POWER VS. PRECISION: HOW HAVE THE DETERMINANTS OF PGA TOUR GOLFERS' PERFORMANCE-BASED EARNINGS EVOLVED SINCE THE 1990'S?

by

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ABSTRACT

This paper improves upon the methods for modelling the determinants of PGA TOUR golfers' performance-based earnings by incorporating the most recent and accurate PGA TOUR statistics while controlling for year and individual fixed effects. Using a panel of golfers from the 2004 through 2011 PGA TOUR seasons, I find that a one standard deviation improvement in putting renders the average golfer 27 percent additional earnings; meanwhile, the same degree of improvement in driving distance offers only 14 percent more earnings. Even as PGA TOUR golf course yardages and driving distances continue to grow, this study shows that improved driving distance yields are no greater than those to scrambling, greens in regulation, or strokes gained-putting .

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CHAPTER 1

Introduction

There are more than 30 million golfers in North America who contribute to an estimated $85 billion golf industry (Economic Impact Reports, 2008 & Strategic Networks Group, 2009). At the summit of this golf mountain sits a giant corporate enterprise called the PGA TOUR[1]. Based out of the United States, the PGA TOUR organizes and oversees weekly tournaments where top professional golfers from around the world compete for large financial payoffs. In 2008, the Tour reported revenues of $981 million of which approximately $270 million was paid out in prize money to more than 260 golfers (Klayman, 2009). The biggest earner in 2008, Vijay Singh, played in 23 individual tournaments and took home greater than $6.6 million. Meanwhile, the lowest earner that year, Rick Fehr, competed in one single event earning just $5,940.

The list of golfers on the Tour can change dramatically from year to year. Not only do the individual identities who comprise the Tour change but the distinct skill sets that characterize them evolve as well. Players' swings change as they practice to improve; their skill sets are affected as they adapt to their annual schedules and golf course conditions. This evolution has held a longstanding interest among writers, analysts, and casual golf fans who attempt to evaluate the game of golf. The PGA TOUR organization depends on such evaluation as they maintain their commitment to the integrity of the game and to the preservation of the records of those who have contributed to its rich history (PGA TOUR).

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[1] Often refer to as simply the "Tour" and in this paper.
[2] Golf's four annual Major Championships are the Masters Tournament, US Open, British Open, and PGA

Aside from the recent dispute regarding long putters, the most hotly debated issue surrounding the evolution of professional golf in the 21st century has been that of increased driving distances and the subsequent lengthening of PGA TOUR golf courses. No matter what is responsible for the increased driving distances on Tour, the fact that this trend exists presents those curious with some interesting questions. From the PGA TOUR's perspective, as they aim to maintain the integrity of the game, it is important to evaluate if the intricate skill set of what makes a great professional golfer has undergone any transformation. As the sport continues to grow, they can proceed with an improved awareness of the direction the game is headed and how they can properly steer it. Golfers throughout the ranks will benefit to know how certain skills are rewarded so that they can optimize practice time and maximize their chances of success on Tour.

Measuring the determinants of earnings and their respective contributions is certainly not unique to professional golf or sport. My method parallels those employed by countless labour economists; and, therefore, this thesis should not be ignored by all of whom are uninterested in golf.

In this thesis, I present the question, "how have the determinants of PGA TOUR golfers' performance-based earnings evolved since the 1990's?" In doing so, this paper improves upon the existing methods for modelling PGA TOUR earnings by incorporating recently developed and highly accurate PGA TOUR statistics, notably proximity to hole and strokes gained-putting, whilst controlling for year and individual golfer effects.

The remainder of this research paper is laid out as follows. Chapter two provides background to the subject matter to round out the reader's understanding. Chapter three presents a review of the existing literature and main academic contributions in the field of study. Chapter four introduces and describes the sample data. Chapter five explains the estimation procedure. Chapter six presents results. Chapter seven concludes with an overall summary of the paper's findings and divulges ideas for further research.

CHAPTER 2

Background

The 2012 PGA Championship was recently played at the Ocean Golf Course, within the Kiawah Island Golf Resort, measuring a behemoth 7,676 yards to become the longest Major Championship[2] golf course in history (PGA Championship). Holding this record may be noteworthy, but it is no rare feat that the record was broken. In fact, the 2012 edition of the PGA Championship is the fourth in the past nine years to set a new record for longest Major Championship (See Table A.1). This is exemplary of why PGA professional swing coach, Hank Haney, has said power is "the single biggest thing that determines a player's potential" (Haney, 2006). How has professional golf reached a time when power seems to outweigh the importance of precision?

There are two distinct occurrences that have principally contributed to this result. The first, beginning in the mid-1990s and continuing to a lesser degree today, is the significant advancement in golf equipment technology[3]. All types of golf clubs have become much more forgiving, minimizing the negative effects of off-centre strikes. Clubs are presently constructed using an array of high energy materials including combinations of steel, tungsten and titanium alloys. Drivers are larger and longer to enhance swing speeds and maximize driving distance. Grooves on irons and wedges have become deeper and wider providing players with superior control of their golf ball on approach shots, which, in turn minimizes the penalty for wayward drives that miss the fairway.

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[2] Golf's four annual Major Championships are the Masters Tournament, US Open, British Open, and PGA Championship

[3] Go to http://golftecblog.com/2011/05/13/changes-in-golf-club-technology/ for a brief list of golf technology's advances over the past ten years.

Secondly, much to the credit of Tiger Woods, professional golf has transformed, athletically speaking, into much more of a 'sport'. Since Woods' historic12-stroke victory at the 1997 Masters Tournament[4], his competitive drive and penchant for weight training set a new standard among golf professionals whilst spawning a young generation of golfers, many of whom have become today's top professionals (Hammond, 2009). If you were to observe the physical states of the top professional golfers today compared to 20 years ago, there would undoubtedly be a stark difference in their athletic appearance and overall physical health. Two-time Major Champion and former number one ranked golfer in the world, Greg Norman, says, "when I was a kid, we were told that exercising was bad for your swing" (Greg Norman Strengthens, 2004) In the past, golfers were under the impression that exercise negatively affected their game. Things have definitely changed. In a recent interview, two-time US Open winner, Lee Janzen, said "there are probably only a handful of guys [on Tour] that are not doing some sort of exercise." Janzen continues, "most of us see now that it is a key part of being competitive on Tour" (Hill, 2006, p.26). With scarce exception, PGA TOUR professionals follow a strict dietary and workout regime to maintain top physical form year round. The modern golfer is much stronger, more flexible and more disciplined than ever before.

Breakthroughs in equipment technology and the enhanced athleticism of the modern professional golfer have combined to yield dramatic results in PGA TOUR driving distances. For example, in 1992, the Tour average driving distance was barely greater than 260 yards with the longest hitter, John Daly, averaging 283 yards per drive. Nine

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[4] The Masters Tournament is the season's first Major Championship held at Augusta National. It was first played in 1934.

seasons later, the 2001 average driving distance measured in at 279 yards with Daly leading the way at 307 yards (PGA TOUR Statistics).

Another theme on Tour at the turn of the millennium was Tiger Woods' complete and absolute dominance. Throughout the 2000 and 2001 seasons, Tiger broke a slew of records and strung together what is often considered the greatest stretch in professional golf history; winning 14 times and holding all four Major Championship titles at one time (About Tiger Woods, 2012). It was around this time that the PGA TOUR began renovating a number of their championship golf courses adding yardage to make them play more difficult (See Figure B.2). This process has since been referred to as 'Tiger-Proofing', an endeavour to make the courses more challenging to the Tour's greatest player. However, it likely induced an opposite effect making the courses more difficult to his shorter hitting competitors and making it relatively easier for Woods (Fitzpatrick, 2008). Nonetheless, the Tour acted to offset the improvement in driving distances by adding yards to many of the championship courses on Tour. From 1992 to 2001, the annual average yardage change among the four Major Championships was an increase of five yards. From 2001 to 2008 however, the annual average yardage change among the four Majors was a whopping 59 yards. It has levelled off in years since.

Perhaps in response to the added yardage of PGA TOUR golf courses, or maybe just the continuation of the trend from better fitness and ever-improving equipment technology, driving distances have continued to soar. When the 2011 season wrapped up the average driving distance reported was 291 yards with J.B. Holmes averaging a gargantuan 318 yards (PGA TOUR Statistics).

Before moving into the data and modelling of this paper, it is important to review the existing literature. The next chapter will enhance one’s understanding of the current literature and demonstrate why this paper’s research is the logical next step.

CHAPTER 3

Literature Review

It is widely accepted that putting and short game skills, as opposed to driving, are the most important aspects of skill in golf. This notion stems from the fact that in a typical round of golf, an individual player uses their driver a maximum of 14 times[5] while putting and short game shots often take up 30 to 50 strokes per round. Further, because a drive rarely results in the ball ending up in the hole, and is not directly associated with scoring, it is easy to discount the skill as having less importance. Conversely, an improvement in putting can have a very direct result on scoring.

As emphasized in Chapter One, driving distance is the aspect of a professional golfer's skill set that has undergone the most notable transformation in recent years. Assuming that the relative gains to driving distance have increased, one could reasonably expect the relative gains from at least one other performance skill to have fallen. Thus, it is important to examine PGA TOUR earnings with respect to the contributions from each determinative skill factor. The literature related to my research has certainly focused in this area. A recurring theme among academics who have previously modelled PGA TOUR success (Berry, 1999, Nero, 2001, Alexander & Kern, 2004) is that although putting skill contributes the most financial benefit to professional golfers, improvement in driving distance can also be quite significant.

