

## Abstract

McFALL, TODD ALAN. Creating the Hot Hand Effect with a Grand Prize. (Under the direction of Charles Knoeber.)

My dissertation is titled “Creating the Hot Hand Effect with a Grand Prize.” It develops a theory of how the addition of a grand prize for performance in a sequence of tournaments affects agents’ effort and participation decisions. The theory’s predictions are empirically tested with data from the Professional Golfers’ Association (PGA) Tour.

The theoretical model examines choices made by two identical players who compete in two different three tournament “seasons.” The first type of season provides a prize to the winner of each tournament, while the second type provides an additional grand prize to the overall winner. The model yields three testable hypotheses. First, the effort exerted by each player and the likelihood of participating in a tournament are constant across each tournament in the season without a grand prize. Second, effort and the likelihood of participation is larger throughout much of a season with a grand prize relative to a season without a grand prize because both the payoff to winning and the opportunity cost of not participating in a tournament increase with the addition of a grand prize. Finally, the key finding of the model is that the introduction of a grand prize by the principal *induces* a “hot hand effect.” Specifically, the incentives that players face diverge in the middle of the season because the player who has early success (was lucky) in the first tournament of the season has a larger payoff to winning the second tournament of the season because only he can win the grand prize early and avoid the late season effort costs that are associated with winning the grand prize. So, the winner of the first tournament is more likely to also win the second tournament even though both players are equally skilled.

These theoretical predictions regarding performance and participation are tested with data from the Professional Golfers’ Association (PGA) Tour. An invitation to the season-ending Tour Championship event, created in 1987, acts as the PGA Tour’s “grand prize.” Golfer performance and participation is generally consistent with the theoretical predictions in seasons with (after 1987) and without (before 1987) the Tour Championship.

# Creating the Hot Hand Effect with a Grand Prize

By: Todd A. McFall

A Dissertation Submitted to the Graduate Faculty of  
North Carolina State University  
in Partial Satisfaction of the Requirements  
for the Degree of Doctor of Philosophy

Department of Economics  
2005

Approved by:

---

Dr. Lee A. Craig

---

Dr. Charles R. Knoeber  
(Chair)

---

Dr. Walter N. Thurman

---

Dr. Tomislav Vukina

## Biography

Todd A. McFall was born to Melvin and Elizabeth McFall in Fort Wayne, IN on September 19, 1974. He graduated from R. Nelson Snider High School in 1993 and attended Miami University in Oxford, OH, where he graduated with a B.S. in Social Studies Education. After attending Miami, he taught high school mathematics in Danville, IL and Wilmington, NC. He entered N.C. State's Ph. D program in 1999 and started teaching in the Department of Economics at Wake Forest University in August of 2004.

## Acknowledgements

I am as shocked as anyone that I have finished a dissertation in anything. This fact no doubt means that there are plenty of people who need to be thanked. Without their help, I know I would not have finished this project. First, there are several professors in the N.C. State Department of Economics that have offered insight and support while writing this dissertation or taking classes at the university. In particular, Chuck Knoeber offered support of a silly idea and helped me in many ways to make it blossom into something presentable. Wally Thurman helped me scale many theoretical and empirical brick walls. They have offered patient explanations, helpful suggestions, and constructive criticism over the past three years. Thanks to both men for walking that fine line of not hurting my feelings and pushing me to do better. I know the line can be mighty fine at times! (I still do not think that Wally considers golf a sport, though.)

Additionally, Professors Steve Margolis, Lee Craig, Tom Vukina, Jim Easley, David Flath, Doug Pearce, John Seater, Steve Allen, and Mike McElroy have all offered their expertise at various times over the past five years. My colleagues at Wake Forest have offered tremendous support in helping me make the transition from grad student to something resembling a professor. Finally, Professors Mike Curme, Mike Fuller, and Johnny Hill of Miami planted seeds of interest in economics and teaching and Laura Menzie planted seeds of interest in learning many years of ago.

Second, the data I use in this dissertation were not easily found. Once I figured out where to locate the results I needed help from the good people at the U.S. Golf Association in Far Hills, NJ, the PGA Tour headquarters in Ponte Vedre, FL, and the Wilson Library at the University of North Carolina-Chapel Hill.

