub-period from January 2003 through December 2010 and July 2002-June 2010. The estimated coefficients indicate that the skill of PGA Tour players implied by their OWGRs is approximately 0.2 to 0.5 strokes per round worse than their actual skill. Consistent with previous results, the bias against PGA Tour players is greater for the January-December estimation periods than for the July-June periods, reflecting that the PGA Tour season effectively ends well before December. In other work, we have estimated that the difference in skill between the top and bottom half of players in a typical PGA Tour event is approximately 0.5 strokes per round. Therefore, we believe that the implied skill bias of 0.2 to 0.5 strokes per round is not only statistically significant but also significant from a practical perspective. Among professional golfers, a player with a mean neutral score that is 0.5 strokes per round lower than that of another golfer is a much better player.

6. Concluding Remarks

Using 18-hole scoring data of all golfers participating in tournaments from 2002 to 2010 on the major tours (PGA, Europe, Japan, Asian, Sunshine and Australasia) and from the developmental

[10] This same concept is used in (Connolly and Rendleman, 2012) as a means to assess the selection efficiency of the PGA Tour's annual FedExCup competition.

Estimation Period	PGA Coef.	p-value	Adj. R^2
Jan 2003-Dec 2004	0.36	0.00	0.73
Jan 2005-Dec 2006	0.36	0.00	0.66
Jan 2007-Dec 2008	0.54	0.00	0.52
Jan 2009-Dec 2010	0.41	0.00	0.66
Jul 2002-Jun 2004	0.23	0.00	0.74
Jul 2004-Jun 2006	0.23	0.00	0.69
Jul 2006-Jun 2008	0.46	0.00	0.62
Jul 2008-Jun 2010	0.20	0.00	0.61

Table 6: Implied Skill Bias: The PGA coefficient is the estimated coefficient associated with the PGA Tour indicator variable in a regression across all players in the top 200 of the Official World Golf Rankings of implied SBSE against SBSE and a {1,0} variable indicating whether the PGA tour is a player's primary tour affiliation.

tours (Nationwide and Challenge), we test for bias in OWGR rankings by comparing the OWGR rankings with two methods, score-based skill estimation (SBSE) and Sagarin rankings, which do not use tour information in their computations. We find a persistent, large and statistically significant bias in the OWGR rankings against PGA Tour golfers; a golfer of a given estimated SBSE skill level, or a given Sagarin rank, is likely to be penalized in the OWGR rankings for playing events on the PGA tour and rewarded for playing elsewhere. These findings are important, because OWGR rankings determine, in part, eligibility to play in major tournaments, World Golf Championships and other events.

The current OWGR point system evolved from a system proposed by Mark McCormack in the late 1960s. Two OWGR coordinators, Tony Greer and Ian Barker, recently wrote in response to a query from Mike Stachura, that the "OWGR is better and more accurate today than it was 10 years ago due to the constant review of the system by the technical committee" but then go on to say that "the OWGR system is not based on mathematical science" (Statchura, 2012). Designing a ranking system is difficult, and we are not proposing SBSE method as an alternative world ranking system. However, a ranking system where points are determined by a committee, rather than objective analysis, could easily lead to the biases described in this paper.

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A. Appendix: Further Ranking Details and Bias Results

This appendix contains more detailed results. Table A.1 shows the SBSE rankings of the top 100 OWGR ranked players at the end of December 2010.

Table A.2 summarizes results of regressions of OWGRs against SBSE rankings (panels A and B) and Sagarin rankings (panel C and D), where both regressions include an indicator variable that takes on the value of 1 if a player's primary tour affiliation is the PGA Tour. As shown in Panel A, over the entire eight-year period, Jan 2003-Dec 2010, among players in the top 200 of the OWGR, after controlling for SBSE rankings, those whose primary tour affiliation is the PGA Tour tend to be penalized almost 37 OWGR ranking positions relative to non-PGA Tour players. The penalty varies somewhat by two-year sub-period, ranging from approximately 30 to 50 OWGR positions. In all cases, the estimate of the PGA Tour penalty is highly significant, with p-values less than 0.1%.

Panels C and D of Table A.2 indicate that PGA Tour players also tend to be penalized in the OWGR when Sagarin rankings are used as a benchmark, although the effect is not as large as with SBSE rankings. As with the SBSE benchmark, the penalty tends to be less using mid-year rankings than end-of-year rankings. All but two PGA Tour coefficient estimates are statistically significant at the 0.05 level.