The related literature (Berry, 1999, Nero, 2001, Alexander & Kern, 2004) speaks to how golfer performance translates to success on the PGA TOUR. In professional golf there are

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[5] In a typical round, a golfer uses their driver for tee shots on par 4 and 5 holes, of which there are usually 14.

two closely related measures of annual success; one is earnings, the other is ranking. Specifically, earnings are exactly the prize money accumulated by a golfer over the course of a PGA TOUR season. Each PGA TOUR tournament consists of four 18-hole rounds played over four days. After two rounds, the field is cut down for the final two rounds (usually to the top 70 and ties). The remaining players are awarded prize money based on their ranked position after the fourth and final round. Thus, a players' relative success in a tournament can be directly measured by their earnings.

Further, earnings and ranking are not only measures of weekly success; they also directly translate to annual success. Earnings are accumulated throughout the season and only the top 125 money earners are provided full-time status[6] for the following season. Therefore, for many PGA TOUR golfers, the future of their careers lies within that top 125 threshold.

A previous study related to the monetary measure of PGA TOUR success is "Relative Salary Efficiencies of PGA Tour Golfers" by Peter Nero (2001). Here, Nero models earnings on a handful of key statistical categories and posits the degree of earnings contribution that improvements in specific fundamental skill areas could have. Nero uses his estimated earnings equation to calculate the relative performance of different golfers from the early to mid 1990s. His model is weak in that he utilizes only four skill variables; putting average[7], driving distance[8], driving accuracy[9], and sand save

[6] Full-time status – A golfer with full-time status is eligible to play in any 'regular' PGA Tour event.
[7] Putting Average – The average number of putts taken per hole.
[8] Driving Distance – The average distance of a drive measured in yards.
[9] Driving Accuracy – The percentage of times a drive lands in the fairway.

percentage[10]. Furthermore, Nero's sole non-skill control variable is for the number of events in which a golfer competes.

Alexander and Kern (2004) find that the returns to driving distance have increased over the years, but that putting performance remains the most important skill in improving one's earnings. They use an unbalanced panel of individual PGA TOUR golfers from 1992 to 2001 and form an earnings equation that relates a golfer's earnings to a vector of skill variables and a vector of external variables. Furthermore, they follow Berry's (1999) method to improve upon the PGA TOUR's tracking of iron play, chipping ability, putting ability and sandplay by eliminating much of the collinearity that can persist among these somewhat entangled statistics. The PGA TOUR measures greens in regulation[11] (GIR) and presents it as their best measure of iron play. However, Alexander and Kern recognize that GIR is also dependent upon driving skills as the better positioned a golfer is after his tee shot the more likely he is to reach the green. Therefore, Alexander and Kern model GIR on driving distance and driving accuracy and use the residuals as a 'pure' measure of iron play. I elect to use the raw form of GIR in my analysis as it provides a tangible, applicable metric for improving golfers' outcomes. Alexander and Kern follow the same practice to yield 'pure' measures for putting, chipping and sandplay.

Although Alexander and Kern used regression practices to extract a more pure measure of the skill components inherent in golf, their work may yet be improved upon using a

[10] Sand Save Percentage – The percentage of times a golfer scores par or better from a greenside sand bunker.
[11] Greens in Regulation – Percentage of times a player reaches the putting surface in par-less two shots.

completely unbiased measure of putting ability that has recently been developed and adopted by the PGA TOUR.

Broadie (2008) explains the first major contributions of Golfmetrics to the current common golf statistics repertoire. This statistic is called *Strokes Gained-Putting* (SGP) and it has become the primary putting statistic used by the PGA TOUR. SGP was developed as a non biased metric for measuring golfers putting performance (Broadie, 2008). Prior to the introduction of SGP, the most common putting statistics was Average Putts (AVP). This measures the average number of putts a golfer takes to score their ball in the hole after reaching the green. To illustrate the flaw in using this statistic in regression estimation, imagine a player who does not reach many greens in regulation but after missing the green, chips the ball close to the hole and often one-putts for par. Compare that to a golfer who hits many greens in regulation but because of the longer length of his approach shots ends up further from the hole for his first putt and thus, normally two-putts. The two players could be equally skilled putters but because the former is a weaker ball-striker, his initial putts are shorter, and thus his AVP is lower than that of the latter golfer. One can eliminate this bias by using average putts per green in regulation (Peters, 2008). Nonetheless, strokes gained-putting is an even better metric, as is demonstrated later in this chapter.

It is easy to see how the Average Putts measure is flawed. Broadie’s strokes gained-putting metric controls for this bias and provides each player a value which compares it to the average Tour professional, controlling for the distance of each putt recorded[12]. This empirical paper includes strokes gained-putting as the putting metric in its analysis.

The most recent study evaluating PGA TOUR golfers' earnings as a function of their individual skill statistics is by Andrew Peters (2008). Peters follows a similar procedure as Alexander and Kern (2008) yet he focuses on the role of experience as a control in his regressions with PGA TOUR data from the 2002 to 2005 seasons. Once more, the main issue in Peters' research is the ultimate bias associated with the statistic he employed to capture putting skill. Although he explains how using average putts per green in regulation, rather than average putts per green, eliminates the effect of missing greens and chipping close, he fails to eliminate the remaining bias that exists when the distance of a player's initial putt is not accounted for. For example, Player A hits his approach shot onto the green 25 feet from the hole and converts his putt for a score of three. Player B hits his ball onto the green only two feet from the hole and converts his putt as well. Although both players had one putt per green in regulation, it is easy to understand how Player A has displayed better putting skill by converting the 25-foot putt. Therefore, there remains bias in Peters' choice for a measure of putting skill.

A thorough examination of the related literature proves that since the introduction of Broadie's strokes gained-putting as an unbiased measure of putting skill, there has been no empirical study modelling PGA TOUR earnings that includes SGP. A second measure

[12] Strokes Gained Putting - The number of putts a player takes from a specific distance is measured against a statistical baseline to determine the player's strokes gained or lost on a hole. The sum of the values for all holes played in a round minus the field average strokes gained/lost for the round is the player's Strokes gained/lost for that round. The sum of strokes gained for each round are divided by total rounds played. The Strokes Gained - Putting concept is a by-product of the PGA TOUR's ShotLink Academic program, which encourages members of the academic community to perform research against the wealth of ShotLink statistical data. Professor Mark Broadie from Columbia Business School developed the early concept which was later refined by the TOUR (2564).

that remains relatively new to PGA TOUR statistics is *Proximity to Hole*; adopted in 2001. Proximity to hole acts complimentary to greens in regulation as a metric of the success of approach shots. Imagine two players who both reach the green on their approach shots. Player A takes two putts from 26 feet away to achieve an SGP of 0.0 on the hole while Player B takes one putt from two feet away to achieve an SGP of 0.0. Player B has scored one less stroke than Player A. If proximity to hole was unaccounted for the one stroke difference would be credited to random error. Thus, this piece of empirical research includes both proximity to hole and strokes gained putting, as well as driving distance, driving accuracy, greens in regulation. I also include scrambling[13] which accounts for both chipping and sand skills.

I control for other observable and unobservable factors, explained in the following, in the form of fixed effects. Sponsorship on the PGA TOUR can change dramatically from season to season as television ratings and general popularity fluctuates. The result is that the total prize money available at each event and throughout the Tour season changes considerably as well. Alexander and Kern (2005) use a control variable, denoted purse, to account for the varying levels of potential earnings each season. In this paper, however, the year fixed effects will capture the changes in prize money from season to season as well as any yearly unobservable effects that have a systematic influence on earnings.

Individual golfers also have time invariant characteristics, such as sponsorship, coaching, and amateur experience, that may have an impact on their overall performance on Tour. A golfer's source and level of sponsorship may certainly affect their earnings. Although

[13] Scrambling - The percentage of time a player scores par or better provided he has missed the green in regulation.

sponsorship can change, it is common for golfers to sign long term contracts that are maintained for several years (Tiger Signs New Deal With Nike, 2006). Coaching is another influence on golfers' performance, evidenced by the lucrative contracts negotiated between players and coaches. Again, the coach-player relationship usually lasts several years and is assumed to be time invariant. Caddies also fall into this category. A golfer's amateur experience, like whether or not they played golf at the collegiate level, and their place of birth are other examples of time invariant factors that may have an effect on individual PGA TOUR earnings. The aforementioned factors, including any other unobserved characteristics that influence performance-based earnings, are all captured by individual fixed effects.

In Chapter Four, sample data are presented and described as this paper moves into the empirical component. The subsequent chapters present an empirical depiction of the PGA TOUR earnings function as I tackle the question, "How have the determinants of PGA TOUR golfers' performance-based earnings evolved since the 1990's?"

CHAPTER 4

Data and Descriptive Statistics

The sample data used throughout my regression analysis is an unbalanced panel of individual golfers competing on the PGA TOUR from 2004 through the 2011 seasons. In my replication of Alexander and Kern's (2004) work, I draw upon a sample of PGA TOUR golfers from the 1992 and 2001 seasons. The data was extracted from the statistics portion of the PGA TOUR's website (PGA TOUR Statistics). From season to season the list of golfers can change dramatically as players become injured, fail to earn enough money to remain on Tour, or qualify from outside the PGA TOUR. Although the number of individual earners in a given Tour season can be upwards of 260, the usable sample is substantially less as some players do not play sufficient rounds to have their performance statistics officially listed. The number of golfers in each cross-section varies from a low of 182 (in 2011) to a high of 202 (in 2005) with 585 unique individuals making up 1543 total observations.