Third, and I know everyone says this, but I think I have the best friends in the world. I cannot think of better colleagues to have gone through grad school with than my friends at NC State. To name names would mean I would leave some out, and I do not want to do that, but here it goes—Claudiney, Parker (you're always Parker to me!), Varun, Kshama, Olga, He, Beth, Erin, Tory, Hulya, AD, Peyton, Allie K, Adrian, Bailey, John, Brandon, and DKL. My friends who are not necessarily interested in economics, but are interested in me also need thanking because they have heard and asked about this for quite a while. Action, RPK, Foley, the guys on SOA, Wings, CCC, madge, the Whittons, the Denglers (my Christmas '01 savers), the mighty CD, Ford, Big B, Marty, KRahn, and Loomis. You all have provided the necessary support that makes life easier or the late night rabble-rousing/early morning golf that makes life more fun.

Finally, Mom, Dad, and Lo have been the best through all this. You were the ones who said, "Go do it!" and you were the ones who said, "Keep going!" throughout the entire process. Thanks a million! I love you!

## Table of Contents

List of Tables .....	vii
List of Figures.....	viii
1. Chapter I-	
A. An Overview of the Dissertation.....	1
B. Tournaments through the Eyes of Economists.....	3
C. The Professional Golfers’ Association (PGA) Tour before and after the Tour Championship.....	5
D. Findings.....	8
E. Plans for Research.....	11
2. Chapter II- Related Literature.....	13
A. Theoretical Studies of Tournaments.....	13
B. Empirical Studies of Tournaments.....	17
C. Hot Hand Studies.....	20
D. Original Ideas in this Dissertation.....	22
3. Chapter III- A Theoretical Explanation of how a Grand Prize affects Effort and Participation decisions in a Series of Tournaments.....	23
Section 1: Modeling Effort in Two Types of Seasons.....	25
Section 1a: Effort in a Season without a Grand Prize is Constant.....	26
Section 1b.1: Third Tournament Effort in a Season with a Grand Prize.....	28
Section 1b.2: The Hot Hand Effect is Created- Second Tournament Effort Choices are Unequal.....	30
Section 1b.3: First Tournament Effort in a Season with a Grand Prize.....	39

Section 1c: Comparing Effort in the Two Seasons.....	40
Section 2: Participation Changes when a Grand Prize is Offered.....	41
Section 3: Conclusion.....	44
4. Chapter IV- Empirical Tests of the Theory with Data from The Professional Golfers' Association.....	46
Section 1: Using PGA Tour Data to Test the Theory.....	46
Section 2: Description of Data.....	51
Section 3: Analyzing Performance.....	55
Section 4: Analyzing Participation.....	74
Section 5: Sources of Error.....	89
Section 6: Conclusion.....	91
5. Chapter V- Conclusion.....	94
Appendix.....	97
References.....	99

## List of Tables

Table 1: Opportunity Cost of Not Competing in a Tournament in a Season with a Grand Prize.....	43
Table 2a-2d: Ranking Distance and Money Distance in Seasons with and without the Tour Championship.....	54
Table 3a-b: Performance in Seasons with and without the Tour Championship.....	57
Table 4: Scores are better in seasons with the Tour Championship.....	58
Table 5: OLS Results using Equation 1.....	65
Table 6: Predictions 2 and 4 are accurate when ranking distance is used.....	68
Table 7: OLS Results using Equation 1a.....	69
Table 8: OLS Results using Equation 2.....	71
Table 9: Prediction 2 is supported.....	73
Table 10: OLS Results using Equation 2a.....	74
Table 11: Participation in Seasons with and without the Tour Championship.....	76
Table 12: Participation <u>does</u> change after the Tour Championship is created.....	77
Table 13: Logit Results using Equation 3.....	83
Table 14: Participation Decisions changed as both types of seasons progressed (ranking).....	85
Table 15: Logit Results using Equation 4.....	87
Table 16: Participation decisions changed as both types of seasons progressed (money).....	89