Table A.3 shows the difference between the average OWGR rankings of PGA Tour and non-PGA Tour players for five groups of players grouped on the basis of SBSE and Sagarin rankings. When SBSE is the benchmark, year-end OWGRs of PGA Tour players within quintile 2 average approximately 46 positions worse than for non-PGA Tour players, and mid-year OWGRs average approximately 28 positions worse for PGA Tour players in quintile 2. OWGR differences vary by year, being as high as 68 OWGR positions at the end of 2008. When Sagarin rankings are used as the benchmark, average OWGR ranking differences are not as large but are still significant in both an economic sense and a statistical sense. With the Sagarin benchmark, year-end OWGRs of PGA Tour players within quintile 2 average approximately 24 positions worse than for non-PGA Tour players, and mid-year OWGRs average approximately 15 positions worse.

OWGR rank	Player	Tour affil	SBSE rank	Rank diff	OWGR rank	Player	Tour affil	SBSE rank	Rank diff
1	L. Westwood	EUR	3	-2	51	H. Stenson	EUR	74	-23
2	T. Woods	PGA	1	1	52	C. Hoffman	PGA	42	10
3	M. Kaymer	EUR	6	-3	53	J. Overton	PGA	62	-9
4	P. Mickelson	PGA	7	-3	54	A. Cabrera	PGA	45	9
5	J. Furyk	PGA	4	1	55	B. Jones	JPN	69	-14
6	S. Stricker	PGA	2	4	56	L. Glover	PGA	39	17
7	G. McDowell	EUR	20	-13	57	H. Slocum	PGA	70	-13
8	P. Casey	PGA	5	3	58	T. Taniguchi	JPN	96	-38
9	L. Donald	PGA	9	0	59	R. Palmer	PGA	89	-30
10	R. McIlroy	EUR	12	-2	60	R. Green	EUR	65	-5
11	I. Poulter	PGA	18	-7	61	B. Haas	PGA	50	11
12	E. Els	PGA	13	-1	62	M. Manassero	EUR	67	-5
13	M. Kuchar	PGA	8	5	63	S. Dyson	EUR	71	-8
14	D. Johnson	PGA	15	-1	64	S. Noh	EUR	86	-22
15	R. Goosen	PGA	10	5	65	K. Na	PGA	36	29
16	F. Molinari	EUR	21	-5	66	T. Hiratsuka	JPN	95	-29
17	R. Karlsson	EUR	47	-30	67	W. Liang	EUR	80	-13
18	E. Molinari	EUR	40	-22	68	T. Jaidee	EUR	60	8
19	H. Mahan	PGA	16	3	69	R. Davies	EUR	93	-24
20	L. Oosthuizen	EUR	44	-24	70	A. Hansen	EUR	59	11
21	R. Allenby	PGA	22	-1	71	S. Verplank	PGA	53	18
22	Z. Johnson	PGA	14	8	72	J. Holmes	PGA	63	9
23	P. Harrington	PGA	19	4	73	F. Andersson	EUR	97	-24
24	A. Scott	PGA	48	-24	74	D. Willett	EUR	73	1
25	G. Ogilvy	PGA	25	0	75	K. Perry	PGA	26	49
26	T. Clark	PGA	17	9	76	S. Appleby	PGA	90	-14
27	M. Jimenez	EUR	46	-19	77	S. Garcia	PGA	43	34
28	R. Fowler	PGA	49	-21	78	B. Davis	PGA	92	-14
29	J. Rose	PGA	31	-2	79	D. Toms	PGA	27	52
30	K. Kim	JPN	61	-31	80	R. Barnes	PGA	84	-4
31	A. Kim	PGA	51	-20	81	M. Sim	MUL	58	23
32	B. Watson	PGA	33	-1	82	M. Matsumura	JPN	99	-17
33	R. Fisher	EUR	34	-1	83	J. Senden	PGA	41	42
34	C. Schwartzel	EUR	28	6	84	S. Kjeldsen	EUR	68	16
35	N. Watney	PGA	11	24	85	B. Molder	PGA	64	21
36	C. Villegas	PGA	24	12	86	B. Snedeker	PGA	55	31
37	R. Ishikawa	JPN	77	-40	87	D. Horsey	EUR	94	-7
38	J. Day	PGA	29	9	88	O. Wilson	EUR	78	10
39	B. Crane	PGA	38	1	89	S. Gallacher	EUR	91	-2
40	P. Hanson	EUR	35	5	90	V. Singh	PGA	54	36
41	Y. Ikeda	JPN	75	-34	91	S. Sonoda	JPN	98	-7
42	S. O'Hair	PGA	23	19	92	J. Dufner	PGA	66	26
43	Y. Yang	PGA	52	-9	93	G. Fdez-Castano	EUR	72	21
44	R. Moore	PGA	56	-12	94	R. Sabbatini	PGA	76	18
45	B. Van Pelt	PGA	30	15	95	K. Miyamoto	JPN	100	-5
46	S. Cink	PGA	37	9	96	G. Bourdy	EUR	85	11
47	K. Choi	PGA	32	15	97	D. Clarke	EUR	83	14
48	H. Fujita	JPN	79	-31	98	R. Jacquelin	EUR	88	10
49	A. Quiros	EUR	57	-8	99	J. Donaldson	EUR	81	18
50	M. Laird	PGA	87	-37	100	J. Luiten	EUR	82	18