The PGA TOUR tracks a plethora of outcome-orientated and independent skill statistics. Traditionally, Tour success is measured in two closely related, outcome-oriented, fashions; one is earnings, the other ranking. Specifically, earnings are exactly the prize money accumulated by a golfer over the course of a PGA TOUR season. Each weekly tournament consists of four 18-hole rounds played over four days. After two rounds the field is cut approximately in half; usually to the top 70 and ties. The remaining golfers are awarded prize money based on the ranked position of their aggregated 72-hole score. Thus, a player's success in a tournament translates directly to their earnings. The top ranked player in a given week can earn upwards of a million dollars while the last place finisher may earn only a few thousand (Yahoo Sports Leaderboard, 2012). Moreover, the money a player accumulates in the run of a season directly impacts their future on Tour since only the top 125 earners are guaranteed full-time status[14] the following season. The top ranked money earner in the 2011 edition of the PGA TOUR, Luke Donald, earned $6,683,214 while the bottom ranked player was awarded only $6,330 (PGA TOUR Statistics).

The primary dependent variable used throughout this paper's empirical analysis, and in the majority of related literature, is precisely the earnings accumulated by PGA TOUR golfers each season. Earnings are not only the primary measure of success on Tour, but they translate seamlessly to other aspects of economic study. Earnings also provide the common reader, who may have little understanding of golf, with a recognizable measure of a professional golfer's success. A second, often cited, measure of success on Tour is the number of events in which a player finishes in the top ten (PGA TOUR Statistics). Top ten finishes measure success directly related to other competitors in each tournament and act to quantify the number of times a player is in contention to win a Tour event. This provides a secondary outcome which will serve as a robustness check in my regression analysis.

The PGA TOUR has a highly accurate system for measuring virtually every shot taken in almost every tournament played, called ShotLink[15]. This provides the PGA TOUR with a catalogue of data representing hundreds of categories of statistics for each and every golfer. Common performance statistics used as explanatory variables among Shmanske

[14] Full-time status – A golfer with full-time status is eligible to play in any 'regular' Tour event.
[15] The PGA Tour's ShotLink Academic program encourages members of the academic community to perform research against the wealth of ShotLink statistical data.

(1992), Alexander and Kern (2005) and Peters (2008) are driving distance, driving accuracy, greens in regulation, average putts per green in regulation and sand save percentage. Nero (2001) uses all of the above but neglects to include greens in regulation in his model.

I have chosen six different PGA TOUR statistics representing the individual skill components of the game to include as explanatory variables in my empirical modelling. These six skill statistics are driving accuracy (percentage), driving distance (measured in yards), greens in regulation (percentage), proximity to hole (measured in feet), scrambling (percentage), and strokes gained-putting (measured in strokes). In the following paragraphs I will describe each measure in detail, with their expected signs presented with respect to earnings.

The skill of driving a golf ball is broken into two components; driving accuracy and driving distance. The PGA TOUR measures driving accuracy as the percentage of time a tee shot comes to rest in the fairway, regardless of club used (PGA TOUR Statistics). Driving accuracy is expected to have a positive sign as it benefits players to hit shots from the fairway where they have the most control and precision.

The Tour presents driving distance as the average number of yards per measured drive. These drives are measured on two holes per round. Care is taken to select two holes which face in opposite directions to counteract the effect of wind. Drives are measured to the point at which they come to rest regardless of whether they are in the fairway or not (PGA TOUR Statistics). A positive sign is expected as longer drives place the golfer nearer to the hole yielding shorter, easier approach shots.

The third performance variable is presented by the PGA TOUR as a representation of iron-playing ability; greens in regulation (GIR). The PGA TOUR measures GIR as the percent of time a player was able to hit the green in regulation. A green is considered hit in regulation if any portion of the ball is touching the putting surface after the GIR stroke has been taken. The GIR stroke is determined by subtracting two from par; first stroke on a par-3, second on a par-4, third on a par-5 (PGA TOUR Statistics). The expected sign for this variable is positive as more accurate iron shots that reach the green in regulation yield lower scores, hence a lower rank and higher earnings.

The fourth performance variable, proximity to hole, has not previously been used in empirical research and has only been recorded by the PGA TOUR since the 2001 season. This variable measures the average distance, in feet, the ball comes to rest from the hole after the player's approach shot. The approach shot distance must be determined by a laser, and the shot must not originate from on or around the green. The shot also must end on or around the green or in the hole[16]. I expect a negative sign for this variable as a player who hits their approach shots nearest to the hole will have a higher likelihood of converting his initial putt, yielding lower scores and higher earnings.

The fifth performance variable used in my analysis is called scrambling. In scrambling, the Tour measures the percent of time a player scores par or better after missing the green in regulation (PGA TOUR Statistics). In previous literature, researchers have often captured this type of skill by using sand save percentage (Shmankse, 2001, Nero, 2001, Peters, 2008) or by constructing a proxy for ability around the green (Alexander & Kern, 2004). Scrambling provides a measure of skill which accounts for all types of shots from

[16] 'Around the green' indicates that the ball comes to rest within 30 yards of the green.

around the green. This variable's expected sign is positive as a higher scrambling percentage yields lower scores and higher earnings.

The sixth and final performance variable measures putting skill and is denoted by the PGA TOUR as strokes gained-putting[17] (SGP). The number of putts a player takes from a specific distance is measured against a statistical baseline to determine the player's strokes gained or lost on a hole. The sum of the values for all holes played in a round minus the field average strokes gained/lost for the round is the player's strokes gained/lost for that round. The sum of strokes gained for each round is divided by total rounds played (PGA TOUR Statistics). This variable is expected to have a positive sign since positive SGP values translate directly to strokes gained which yield a lower ranking and higher earnings.

Lastly, I include a non-performance control variable in my regression model that influences earnings and thus, ranking. The control variable, denoted events, is the number of tournaments in which a player enters in a given season. For various reasons, golfers do not regularly attend every tournament on Tour in a given season. Some tournaments have special qualification criteria and as a result, many players are not eligible to play. Players also take time off to relax and spend with their families. Some have to recover from injury. In any case, the expected sign for this variable is positive since the more events a golfer plays the more opportunities they have to earn money. Following Alexander and

[17] The Strokes Gained - Putting concept is a by-product of the PGA TOUR's ShotLink Academic program. Professor Mark Broadie from Columbia Business School developed the early concept which was later refined by the TOUR (2564). An inside look at the PGA Tour's newest statistic from Mark Broadie available at http://www.golf.com/tour-and-news/strokes-gained-putting-behind-newest-pga-tour-stat

Kern (2005), events squared are also included to test for diminishing returns to events played.

Descriptive statistics for the variables used in my empirical models are presented in Table A.2. These face-value statistics present some interesting trends visible on the PGA TOUR. Tour golfers have averaged $1.24 million annually over the past eight seasons while playing in approximately 25 events each year. From 2004 to 2011, their adjusted earnings have remained virtually constant. Average driving accuracy has fallen from a high of 64.1 percent in 2004 to a low of 61.7 percent in 2011; a decrease of 3.7 percent. While accuracy has fallen, Tour driving distance has increased slightly from 287.2 to 291.1 yards. The relative success of golfers' approach shots have increased slightly over the eight year span. Tour professionals are hitting 0.8 percent more greens in regulation and hitting their approach shots an average of 1.1 percent closer to the hole in 2011 than in 2004. Scrambling percentage has remained quite constant with an average of 57.7 percent, a minimum of about 43 percent and maximum of just over 68 percent. Strokes gained-putting has had the largest relative change over the eight year span, increasing by more than 10 percent with a pooled average of 0.026 strokes gained per round[18].

Table A.2 also provides descriptive statistics for a sample of golfers from the 1992 and 2001 PGA TOUR seasons. The average Tour golfer in these two years combined earned $626,054 annually while playing in 27 events each year. Average driving accuracy was 67.4 percent while driving distance averaged 270 yards. Greens in regulation percentage averaged 67.4 while the average golfer from the 1992 and 2001 pooled sample averaged

[18] Bear in mind that the average SGP on Tour is always 0.0 and that this sample drops a number of the lowest money earners on Tour who played too few rounds to qualify for statistical recording.

59.2 in scrambling percentage. Statistics for proximity to hole and strokes gained-putting are not available for the 1992 and 2001 PGA TOUR seasons. Of the available skill statistics, driving distance shows the most change from 1992 to 2001 as it increases over seven percent. It should also be noted that earnings grew by greater than 164 percent in constant dollars.

To provide further comparison to PGA TOUR statistics in the 1990s, Table A.3 presents the Quartile Coefficient of Dispersion[19] (QCD) for the key variables from two periods; 1992 to 2001 and 2004 to 2011. The skill variable with the smallest quartile coefficient of dispersion (x100), QCD, over the timeframe is driving distance measuring 2.0. Driving accuracy has a QCD of 5.6, greens in regulation measures 2.7, proximity to hole is 2.9, scrambling has a QCD of 3.9 and the dispersion of strokes gained putting measured 18.1, nine times that of driving distance. In comparison to the skill variable measures in the pooled 1992 to 2001 sample, there persists less dispersion in more recent years, with the exception of driving accuracy. It is also worth noting that the QCD of driving distance is smaller in the more recent sample period, contrasting the belief that longer hitting golfers gain more from advances in technology than do shorter hitters. It appears that the dispersion of average driving distance values is actually contracting with time.

[19] Quartile Coefficient of Dispersion provides a unit less measure of dispersion. It is calculated by the ratio of the difference between the third and first quartiles to the sum of the first and third quartiles.