## List of Figures

Figure 1: The Grand Prize's Effect on Third Tournament Effort.....	30
Figure 2: Second Tournament Nash Equilibrium.....	35
Figure 3: Second Tournament Optimal Effort.....	35
Figure 4: The number of players who view the Tour Championship as an incentive decreases as a season progresses.....	51
Figure 5: The Tour Championship changed the incentives faced by PGA Tour players who were ranked in the Top 30 on the money list.....	56
Figures 6a-d: The relationship between a player's score and his ranking distance changes after the Tour Championship was created.....	66
Figures 7a-d: The relationship between a player's score and his money distance changes after the Tour Championship was created.....	71
Figures 8a-d: The Relationship between Ranking Distance and Participation.....	83
Figures 9a-d: The Relationship between Money Distance and Participation.....	87

## Chapter 1- An Overview of the Dissertation

### **A. The Tour Championship- another grand prize in a series of contests**

In 1987, the Professional Golfers' Association (PGA) Tour created a season-ending tournament for elite players called the Tour Championship. An invitation to this tournament is a prize awarded to a player who earns enough money to be in the top 30 on the PGA Tour's money list. The creation of this tournament not only transformed the PGA Tour from a series of largely independent tournaments into a series of tournaments that were linked together by the Tour Championship, but it also caused the PGA Tour's season to look like many other sports leagues' seasons. Instead of being just a series of contests, each with its own prize, the PGA Tour became a series of contests with a grand prize, which is awarded based upon cumulative performance.

This type of incentive structure is a familiar concept to anyone who follows sports, as nearly all major sports leagues' seasons are constructed in the same manner. Most leagues in North America have a regular season which determines who wins a chance to participate in the leagues' postseason playoffs, a type of grand prize. The playoffs then determine which participant will win the ultimate grand prize, the title of league champion for the season.

For instance, Major League Baseball has used this format for over 100 years to determine its champion. Teams play a 162 game regular season from early-April to late-September. Since 1995, the eight best teams then play a three-round single elimination tournament in which each round is a best-of-five or best-of-seven game tournament. The winner of the post-season tournament is declared World Series champion.

The use of a grand prize as an incentive is not exclusive to sports leagues. The internal labor markets of firms and the competition to gain intellectual property have all been characterized as a series of contests to win a grand prize. For workers in firms, a grand prize can be anything from being declared president or chief executive officer of the firm to being granted a promotion with a more prestigious title and/or a larger salary (Rosen 1992). The success of the competitors in the U.S. pharmaceutical market is almost completely dependent upon earning patents on discoveries which can be used to create new drugs. The competition between firms to acquire these patents amounts to a sequence of contests with a grand prize (Fudenberg and Tirole 1987).

The goal of this dissertation is to analyze the effects of grand prizes by theoretically and empirically answering two questions. The first question is: How do agents' optimal effort choices in a series of tournaments change when a grand prize is introduced? The second is: How does the likelihood of participation in a particular tournament in a series of tournaments change when a grand prize is introduced? Answers from a theoretical model are tested by examining the effect of the introduction of the Tour Championship into the Professional Golfers' Association (PGA) Tour.

There are five chapters in the dissertation. This chapter provides an overview of the dissertation by giving a brief synopsis of prior studies of tournament theory, a description of the PGA Tour, a short summary of the theoretical and empirical findings of the dissertation, and a presentation of ideas for future research on this topic. The second chapter reviews related theoretical and empirical studies of tournaments and empirical studies of the hot hand. The third chapter presents a theoretical model that describes how the optimal effort decisions and the participation decisions of contestants in a series of

tournaments are affected by the existence of a grand prize. The fourth chapter tests the efficacy of the theoretical findings with data from the PGA Tour. The fifth chapter offers concluding remarks.

### **B. Tournaments through the Eyes of Economists<sup>1</sup>**

With perfect monitoring, a worker (or an agent) is paid a wage equal to his marginal product of labor. Often, however, a worker cannot be monitored perfectly by a supervisor. This leads to asymmetric information between the supervisor (principal) and the worker (agent) regarding how much effort the worker is exerting. This asymmetry, in turn, distorts the incentives the agent faces to exert effort and leads to inefficient outcomes in labor markets.