Table A.1: Top 100 OWGR ranked players as of December 19, 2010, together with their SBSE ranks estimated using scoring data from Jan 2009-Dec 2010. The tour affiliation abbreviations are: PGA Tour (PGA), European Tour (EUR), and Japan Tour (JPN). The multiple tour affiliation is abbreviated MUL.

Panel A: Using January-December Sub-periods and Score-Based Rankings

Period	Coef.	Est.	S.E.	p-value	Adj. R^2
Jan 2003-Dec 2010	Intercept	-11.4	3.9	0.00	0.63
	Skill Rank	0.9	0.0	0.00	
	PGA TOUR	36.7	3.0	0.00	
Jan 2003-Dec 2004	Intercept	-9.6	7.5	0.20	0.66
	Skill Rank	0.9	0.0	0.00	
	PGA TOUR	30.7	5.7	0.00	
Jan 2005-Dec 2006	Intercept	-11.6	7.4	0.12	0.67
	Skill Rank	0.9	0.0	0.00	
	PGA TOUR	33.5	5.6	0.00	
Jan 2007-Dec 2008	Intercept	-18.4	9.8	0.06	0.53
	Skill Rank	0.9	0.1	0.00	
	PGA TOUR	49.5	7.5	0.00	
Jan 2009-Dec 2010	Intercept	-9.3	7.0	0.19	0.66
	Skill Rank	0.9	0.0	0.00	
	PGA TOUR	35.4	5.5	0.00	

Panel B: Using July-June Sub-periods and Score-Based Rankings

Period	Coef.	Est.	S.E.	p-value	Adj. R^2
Jul 2002-Jun 2010	Intercept	-1.8	3.8	0.63	0.62
	Skill Rank	0.9	0.0	0.00	
	PGA TOUR	26.3	2.9	0.00	
Jul 2002-Jun 2004	Intercept	-0.3	6.9	0.97	0.67
	Skill Rank	0.9	0.0	0.00	
	PGA TOUR	21.0	5.3	0.00	
Jul 2004-Jun 2006	Intercept	-0.5	7.3	0.95	0.65
	Skill Rank	0.9	0.0	0.00	
	PGA TOUR	22.0	5.5	0.00	
Jul 2006-Jun 2008	Intercept	-15.8	9.2	0.09	0.56
	Skill Rank	0.9	0.1	0.00	
	PGA TOUR	43.4	6.9	0.00	
Jul 2008-Jun 2010	Intercept	4.3	7.5	0.57	0.60
	Skill Rank	0.8	0.1	0.00	
	PGA TOUR	22.0	5.9	0.00	