CHAPTER 5

Empirical Model

To examine the change in the determinants of PGA TOUR golfers' performance-based earnings, I estimate the following model from a panel of golfers from the 2004 through 2011 seasons. The primary regression is modelled as follows with the variables and their descriptions listed in Table 1;

$$(1)\ EARNINGS_{it} = \beta_1 DrivingAccuracy_{it} + \beta_2 DrivingDistance_{it} + \beta_3 GreensInRegulation_{it} + \beta_4 ProximityToHole_{it} + \beta_5 Scrambling_{it} + \beta_6 SGP_{it} + \gamma_1 EVENTS_{it} + \gamma_2 EVENTS_{it}^{2} + \alpha_t + \rho_i + \varepsilon_{it} \quad .$$

Table 1 - List of Variables and Descriptions

Variable	Description
$EARNIGNS_{it}$	Earnings, adjusted to 2004 constant dollars for golfer *i* in year *t*
α_t	Year *t* fixed effects
ρ_i	Individual *i* fixed effects
$DRIVING\ ACCURACY_{it}$	Measured as a percentage times one hundred for golfer *i* in year *t*
$DRIVING\ DISTANCE_{it}$	Measured in yards for golfer *i* in year *t*
$GREEENS\ IN\ REGULATION_{it}$	Measured as a percentage times one hundred for golfer *i* in year *t*
$PROXIMITY\ TO\ HOLE_{it}$	Measured in feet for golfer *i* in year *t*
$SCRAMBLING_{it}$	Measured as a percentage for golfer *i* in year *t*
$STROKES\ GAINED\text{-}PUTTING_{it}$	Measured in strokes for golfer *i* in year *t*
$EVENTS_{it}$	Controls for the number of tournaments participated in by golfer *i* in year *t*.
$EVENTS_{it}$^2	Squared term for the number of tournaments played by golfer *i* in year *t*
ε_{it}	Residual error term

This regression yields constant dollar values that are easily understood and comparable to previous empirical work (Nero, 2001, Alexander & Kern, 2004, Peters, 2008) in this area.

A secondary regression is modelled identically to that of model (1) with the exception that the dependent variable, 2004 adjusted earnings (Economic Report of the President, 2012), is transformed using the natural log function;

$$(2)\ LN(EARNINGS_{it}) = \beta_1 DrivingAccuracy_{it} + \beta_2 DrivingDistance_{it} + \beta_3 GreensInRegulation_{it} + \beta_4 ProximityToHole_{it} + \beta_5 Scrambling_{it} + \beta_6 SGP_{it} + \gamma_1 EVENTS_{it} + \gamma_2 EVENTS_{it}^2 + \alpha_t + \rho_i + \varepsilon_{it} \quad .$$

A third model is constructed to observe the year to year changes in the coefficient estimates. For each year, 2004 through 2011, the following regression is run;

$$(3)\ EARNINGS_i = \beta_1 DrivingAccuracy_i + \beta_2 DrivingDistance_i + \beta_3 GreensInRegulation_i + \beta_4 ProximityToHole_i + \beta_5 Scrambling_i + \beta_6 SGP_i + \gamma_1 EVENTS_i + \gamma_2 EVENTS_i^2 + \varepsilon_i \quad .$$

Model (3) again uses a natural log transformation to linearize the dependent variable which provides a better fit for the model. With the natural log transformation, translating coefficient estimates to dollar earnings is less intuitive than those provided by model (1). Nonetheless, the intention of this model is only to provide year to year coefficient estimates so we may observe recent trends.

CHAPTER 6

Empirical Results

6.1 Pooled Regression Models

The results of model (1), a pooled panel regression of 2004 adjusted earnings under various specifications, are presented in Table A.4. Following the results of a Hausman specification test which suggested fixed effects, specifications include both year and individual fixed effects. The year effects capture changes in prize money and any unobserved effects that have a systematic influence on earnings, while individual effects capture time invariant characteristics of each golfer, such as sponsorship, coaching and amateur experience. All regressions presented in this paper are run using robust standard errors.

The first three columns of Table A.4 present regression results without controlling for the number of events a golfer enters in a season. Column (1) is without fixed effects, column (2) with only year effects, and column (3) has both year and individual fixed effects. Adding year effects to the model alters the coefficient estimates slightly, rendering driving accuracy highly significant, and yields a slight improvement in fit, R-squared improves from .33 to .35. Comparing column (2) to column (3), controlling for individual fixed effects has a substantial effect on all the coefficients, most notably driving accuracy and proximity to hole as it renders them statistically insignificant. Column (4) controls for the number of events in which golfers participate and column (5), the full model, includes the squared number of events to control for decreasing marginal returns to events played. The full model presents events and events squared as highly significant while rendering driving accuracy insignificant.

The results reveal expected signs for all explanatory variables with exception to driving accuracy once individual fixed effects are included. Its statistical insignificance, however, fails to rule out the possibility of a positive population parameter, thus its negative sign can largely be ignored. Proximity to hole also becomes statistically insignificant once individual effects are included. Furthermore, the resultant regression specification captures 73 percent of the variation in adjusted earnings.

The interest here is to evaluate the contributions of individual skill performance, and marginal improvement in them, to earnings on the modern PGA TOUR and evaluate their relative evolution over time. Recall that the resultant regressions provide values for marginal improvement in a single variable whilst holding the other variables constant at their respective arithmetic means.

The average PGA TOUR professional from 2004 to 2011 earned $1,131,519. Authors of previous empirical work in this area have interpreted such regression estimates using various marginal changes in the dependent variables; various magnitudes of percentage changes, elasticities, degrees of standard deviations. The sixth column of Table A.4 presents the elasticity estimates to mirror Alexander and Kern’s (2004) results. A more appropriate, raw dollar, focus is to examine the results of a one standard deviation improvement in each statistical category. Following the results from column (5), a one standard deviation improvement in driving distance, an additional 8.6 yards, yields an increase in earnings of approximately $159,000 or 14 percent in annual earnings. If the average PGA golfer increased their scrambling percentage by one standard deviation, improving from 57.7 to 61.1 percent, it would be provide them with $170,000 or 15 percent in additional earnings. There is an even greater payoff for a one standard deviation improvement in greens in regulation percentage, 2.7 percentage points, yielding the average Tour professional an extra $247,000 or 22 percent in earnings. Lastly, the greatest contribution to performance-based earnings on the PGA TOUR for a one standard deviation improvement in the skill distribution, not surprisingly, is generated by putting. If the average Tour player were to improve their strokes gained putting metric by 0.354 strokes per 18-hole round they would reap an additional $309,000 or 27 percent in earnings. Further, the number of events played generates a positive effect on earnings up to approximately 26 events. Thus, the average Tour golfer from the 2004 to 2011 seasons is fairly rational participating in 25.4 events. The relationship we see here resonates with previous literature (Alexander and Kern, 2005) in that events played display diminishing marginal returns. This is likely due to the fatigue that comes from extensive travel by PGA TOUR professionals.

Let us examine Alexander and Kern's (2005) findings from an analysis of PGA TOUR data from 1992 to 2001. Their results imply that a one standard deviation improvement in driving accuracy would yield the average golfer from the 1992 to 2001 PGA TOUR seasons an additional 25 percent in earnings, a one standard deviation improvement in driving distance yields a 37 percent increase in earnings. Evaluating the estimate for driving accuracy in Table A.4 is useless. But when we compare driving distance coefficient estimates, it appears that the average golfer from the 2004 to 2011 PGA TOUR earns substantially less, 14 percent versus 37 percent, than the average golfer from the 1990s. These primary results certainly appear to contradict the theory that the modern PGA TOUR provides higher payoffs for those with longer driving distances. The explanatory variables representing iron, chip, sand and putt performance cannot be compared due to Alexander and Kern's proxy measures which have mean zero.

Table A.5 displays the same progression of specifications as Table A.4 except that the dependent variable has undergone a natural log transformation[20]; column (5) represents model (2). The estimated coefficients are very similar in direction and significance to those previous. However, the coefficient assigned to driving accuracy has been slashed to zero and the estimated coefficient for proximity to the hole has gone from no statistical significance to full statistical significance. It may be that some aspect of the non-transformed earnings model prevents the linear effects of proximity to hole from being captured. Once the transformation takes place, the linear relationship reveals the proximity to hole measure as a statistically significant explanatory variable and an important determinant of PGA TOUR earnings. The transformed earnings model also explains a greater degree of the variation in earnings; approximately 80 percent.

6.2 Annual Regression Model

Table A.6 presents model (3), the results of an OLS regression of natural log adjusted earnings on the six skill components and controls is performed for each individual year. This helps evaluate whether the determinants of performance-based earnings on the PGA TOUR have changed throughout the sampling period. Again, natural log adjusted

[20] See http://cooldata.wordpress.com/2010/03/04/why-transform-the-dependent-variable/ for a clear explanation of why statisticians/econometricians often use natural log transformations.

earnings were used as they provide a more accurate fit for the model than do raw dollar earnings.

Looking across the years, the results do not display much variety for driving accuracy, proximity to hole, scrambling or strokes gained-putting. The coefficient estimates for driving distance and greens in regulation do present a degree of excitement however. The coefficient estimates for greens in regulation are statistically significant from 2004 to 2006 but lack statistical significance from 2007 through 2010 with an estimate very near to zero in 2008. On the other hand, driving distance coefficient estimates begin insignificant and become highly statistically significant in 2008 through to 2011.