There are many ways to mitigate the asymmetry, which is known as the principal-agent dilemma. Agents can be paid by a piece rate method, with a salary, can be pitted against each other in a tournament, or by some combination of the three. Ultimately, the mechanism that is optimal for the principal depends upon the intricacies of the production process. Green and Stokey (1983) showed that piece rate contracts are superior to tournaments when shocks to the production process are largely idiosyncratic and thus different for the agents producing the good. On the other hand, a tournament is superior to a contract when the production shocks are largely common and affect all agents equally. With a tournament, shocks are differenced out and the agents' effort choices and talents determine how much each agent is paid.

Lazear and Rosen (1981), Rosen (1986), Fudenberg and Tirole (1987), Baik (1994), and Ferrall and Smith (1999) all develop certain aspects of tournaments, some of

---

<sup>1</sup> The discussion below is meant to be only a brief introduction to tournament theory. A more detailed discussion can be found in Chapter 2.

which are central to this dissertation. These ideas are: a) agents' optimal effort decisions in a tournament are related to the spread between the prizes given to the winner and loser of the tournament, not the level of prizes, b) a potential consequence of using a tournament is that players "fake" their ability levels in order to play in tournaments that offer large prizes, c) the size of grand prize given to the winner of a single-elimination rank order tournament can affect optimal effort choices at every stage of the tournament, d) differences in players' relative ability levels can be overcome by differences in players' valuations of prizes, and e) the incentives to exert effort that identical contestants face in a sequence of tournaments can diverge.

Economists have applied tournament theory to studies of many real-world phenomena. Corporate pay structures, agriculture commodity production, contracts in the financial industry, and, of course, sports have all been studied using the framework of tournament theory.

Erickson (1999), Bebchuk, Fried, and Walker (2002), and Rosen (1992) all use tournament theory to describe CEO pay in various economies around the world. Knoeber and Thurman (1994) study the use of tournaments in poultry production and find support for several predictions in these markets. Finally, economists have used tournament theory to study sporting contests. Ehrenberg and Bognanno (1990a and 1990b) and Orszag (1994) study the pay structure of professional golf tournaments and its effect on the performance of golfers in these tournaments. The studies by Ehrenberg and Bognanno provide evidence supporting tournament theory, while the study by Orszag does not. Scymanski (2004) is a summary of these and other studies of tournaments in the sporting world.

### **C. The PGA Tour before and after the Tour Championship**

Every season, the Professional Golfers' Association (PGA) Tour consists of approximately 150 golfers who compete from mid-January to early-November. In every season since 1981, the PGA Tour has sanctioned around 50 worldwide events. However, in any particular season, only about 40 of these can be characterized as a "typical" PGA Tour event. These "typical" tournaments are included in the dataset used in Chapter 4. A typical tournament starts with 156 golfers who play two 18-hole rounds. After two rounds, approximately the highest scoring half of the field is cut and the remaining competitors play two more rounds. After the completion of four rounds, the purse for the tournament is allocated to those golfers who survived to play all four rounds. The purse for each tournament is divided in the same manner. The winner of the tournament, who is the golfer with the lowest score for the 72-hole tournament, receives 18% of the tournament's purse. The golfer who shoots the second lowest score receives 10% of the purse, the third place golfer receives 6.8% of the purse, and so on to the last place golfer who survives the midway cut. He receives 0.2% of the total purse. The largest purse for the 2004 season was for the Tour Players' Championship, which takes place every March in Florida. The TPC had a purse of \$8 million in 2004. There were three tournaments that offered a purse of \$3 million, which was the smallest purse of the season. (pgatour.com) In general, the events with the largest purses are the events with the best fields and are the most prestigious events.

The fields for PGA Tour events are determined by a number of criteria. First, the PGA Tour keeps a running total of each player's money earnings for the season. The ranking is updated after every tournament. At the end of the season, the top 125 players

are granted full exemption status for the next season. These 125 players can play in any tournament they choose for the coming season.<sup>2</sup> There are also other exemption rules that are either stronger or weaker than the money list exemption. For instance, a player who wins a PGA Tour event earns a two-year exemption to all events, no matter where he finishes on the Tour's money list. On the other extreme, a player can earn a one week exemption to a tournament if he finishes in the top ten in the tournament that was played in the prior week. (pgatour.com)