Panel C: Using January-December Sub-periods and Sagarin Rankings

Period	Coef.	Est.	S.E.	p-value	Adj. R^2
Jan 2003-Dec 2010	Intercept	11.0	4.0	0.01	0.54
	Sagarin Rank	0.8	0.0	0.00	
	PGA TOUR	18.8	3.1	0.00	
Jan 2003-Dec 2004	Intercept	15.2	7.6	0.05	0.57
	Sagarin Rank	0.8	0.1	0.00	
	PGA TOUR	10.6	5.9	0.08	
Jan 2005-Dec 2006	Intercept	16.0	7.5	0.03	0.55
	Sagarin Rank	0.8	0.1	0.00	
	PGA TOUR	11.2	5.9	0.06	
Jan 2007-Dec 2008	Intercept	7.6	9.6	0.43	0.44
	Sagarin Rank	0.8	0.1	0.00	
	PGA TOUR	29.6	7.5	0.00	
Jan 2009-Dec 2010	Intercept	2.7	7.3	0.71	0.59
	Sagarin Rank	0.8	0.1	0.00	
	PGA TOUR	25.5	5.8	0.00	

Panel D: Using July-June Sub-periods and Sagarin Rankings

Period	Coef.	Est.	S.E.	p-value	Adj. R^2
Jul 2002-Jun 2010	Intercept	10.4	3.9	0.01	0.57
	Sagarin Rank	0.8	0.0	0.00	
	PGA TOUR	16.4	3.0	0.00	
Jul 2002-Jun 2004	Intercept	12.7	7.4	0.09	0.59
	Sagarin Rank	0.8	0.0	0.00	
	PGA TOUR	12.0	5.8	0.04	
Jul 2004-Jun 2006	Intercept	13.6	7.2	0.06	0.61
	Sagarin Rank	0.8	0.0	0.00	
	PGA TOUR	9.2	5.6	0.10	
Jul 2006-Jun 2008	Intercept	1.2	9.7	0.90	0.48
	Sagarin Rank	0.8	0.1	0.00	
	PGA TOUR	31.3	7.3	0.00	
Jul 2008-Jun 2010	Intercept	10.3	7.1	0.15	0.60
	Sagarin Rank	0.8	0.0	0.00	
	PGA TOUR	15.0	5.7	0.01	

Table A.2: Regression Estimates of OWGR Bias Using Score-Based Skill Rankings and Sagarin Rankings

	Score-Based Skill Quintile Jan-Dec						Score-Based Skill Quintile Jul-Jun				
	1	2	3	4	5		1	2	3	4	5
Jan 2003-Dec 2010	13.6*	46.4*	46.5*	29.9*	4.8	Jul 2002-Jun 2010	6.2*	28.4*	45.4*	16.7*	5.7
Jan 2003-Dec 2004	12.3*	35.8*	51.7*	20.3	-9.3	Jul 2002-Jun 2004	9.3*	20.2*	42.2*	15.4	3.1
Jan 2005-Dec 2006	10.0	48.2*	35.1*	33.8*	3.2	Jul 2004-Jun 2006	4.0	28.5*	43.9*	13.3	-6.8
Jan 2007-Dec 2008	19.0*	68.2*	44.0*	38.0*	n/a	Jul 2006-Jun 2008	10.1	63.3*	61.3*	18.8	46.2*
Jan 2009-Dec 2010	13.1*	35.2*	54.4*	30.7	14.4	Jul 2008-Jun 2010	3.6	13.7	34.7*	19.4	6.3
	Sagarin Quintile Jan-Dec						**Sagarin Quintile Jul-Jun**				
	1	2	3	4	5		1	2	3	4	5
Jan 2003-Dec 2010	17.2*	24.2*	21.8*	18.4*	5.9	Jul 2002-Jun 2010	7.0	15.1*	27.2*	21.3*	-4.6
Jan 2003-Dec 2004	8.0	27.4*	32.1*	-5.8	-6.8	Jul 2002-Jun 2004	0.1	11.0	21.3	18.9	-4.2
Jan 2005-Dec 2006	14.5*	14.6	23.1	12.2	0.5	Jul 2004-Jun 2006	-4.5	12.1	27.2	8.9	-20.8
Jan 2007-Dec 2008	32.1*	42.3*	4.3	43.4*	38.4	Jul 2006-Jun 2008	24.5*	46.4*	40.0*	11.8	23.4
Jan 2009-Dec 2010	13.9*	15.4	32.3*	24.6	39.4	Jul 2008-Jun 2010	10.7	-4.8	14.8	42.8*	-1.1

Table A.3: OWGR Rank Differences by Benchmark Quintile. Values in the table represent the difference between the average OWGR rankings for PGA Tour and non-PGA Tour players per SBSE or Sagarin quintile. * denotes that the difference is statistically significant at the 0.05 level using the Welch two-sample t-test.