The year by year regressions can undoubtedly aid to identify trends among the coefficient estimates. Yet these annual snapshots lack definitive evidence as to whether or not the determinants of performance-based earnings on Tour have changed throughout the sampling period. A more precise statistical examination of change among regression coefficients is found in the Chow Test[21]. Specifically, the Chow Test is used to test for structural change in some or all of the parameters of a model. Table A.7 presents results of a Chow Test performed to identify the existence of a structural change in parameters between the 2004 to 2007 seasons and the 2008 to 2011 seasons. The Chow Test statistic of 5.37 exceeds the critical value $F_{9,1525} = 2.56$ suggesting that there is indeed a structural change in the parameters between these two groups.

[21] For a brief description of the Chow Test see http://support.sas.com/rnd/app/examples/ets/chow/

6.3 Replication of Alexander & Kern's Results, 2004

Alexander and Kern (2004) utilize an unbalanced panel and a plethora of individual skill measures to "examine the determinants of the earnings of PGA T[OUR] golfers from the period 1992-2001". Skill variables included in their regression analysis are driving accuracy percentage, driving distance in yards, and their respective self-constructed measures for iron, putt, chip, and sand performance. The authors indicate that a number of the statistics recorded by the PGA TOUR are inherently biased measures. Therefore, they derive auxiliary regressions and utilize their residuals to proxy for, what they denote, 'pure' measures of each of the four aforementioned skills; iron, putt, chip, sand.

In an attempt to replicate Alexander and Kern's (2004) empirical results, data has been collected from the 1992 and 2001 PGA TOUR seasons. Taking into account all of the information provided in their paper, their methods are replicated as closely as possible and presented alongside their results in Table A.8. The parameter estimates from the 1992 season are substantially different than those of Alexander and Kern, with varying degrees of difference between the two sets of estimates. On the other hand, the 2001 regression estimates and the pooled regression estimates in column (3) prove relatively similar to their results.

A point-blank summary can be obtained by viewing the ratio of 2001 estimates to 1992 estimates in column (4) of Table A.8. First it should be noted that there are two different sets of values in column (4). Alexander and Kern (2004) use a purse adjustment of 2.97; this paper suggests a purse adjustment of 2.7, which is calculated from the *Economic Report of the President* (2012). Regardless, you can see that the ratio of 2001 estimates to 1992 estimates provide drastic differences in our results. These results are largely influenced by the difference in the 1992 regressions. Part of the discrepancy could be due to having different data sources, even though the primary source is absolutely identical; the PGA TOUR. For example, this paper's sample has a combined 376 observations from 1992 and 2001 while Alexander and Kern have only 341 observations. Data source is the only obvious clue toward how the resultant estimate ratios in column (4) are so different, given that Alexander and Kern's procedure was followed precisely.

Further, a direct comparison to their 1990's work has proven difficult and likely inaccurate at best. For instance, an improvement of one standard deviation in driving distance would produce 14 percent higher annual earnings for the average 2004 to 2011 PGA TOUR golfer. Or, that same golfer could attribute enough practice to improve one standard deviation in strokes gained-putting where he would gain 27 percent higher earnings. Alexander and Kern (2004) report that from 1992 to 2001 the average Tour golfer would earn approximately 37 percent in additional earnings from a gain of one standard deviation in their driving distance. It gets complex when comparing putting coefficient estimates. They measure a reasonable improvement in putting to be one putt less per round, which would yield a 105 percent increase in earnings for the average 1992 to 2001 PGA TOUR golfer. This one stroke improvement per round translates to one full stroke gained in SGP, about three standard deviations, which would render the 2004 to 2011 Tour golfer approximately 91 percent in additional earnings. Therefore, we may observe that additional earnings gained from a one-stroke per round improvement in putting has fallen from 105 to 91 percent from the1992 to 2001 period to the 2004 to 2011 period.

Nonetheless, recognizing a three standard deviation change in a variable is certainly a cause for concern. Alexander and Kern's (2004) methods of 'purifying' measures for iron, putt, chip and sand create problems for interpretation since their summary statistics are not measures of primarily sourced PGA TOUR statistics but mean-zero residuals from auxiliary regressions.

6.4 Robustness Checks

It is important that the results of the performance-based earnings model provided previously are consistent across different specifications. Therefore, this paper provides secondary and tertiary specifications use ranking and top ten finishes as dependent variables. As aforementioned, these are both commonly expressed measures of success on the PGA TOUR. Table A.9 presents pooled regression results from the 2004 through 2011 Tour seasons for natural log adjusted earnings, ranking, and top ten finishes.

The results indicate that the statistical significance of the explanatory variables as determinants of earnings on the PGA TOUR is no mistake. When earnings are replaced by ranking, all of the independent skill variables change sign; which is expected since earnings and ranking are inversely related. Further, the same four variables remain highly statistically significant; greens in regulation, proximity to hole, scrambling, and strokes gained-putting. Column (3) provides regression results with top ten finishes as the dependent outcome variable. Again, the explanatory variables remain highly statistically significant with the exception of proximity to hole, which displays significance only at the 95 percent level. Further, driving distance becomes significant as a determinant of top ten finishes at the 95 percent level.

Utilizing various outcome variables that denote success on the PGA TOUR has provided additional support to our primary regression model. The use of earnings as the primary outcome measure for this empirical analysis proves accurate since the regression results are consistent across specifications.

CHAPTER 7

Conclusion

This paper aims to evaluate how the determinants of PGA TOUR golfers' performance-based earnings have evolved since the 1990's. The catalysts for such research with respect to professional golf are the large gains in driving distance and lengthening of championship golf courses having taken place since the late 1990's. As championship golf courses were consistently lengthened to match augmented driving distances (see Figure B.2), the overall effect has certainly been debatable. The recent development of PGA TOUR metrics, proximity to hole and strokes gained-putting, have also added motivation to construct an updated model of Tour golfers' performance-based earnings.

Using a panel regression of golfers from PGA TOUR seasons spanning 2004 to 2011 has revealed measurable differences in the annual contributions to earnings across the majority of golfers' skill categories. Most notably, there appear to have been two different segments (evidenced by the Chow Test) throughout the eight year span. From 2004 to 2007, driving distance was an insignificant indicator of PGA TOUR earnings while greens in regulation displayed statistically significant predictive power. However, from 2008 through2011, it seems there was a shift. The returns to driving distance increased notably in magnitude and reached a high level of statistical significance. Meanwhile, greens in regulation seemed to lose its power as a statistical indicator of performance-based earnings.

This paper reveals that for a one standard deviation improvement in putting skill, the average PGA TOUR golfer would gain 27 percent in earnings. Meanwhile the same magnitude of improvement in driving distance renders only an additional 14 percent in earnings. It appears that aptitude for putting is twice as important as driving distance on the PGA TOUR. These results echo those of previous empirical studies and many casual golf enthusiasts who have made similar claims.

Although driving distance's influence on earnings was augmented late in the time span studied, it is yet to be completely understood how earnings contributions of both driving distance and putting skill have evolved since the 1990's. Whilst this paper provides an improved model for studying the determinants of PGA TOUR golfers' performance-based earnings, it lacks the precise comparative power as previous empirical works in this field have used quite different, admittedly inferior, methods.

This paper improves upon previous methods for modelling the determinants of PGA TOUR golfers' performance-based earnings by incorporating the most recent and accurate PGA TOUR performance statistics and including fixed effects into the empirical modelling. While there have been barriers throughout this evaluation of the evolution of earnings on Tour, I believe I have provided a jumping block for more detailed research. Moving forward, it would be beneficial to analyze PGA TOUR earnings models by incorporating tournament specific information so that the respective schedule of tournaments each golfer participates and their inherent field size and strength can factor into the empirics. Further, since a golfer's state and performance is not constant throughout the PGA TOUR season, evaluating an earnings model with weekly characteristics, rather than simply annually, could also be an advantage.

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APPENDIX A

Table A.1 - Annual Yardage of the Four Major Championships

Year	*Masters*	*US Open*	*British Open*	*PGA Champ.*	*Avg of all Four*	*Annual Change*	
1992	6925	6809	6970	7148*	6963		
1993	6925	7116*	6860	7024	6981	18	
1994	6925	6946	6957	6834	6916	-66	
1995	6925	6952	6933	6956	6942	26	
1996	6925	6974	6892	7144	6984	42	Average
1997	6925	7213**	7079*	6987	7051	67	change
1998	6925	6797	7018	6906	6912	-140	from
1999	6925	7175	7361**	7401**	7216	304	1992 to
2000	6925	6846	7115	7167	7013	-202	2001
2001	6925	6973	6905	7213	7004	-9	+5 yards
2002	7270*	7214*	7034	7360	7220	216	
2003	7270	7188	7106	7134	7175	-45	
2004	7270	6996	7175	7514**	7239	64	
2005	7270	7214	7279	7392	7289	50	
2006	7445*	7264*	7258	7561**	7382	93	Average
2007	7445	7230	7421*	7131	7307	-75	change
2008	7445	7643**	7173	7395	7414	107	from
2009	7445	7426	7204	7674**	7437	23	1992 to
2010	7445	7040	7305	7514	7326	-111	2011
2011	7445	7574	7211	7467	7424	98	+42 yards

* Record for the respective Championship

** Record for all Major Championships

Source: Yahoo Sports at sports.yahoo.com/sports

Table A.2 - Descriptive Statistics for the Sample of Golfers from the 1992, 2001 and 2004 through 2011 PGA Tour Seasons