The basic shape of the PGA Tour's season and the incentives it provides to players have remained essentially unchanged for over two decades. While it is true that some tournaments have been added to the schedule and some tournaments have been dropped from the schedule, neither the length of the season nor the exemption rules have been altered substantially. However, since 1987, the PGA Tour has implemented two major changes which should affect the incentives that golfers face. First, the value of purses in real terms has increased dramatically in the past two decades. In 1983, the purse for a typical tournament was approximately \$500,000, which meant that the winner of the tournament received about \$90,000. By 2004, the average nominal value of a purse was approximately \$5 million, which, in 1983 dollars, is approximately \$2.63 million. This translates to an increase in real purse value of over 500 percent (pgatour.com) and increased the difference between winning and losing a tournament.<sup>3</sup>

---

<sup>2</sup> This rule has been in effect since 1981. As with any other rule there are exceptions. For instance, the PGA Tour sanctions tournaments like The Masters and the US Open. However, these tournaments determine their fields in a manner that is entirely different from the other events.

<sup>3</sup> Tournament theory predicts that effort grows as the difference between winning and losing grows. However, as is discussed briefly in the empirical section, the rising purses levels likely have created wealth effects which may confound this.

The second major change to the PGA Tour's schedule is the addition of the Tour Championship in 1987. The Tour Championship is a year-end tournament to which the top 30 money winners are invited.<sup>4</sup> Because the value of the purse is large and the field is typically among the finest in all of golf, the Tour Championship is considered a prestigious event. For instance, in 2004, the purse for the Tour Championship was \$6 million, which, in terms of purse size placed it in the upper quarter of tournaments. That year's winner, Retief Goosen of South Africa, won over \$1 million, which was about 30% of the total prize money he had earned for the entire season up to that point. The win also was a feather in the cap of Goosen because he earned it by beating a very strong field of golfers. The other difference between the Tour Championship and a typical event is that every player who is invited to the event receives prize money because no players are cut at the halfway point in the Tour Championship. The last place finisher in the 2004 Tour Championship, Kenny Perry, received over \$92,000 for his efforts, which was about 5% of his season earnings. Thus, just gaining a spot on the Tour Championship can be a tremendous financial and emotional reward for professional golfers.

The Tour Championship changed the dynamic of the entire PGA Tour season because an invitation represents a grand prize that is earned by beating other players in a series of tournaments. Prior to the creation of the Tour Championship, the PGA Tour season consisted of events which were more or less independent of one another. The only common denominator the events shared was the exemption incentives set forth by

---

<sup>4</sup> The Tour Championship was originally called the Nabisco Championship. The field for the Nabisco Championship consisted of the top 30 winners of Nabisco points. These Nabisco points rankings were highly correlated with money winnings. This entry procedure was stopped in 1991. Since then, the top 30 money winners have been invited to the event.

the PGA Tour.<sup>5</sup> The Tour Championship transformed the PGA Tour season by linking all of the events together. Starting in 1987, the reward for playing well in a tournament was not just the money earned in that tournament, but it was also an increased likelihood of earning an invitation to the Tour Championship. However, the strength of this incentive is not equal across all golfers. As the PGA Tour's season progresses, the very successful player and the very unsuccessful player both quit viewing the Tour Championship as an incentive because one has clinched a spot in the tournament and the other has eliminated himself from the tournament altogether. On the other hand, the incentive is strongest for players who are on the cusp of qualifying for the Tour Championship.

#### **D. Findings**

This dissertation shows that a grand prize links together a sequence of tournaments because players base their optimal effort choices not only on the prize offered in the current tournament, but also on their chance of winning the grand prize. Thus, the addition of the grand prize in a sequence of tournaments affects both the effort choices and participation choices of participants at nearly every stage of the sequence.