Key Variable		*1992*	*2001*	*Pooled 1992 and 2001*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*Pooled 2004 to 2011*	*2004 to 2011 Mean % Change*
Adjusted Earnings*	*Mean*	339,650	897,620	626,054	1,134,632	1,087,062	1,149,868	1,190,481	1,129,691	1,137,324	1,087,507	1,136,934	1,131,519	0.2%
	Std. Dev.	348,109	925,182	758,321	1,214,783	1,182,933	1,125,333	1,123,942	945,667	1,112,571	904,812	1,019,656	1,083,242	
	Min	13,268	35,117	13,268	21,250	60,766	61,381	49,009	32,090	30,215	45,174	91,546	21,250	
	Max	1,809,277	6,063,170	6,063,170	10,905,166	10,278,553	9,317,303	9,906,155	5,790,434	9,250,143	4,251,496	5,611,431	10,905,166	
Top Tens	*Mean*	3.3	3.4	3.4	2.7	2.5	2.7	2.6	2.7	2.4	2.6	2.6	2.6	-3.7%
	Std. Dev.	2.7	2.7	2.7	2.8	2.5	2.6	2.4	2.2	2.4	2.2	2.5	2.4	
	Min	1	1	1	0	0	0	0	0	0	0	0	1	
	Max	13	14	14	18	18	13	12	9	14	11	14	18	
Driving Accuracy	*Mean*	66.3	68.4	67.4	64.1	62.8	63.3	63.5	63.5	63.2	63.4	61.7	63.2	-3.7%
	Std. Dev.	3.3	4.2	3.9	5.3	5.3	5.4	5.2	5.4	5.4	5.1	5.1	5.3	
	Min	56.1	54.1	54.1	1.0	45.4	49.8	41.9	49.0	48.4	50.2	47.0	41.9	
	Max	74	81.1	81.1	9.0	76.0	78.4	75.5	80.4	74.8	76.1	75.7	80.4	
Driving Distance	*Mean*	260.4	279.3	270.1	287.2	288.6	289.5	289.1	287.4	288.1	287.5	291.1	288.5	1.4%
	Std. Dev.	7.5	7.3	12	8.3	9.3	8.7	8.6	8.5	8.5	8.2	8.4	8.6	
	Min	240.6	252.7	240.6	268.2	258.7	265.9	265.3	162.4	258.9	266.4	269.8	258.7	
	Max	283.4	306.7	306.7	314.4	318.9	319.6	315.2	315.1	312.3	315.5	318.4	319.6	
Greens in Regulation	*Mean*	68.5	66.3	67.4	65.0	64.9	65.2	64.6	64.8	65.0	66.9	65.5	65.2	0.8%
	Std. Dev.	5.4	2.9	4.4	2.8	2.8	2.7	2.5	2.6	2.6	2.6	2.5	2.7	
	Min	52.4	57.3	52.4	54.7	55.5	56.9	54.3	57.8	51.3	57.9	59.5	51.3	
	Max	82.3	74.5	82.3	73.3	71.8	74.1	71.0	71.1	70.9	72.5	71.7	74.2	
Proximity to Hole	*Mean*	-	-	-	35.9	36.0	35.8	35.7	35.5	35.3	34.9	35.5	35.6	-1.1%
	Std. Dev.	-	-	-	1.7	1.7	1.7	1.5	1.6	1.6	1.4	1.5	1.6	
	Min	-	-	-	30.8	31.6	31.6	31.9	31.2	30.7	30.2	32.0	30.2	
	Max	-	-	-	41.7	42.4	40.8	39.7	39.6	40.3	38.3	39.8	42.4	
Scrambling	*Mean*	58.6	59.8	59.2	58.2	57.4	57.5	57.0	57.2	58.3	58.1	57.6	57.7	-1.0%
	Std. Dev.	3.8	3.4	3.7	3.5	3.2	3.2	3.3	3.0	3.7	3.6	3.3	3.4	
	Min	46	48.4	46	42.8	47.8	49.0	48.9	48.4	45.1	47.5	47.9	42.8	
	Max	68.3	69.8	69.8	66.1	64.5	66.5	65.3	64.8	68.2	67.2	65.2	68.2	
Strokes Gained-Putting	*Mean*	-	-	-	0.038	0.017	0.037	0.023	0.024	0.022	0.008	0.042	0.026	10.5%
	Std. Dev.	-	-	-	0.337	0.338	0.327	0.332	0.367	0.402	0.377	0.356	0.354	
	Min	-	-	-	-0.991	-0.843	-0.906	-1.031	-0.985	-1.219	-1.008	-1.102	-1.219	
	Max	-	-	-	0.909	0.922	1.037	0.970	-0.975	0.933	0.871	0.844	1.037	
Events	*Mean*	26.7	26.9	26.8	26.2	26.1	26.1	25.5	25.7	24.4	24.7	24.3	25.4	-7.3%
	Std. Dev.	4.4	4.6	4.5	4.7	4.6	4.6	4.6	4.5	4.0	3.8	3.7	4.4	
	Min	15	14	14	15	15	14	14	15	15	15	15	14	
	Max	36	36	36	36	35	36	36	36	32	32	34	36	
Observations		183	193	376	196	202	196	195	192	188	192	182	1,543	

*Nominal earnings are adjusted to constant 2004 dollars using CPI-All Items from the Economic Report of the President Source: Economic Report of the President, Table B-60, at www.gpo.gov (2012).

Table A.3 - Key Variables Quartile Coefficient of Dispersion from Two Periods, 1992-2001 and 2004 to 2011

Variable		*Pooled 1992 and 2001*	*Quartile Coefficient of Dispersion*	*Pooled 2004 to 2011*	*Quartile Coefficient of Dispersion*
Adjusted Earnings*	*1st Quartile*	173,427	62.8	430,246	54.7
	3rd Quartile	760,199		1,469,513	
	3Q - 1Q	586,772		1,039,267	
	1Q + 3Q	933,626		1,899,759	
Driving Accuracy	*1st Quartile*	64.8	3.7	59.7	5.6
	3rd Quartile	69.8		66.8	
	3Q - 1Q	5		7.1	
	1Q + 3Q	135		126.5	
Driving Distance	*1st Quartile*	260.3	3.6	282.5	2.0
	3rd Quartile	279.6		294.2	
	3Q - 1Q	19		11.7	
	1Q + 3Q	540		576.7	
Greens in Regulation	*1st Quartile*	64.7	4.1	63.4	2.7
	3rd Quartile	70.3		66.9	
	3Q - 1Q	6		3.5	
	1Q + 3Q	135		130.3	
Proximity to Hole	*1st Quartile*	-	N/A	34.5	2.9
	3rd Quartile	-		36.6	
	3Q - 1Q	-		2.1	
	1Q + 3Q	-		71.1	
Scrambling	*1st Quartile*	56.7	4.3	55.4	3.9
	3rd Quartile	61.9		60.0	
	3Q - 1Q	5		4.5	
	1Q + 3Q	119		115.4	
Strokes Gained-Putting*	*1st Quartile*	-	N/A	1.026	18.1
	3rd Quartile	-		1.481	
	3Q - 1Q	-		0.455	
	1Q + 3Q	-		2.507	
Observations		376		1,543	

Source: Author's Calculations
Note: The QCD values are mutiplied by 100

*Due to the nature of the QCD formula, the values for Strokes Gained-Putting were each augmented by the absolute value of the minimum (-1.219) to shift the distribution above zero. Thus, the QCD yields a value which is much more appropriate for comparisons.

Table A.4 - Pooled 2004 to 2011 OLS Regression of PGA TOUR Earnings Adjusted to Constant 2004 Dollars with Robust Standard Errors

Variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*Elasticity Estimates**
Driving Accuracy (%)	-14,913*	-25,740***	-14,180	-13,321	-11,726	-0.65
	(6,881)	(7,539)	(10,229)	(10,241)	(10,233)	
Driving Distance (yards)	38,201***	33,807***	15,967*	16,784*	18,452*	4.70
	(4,673)	(4,624)	(7,519)	(7,558)	(7,546)	
Greens in Regulation (%)	69,066***	88,243***	96,793***	94,581***	91,524***	5.27
	(13,801)	(14,908)	(16,071)	(16,032)	(16,066)	
Proximity to Hole (feet)	-161,217***	-169,154***	-26,345	-29,781	-32,020	-1.01
	(18,648)	(18,469)	(21,305)	(21,353)	(21,186)	
Scrambling (%)	82,682***	85,992***	50,006***	49,827***	49,931***	2.55
	(10,184)	(10,051)	(9,543)	(9,521)	(9,494)	
Strokes Gaines-Putting (strokes)	799,070***	787,629***	867,802***	870,170***	871,790***	0.02
	(86,971)	(85,798)	(95,524)	(95,470)	(95,101)	
Events				11,111	210,191***	
				(5,831)	(52,491)	
Events Squared					-3,987***	
					(1,032)	
Constant	-12,506,493***	-11,713,443***	-10,740,814***	-11,050,347***	-13,758,478***	
	(1,881,300)	(1,851,346)	(2,683,830)	(2,697,684)	(2,745,231)	
Year Effects	No	Yes	Yes	Yes	Yes	
Individual Effects	No	No	Yes	Yes	Yes	
R-Squared	0.33	0.35	0.73	0.73	0.73	
N	1543	1543	1543	1543	1543	

* 95% Confidence Level. ** 99% Confidence Level. *** 99.9% Confidence Level

Note: Standard errors for each estimate is in parentheses and elasticity estimates correspond to full model in column five.

Table A.5 - Pooled 2004 to 2011 OLS Regression of Log PGA TOUR Earnings Adjusted to Constant 2004 Dollars with Robust Standard Errors

Variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Driving Accuracy	-0.006	-0.014*	-0.004	-0.002	0.000
	(0.006)	(0.006)	(0.008)	(0.008)	(0.008)
Driving Distance	0.036***	0.032***	0.006	0.008	0.010
	(0.004)	(0.004)	(0.006)	(0.006)	(0.006)
Greens in Regulation	0.073***	0.090***	0.083***	0.076***	0.073***
	(0.01)	(0.01)	(0.011)	(0.011)	(0.011)
Proximity to Hole	-0.164***	-0.163***	-0.056***	-0.066***	-0.068***
	(0.015)	(0.014)	(0.017)	(0.017)	(0.016)
Scrambling	0.079***	0.084***	0.044***	0.043***	0.043***
	(0.007)	(0.007)	(0.008)	(0.008)	(0.007)
Strokes Gaines-Putting	0.805***	0.788***	0.824***	0.832***	0.833***
	(0.064)	(0.064)	(0.072)	(0.071)	(0.07)
Events				0.034***	0.203***
				(0.005)	(0.045)
Events Squared					-0.003***
					(0.001)
Constant	0.227	0.435	6.055**	5.057*	2.735
	(1.337)	(1.32)	(2.014)	(2.013)	(2.117)
Year Effects	No	Yes	Yes	Yes	Yes
Individual Effects	No	No	Yes	Yes	Yes
R-Squared	0.43	0.447	0.785	0.794	0.797
N	1543	1543	1543	1543	1543

* 95% Confidence Level. ** 99% Confidence Level. *** 99.9% Confidence Level

Table A.6 - Annual OLS Regressions of Log 2004 Adjusted Earnings

	Year							
Variable	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*
Driving Accuracy	-0.026*	-0.021	-0.020	-0.043*	-0.018	0.005	0.031*	-0.018
	(0.012)	(0.019)	(0.016)	(0.019)	(0.015)	(0.021)	(0.015)	(0.017)
Driving Distance	0.023*	0.020	0.019*	0.018	0.049***	0.050***	0.060***	0.038***
	(0.009)	(0.011)	(0.008)	(0.011)	(0.010)	(0.011)	(0.010)	(0.010)
Greens in Regulation	0.139***	0.119***	0.143***	0.049	0.007	0.037	0.018	0.140***
	(0.023)	(0.031)	(0.028)	(0.034)	(0.032)	(0.038)	(0.027)	(0.028)
Proximity to Hole	-0.113***	-0.121**	-0.166***	-0.240***	-0.276***	-0.171***	-0.166**	-0.140***
	(0.033)	(0.040)	(0.041)	(0.051)	(0.039)	(0.048)	(0.050)	(0.037)
Scrambling	0.117***	0.065***	0.056**	0.079***	0.106***	0.063**	0.097***	0.097***
	(0.016)	(0.018)	(0.019)	(0.021)	(0.022)	(0.021)	(0.018)	(0.018)
Strokes Gained-Putting	0.588***	0.773***	1.049***	0.783***	0.691***	0.832***	0.847***	0.618***
	(0.135)	(0.169)	(0.170)	(0.210)	(0.184)	(0.183)	(0.192)	(0.175)
Events	-0.037	0.135	0.014	0.093	0.127	0.419*	0.030	0.126
	(0.087)	(0.117)	(0.080)	(0.125)	(0.125)	(0.183)	(0.155)	(0.135)
Events Squared	0.001	-0.002	0.000	-0.001	-0.002	-0.008*	0.000	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.003)	(0.003)
Constant	-2.781	-0.141	2.419	10.795**	1.954	-6.502	-7.299	-7.619
	(3.540)	(4.300)	(3.462)	(4.069)	(3.881)	(4.580)	(4.181)	(3.955)
R-squared	0.638	0.496	0.502	0.370	0.377	0.450	0.507	0.509
N	196	202	196	195	192	188	192	182

* 95% Confidence Level. ** 99% Confidence Level. *** 99.9% Confidence Level

Table A.7 - ChowTest for Structural Breaks in Parameters from 2004 to 2007 versus 2008 to 2011

Variable	*Pooled 2004 to 2007*		*Pooled 2008 to 2011*		*Pooled 2004 to 2011*	
Driving Accuracy	-12,338	(13,253)	1,299	(14,828)	-11,732	(8,834)
Driving Distance	4,276	(10,240)	54,633 ***	(11,776)	18,464 **	(6,969)
Greens in Regulaiton	123,444 ***	(20,021)	63,526 **	(21,102)	91,523 ***	(13,033)
Proximity to Hole	38,863	(31,924)	-59,217 *	(29,881)	-32,006	(20,302)
Scrambling	52,374 ***	(12,841)	39,941 **	(14,242)	49,939 ***	(8,774)
Strokes Gained-Putting	747,170 ***	(137,841)	789,832 ***	(142,523)	871,840 ***	(87,097)
Events	84,429	(77,544)	341,075 ***	(99,271)	210,228 ***	(53,180)
Events Squared	-1,545	(1,525)	-6,725 ***	(2,023)	-3,988 ***	(1,058)
Constant	12,880,000 ***	(3,568,224)	-23,090,000 ***	(4,035,958)	-13,760,000 ***	(2,402,094)
R-squared	0.84		0.75		0.73	
Observations	789		754		1543	
SSE	1.7174E+14		1.8935E+14		4.8394E+14	
Chow Test stat = 57.6 > critical F9,1525 = 2.41						

* 95% Confidence Level. ** 99% Confidence Level. *** 99.9% Confidence Level

Source: Author's calculations

Note: The regressions are run without robust standard errors because when they are used in Stata, the sum of squared residuals (SSE) is not reported. The Chow test to determine if the pooled 2004 to 2007 parameter estimates are statistically different from the pooled 2008 to 2011 paramter estimates returns a value of 57.6. An explanation of the Chow Test can be found at http://support.sas.com/rnd/app/examples/ets/chow/

Table A.8 - Replication of Alexander & Kern's Comparison of the 1992 and 2001 Estimates, Earnings are in 1982-1984 Dollars

Variable	*1992 Estimates*			*2001 Estimates*			*Pooled 2001 & 1992 Estimates*			*Ratio of 2001 Estimates to 1992 Estimates (Adjusted for the growth in Purse)*	
Driving Accuracy	19,238	***	(2,879)	21,219	**	(6,465)	11,732	*	(4,808)	0.37	0.41
Driving Distance	3,608	*	(1,425))	28,099	***	(5,266)	14,099	***	(2,021)	2.62	2.88
Ironplay	4,177		(3,365)	72,335	***	(11,804)	24,298	***	(5,499)	5.83	6.41
Putting	-3,596,277	***	(396,835)	-8,055,228	***	(1,129,226)	-5,660,941	***	(724,378)	0.75	0.83
Sandplay	4,690	**	(1,737)	16,363	***	(4,219)	13,950	***	(2,498)	1.17	1.29
Chipping	74,858		(195,349)	3,293,372	**	(1,019,390)	1,911,415	**	(605,818)	14.81	16.29
Events	40,815	*	(19,473)	61,648		(50,966)	54,074		(28,953)	0.51	0.56
Events Squared	-832	*	(369)	-1,294		(932)	-1,211	*	(524)	0.52	0.58
Constant	-2,897,249	***	(543,645)	-9,518,107	***	(1,561,372)	-5,092,239	***	(540,648)		
Adjusted R-squared	0.51			0.57			0.47			Purse Adjustment	
SSE	6.1844E+12			1.8959E+13			3.0965E+13			2.97	2.70
Observations	183			193			376				
Chow Test stat = 9.21 > critical F9,358 = 2.46											
Alexander and Kern											
Driving Accuracy	6,464	*	(3,232)	24,790	***	(6,406)	10,600	**	(4,141)	1.29	1.42
Driving Distance	9,870	***	(1,753)	30,662	***	(5,296)	14,765	***	(1,860)	1.05	1.15
Ironplay	22,120	***	(5,614)	80,211	***	(11,361)	48,314	***	(6,555)	1.22	1.34
Putting	-4,432,500	***	(478,672)	-8,504,000	***	(1,113,089)	-6,838,600	***	(735,333)	0.65	0.71
Sandplay	5,909	***	(1,813)	18,657	***	(4,082)	13,559	***	(2,728)	1.06	1.17
Chipping	12,867	***	(3,154)	35,036	***	(9,982)	21,046	***	(6,135)	0.92	1.01
Events	34,618		(19,448)	39,754		(53,005)	47,190		(28,428)	0.39	0.43
Events Squared	-692		(374)	-822		(967)	-980		(524)	0.40	0.44
Constant	-3,236,800	***		-10,227,000	***	(1,458,916)	-4,909,200	***	(597,226)		
Adjusted R-squared	.56			.58			0.55			Purse Adjustment	
Observations	341-N2			341-N1			341			2.97	2.70
SSE	2.2938E+12			1.7625E+13			2.51E+13				
Chow Test stat = 9.25 > critical F9,323 = 2.41											

* 95% Confidence Level. ** 99% Confidence Level. *** 99.9% Confidence Level

Source: Author's calculations and Alexander and Kern, 2004

Note: The regressions are run using robust standard errors, which is equivalent to correcting for heteroscedasticity using White covariance estimator, as was done by Alexander and Kern. The Chow test to determine if the 2001 parameter estimates are statistically different from the 1992 paramter estimates returned a value of 9.21; very near to Alexander and Kern's Chow Test statistic of 9.25. This paper's data supported a purse adjustment of only 2.7, as opposed to Alexander and Kern's suggested 2.97. The results for 2001 to 1992 estimate ratios are presented using both purse adjustments. Alexander and Kern's procedure was followed just as they explain in their paper.