The most important theoretical finding is that a grand prize induces serial correlation between the results of the early and middle tournaments. This *hot hand effect* exists because players with early success (good luck) have a greater incentive to work harder in the middle tournaments than contestants with less early success (bad luck). This reason is that the player with early success can clinch the grand prize with success in the middle of the sequence and avoid the high effort costs associated with winning the

---

<sup>5</sup> The money list exemption incentive still does not affect many golfers. In any given season, only a few players are close to 125<sup>th</sup> on the money list and in jeopardy of losing or gaining their exemption status for the following season.

grand prize at the end of the season. For the player without early success, exerting effort in the middle of the sequence increases the chance that he will face the large effort costs associated with winning the grand prize late in the series. On the other hand, the tournaments in a sequence without a grand prize are independent of each other because the incentive to exert effort is constant across each tournament in the sequence, assuming that the prize offered in each tournament is constant. The relationship between a grand prize and the existence of a hot hand effect in a sequence of tournaments has not been discussed in other studies of tournaments.

A second theoretical finding is that a grand prize induces players to exert at least as much effort in every tournament of the sequence in which the grand prize has not been clinched because the marginal benefit of exerting effort is larger when a grand prize is offered. (The second tournament effort choice of the loser of the first tournament is a possible exception to this.)

The theoretical model also permits a calculation of the opportunity cost of not competing in any one of the tournaments in a sequence of tournaments. From these calculations, three conclusions regarding participation can be drawn, which mirror the conclusions about performance. First, throughout a sequence without a grand prize, the opportunity cost of not competing is constant, which means that the probability of a player not competing in a tournament is constant so long as the prize offered remains constant. Second, except for the second tournament of the loser of the first tournament, the probability of a player competing in a tournament at any point in a season with a grand prize is equal to or larger than the probability of a player competing in a tournament at the same point of a season without a grand prize. Finally, the opportunity

cost of not participating in a mid-season tournament in a sequence with the grand prize is largest for the player who has the most early season success, which implies that the player with early success is more likely to participate in a mid-season tournament.

These theoretical findings regarding effort (or performance) and participation are tested with data from six PGA Tour seasons. Three seasons have the Tour Championship, a grand prize, and three seasons do not. Results offer some support for a hot hand effect in seasons with the Tour Championship as players highest on the money list performed best in mid-season tournaments after controlling for player ability. Also, golfers scored better (lower) in seasons with the Tour Championship (although technology and rising purse levels could account for this) and performance was constant for golfers throughout seasons without the Tour Championship.

Empirical results also show some support for the theoretical predictions regarding participation. For instance, in seasons with the Tour Championship, players who were ranked higher on the mid-season money list were more likely to play in a mid-season tournament compared to players ranked lower on the money list. However, in the late stages of a season, the highest ranked players became less and less likely to participate compared to the players who were closest to 30<sup>th</sup> place on the money list because the highest ranked players had clinched their spot in the Tour Championship and were no longer incentivized by the chance of gaining an invitation to the tournaments.

Unexpectedly, in seasons without the Tour Championship, players' rankings on the money list affected the probability of competing in a tournament. This runs counter to the theoretical prediction that the probability of participating in a tournament will be unrelated to a player's ranking on the money list in a season without the Tour

Championship. However, many of the observed patterns can be explained by wealth effects.

### **E. Plans for Future Research**

The empirical findings of this dissertation offer enough support of the theoretical model to warrant further study of the use of grand prizes by organizations. Past studies of the hot hand effect, which have mainly been done by psychologists and statisticians, have largely searched for serial correlation between contestants' trials ("trials" means games, shots, rolls, etc...) or significant deviations from Bernoulli binomial distribution results within the sample of trials. This dissertation shows that the premium a player can receive from winning a grand prize early in a sequence of tournaments deserves attention in future studies of the hot hand theory. Because there are so many forums that offer grand prizes to contestants, the possibilities for cross-organizational studies are plentiful.

Second, this dissertation focuses on the agents' responses to a change in incentives offered by the principal. However, it is entirely possible to study the use of the grand prize from the principal's perspective. Again, there are many organizations that have adopted the use of the grand prize or have changed the way the grand prize is awarded, presumably because they can earn more profit by doing so. Perhaps organizers recognize that the media attention to players who appear to be on a hot streak generates interest in the sport or that the demand for viewing a sport is affected by the number of teams or players who can earn a grand prize. Regardless of the reason for using the grand prize as an incentive in a sequence of tournaments, grand prizes are becoming more prevalent and deserve careful study. Possible avenues include theoretical and cross-organizational studies which analyze the method of awarding the grand prize, the size of

the grand prize, and/or its effect on the demand for the product that is produced by the organization that is awarding the grand prize.