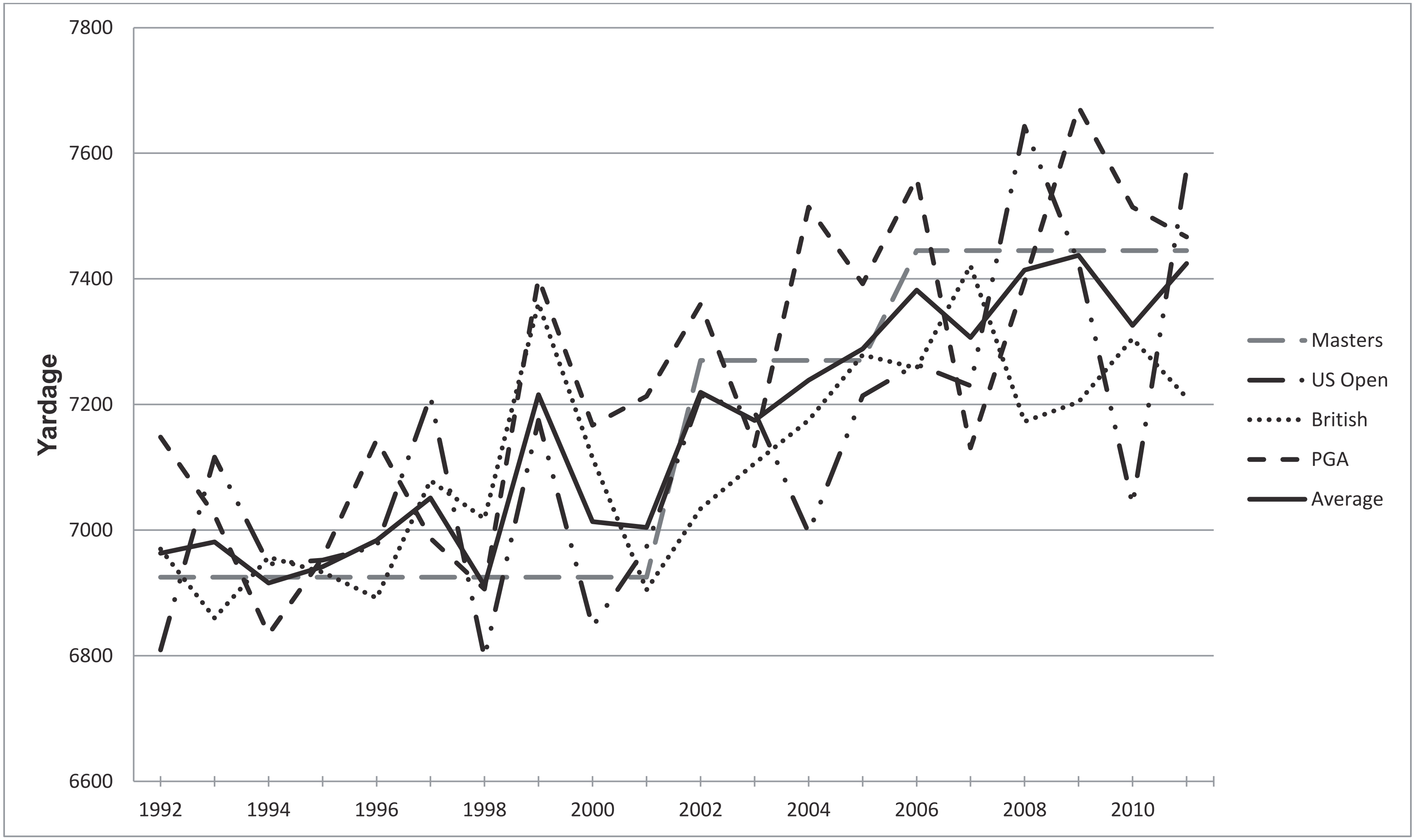
Table A.9 - Pooled OLS Regression with Various Outcome Measures as a Test for Robustness

Variable	*Log Earnings*	*Ranking*	*Top Tens*
Driving Accuracy	0.000	0.076	-0.011
	(0.008)	(0.545)	(0.023)
Driving Distance	0.010	-0.659	0.039*
	(0.006)	(0.422)	(0.018)
Greens in Regulation	0.073***	-4.149***	0.228***
	(0.011)	(0.770)	(0.035)
Proximity to Hole	-0.068***	5.132***	-0.128*
	(0.016)	(1.151)	(0.053)
Scrambling	0.043***	-2.622***	0.125***
	(0.007)	(0.497)	(0.023)
Strokes Gained-Putting	0.833***	-53.748***	2.350***
	(0.07)	(4.926)	(0.229)
Events	0.203***	-14.932***	0.624***
	(0.045)	(3.127)	(0.136)
Events Squared	-0.003***	0.261***	-0.012***
	(0.001)	(0.062)	(0.003)
Constant	2.735	756.783***	-33.606***
	-2.117	-146.928	-6.699
Year Effects	Yes	Yes	Yes
Individual Effects	Yes	Yes	Yes
R-squared	0.797	0.761	0.68
N	1543	1543	1543

* 95% Confidence Level. ** 99% Confidence Level. *** 99.9% Confidence Level

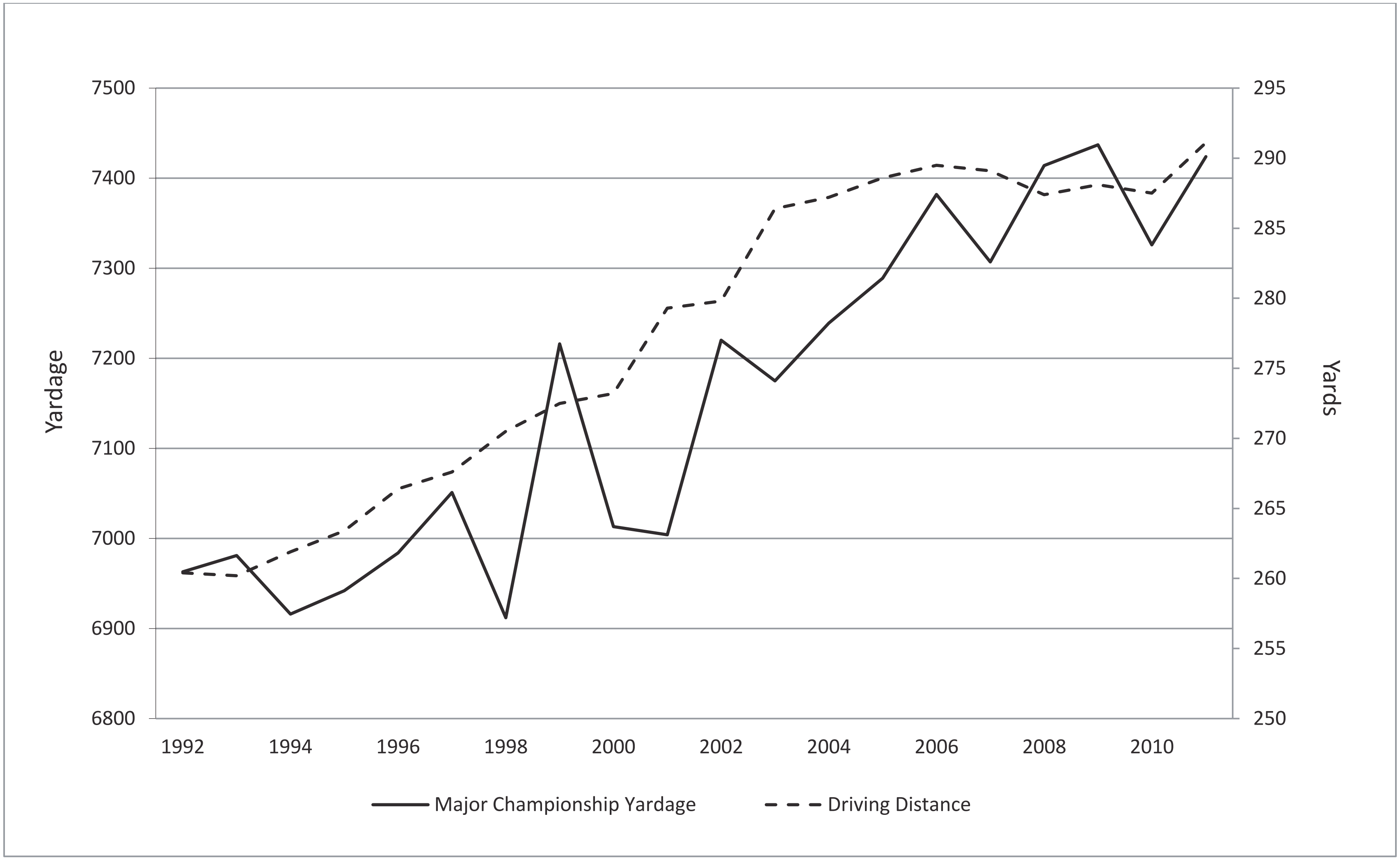
APPENDIX B

Figure B.1 - Average Major Championship Yardage vs Average PGA Tour Driving Distance, 1992 to 2011



Source: Yahoo Sports at sports.yahoo.com/sports

Figure B.2 – Average Major Championship Yardage vs. Average Driving Distance, PGA Tour from 1992 to 2011



Source: Yahoo Sports at www.sports.yahoo.com/sports and author's calculations with data from the PGA TOUR at pgatour.com/r/stats/