## Chapter II- Related Literature

### A. Theoretical Studies of Tournaments

Without a properly designed mechanism, information asymmetries that exist between employers (often known as principals) and employees (agents) can create inefficiencies in labor markets. In a larger context, this dissertation adds to the discussion of how the ill effects of these information asymmetries can be mitigated.

Principals can employ several mechanisms to minimize the inefficiency caused by information asymmetry. Their choice inevitably depends upon the intricacies of production. In this dissertation, chief among these factors is the role idiosyncratic shocks play in the production process.

Green and Stokey (1983) discuss the role random shocks play in constructing proper incentives for agents and show that tournaments can be more efficient than piece rate contracts when shocks are common to the output of all agents. Here, shocks affect the employees equally and have no effect on relative performance. In turn, this makes the ranking of employees by performance a function of effort and skill, and not just luck. This idea is discussed in Holmstrom (1979) and is developed in Grossman and Hart (1983) and Nalebuff and Stiglitz (1981). Gibbons (1998) and Baker, Jensen, and Murphy (1988) summarize the theoretical knowledge about incentives in organizations, discuss incentives provided by organizations that are not explained by economic theory, and offer questions about incentives in organizations that need further study.<sup>6</sup> Baker, Gibbs, and Holmstrom (1994a, b) and Gibbs (1994) discuss the incentives provided by a specific

---

<sup>6</sup> Baker, Jensen, and Murphy (1988) describes a situation that is modeled below. On p. 600, they write “The incentives generated by promotion opportunities, for example, depend on the probability of promotion, which in turn depends on the identity and expected horizon of the incumbent superior ... Promotion incentives are reduced for employees who have been passed up for promotion previously and whose future promotion potential is doubtful.”

firm. Asch and Warner (2001) discuss the incentives for promotion provided by the US military.

For this work, it is important to note that the PGA Tour uses tournaments to reward golfers partly because most shocks that golfers face (i.e. weather, course set-up, etc) often are common to all golfers in a tournament. In particular, weather, a large part of the random component of golf, plays little role in determining how much one golfer is compensated because compensation is based on *relative* and not *absolute* performance.

The ideas from five theoretical papers on tournament theory are used as stepping stones in this dissertation. These are Lazear and Rosen (1981), Rosen (1986), Fudenberg and Tirole (1987) and Baik (1994), and Farrell and Smith (1999). An extensive review of tournaments can be found in Malcomson (1998) and in Scymanski (2004), which reviews the use of tournaments in sport.

Lazear and Rosen (1981) is the seminal work in tournament theory and develops three results that are key to this dissertation. First, the effort level chosen by a contestant in a tournament is positively related to the difference in the size of the prizes that he would receive for winning or losing the tournament, but not to the level of prizes. For example, if contestants in a tournament receive the same prize regardless of their relative performance, then contestants would exert no effort. On the other hand, contestants who compete for an Olympic medal spend years preparing in hopes of winning because the difference between a gold medal and a silver medal is enormous. Second, Lazear and Rosen (1981) shows that the size of the variance of the idiosyncratic shock affects effort choice. The larger is the variance, the more diminished is the incentive to exert effort and the larger is the incentive for a lesser-skilled player to compete against better players and

hope that luck is on his side. Third, Lazear and Rosen use a Cournot-Nash framework to develop the equilibrium effort choices of contestants.

Whereas Lazear and Rosen (1981) analyze an agent's behavior in a one shot tournament, Rosen (1986), Fudenberg and Tirole (1987), and Ferrall and Smith (1999) examine an agent's behavior in a more dynamic setting. Rosen (1986) shows that contestants' optimal effort choices in every stage of a single elimination rank-order tournament depend upon the prizes offered in the remaining stages. In particular, much of the discussion is about the construction of the grand prize of the tournament. Because players view the option to compete in future rounds of the tournament as an incentive to exert effort in the early contests of the tournament, it is necessary for the difference between the prizes in the final round to be larger than the differences between the prizes in the earlier stages of the tournament. In the final round, there are no more tournaments to be played in the future and no option value of continuing to compete. An extreme example of this is a winner-take-all event in which the only person who receives a prize is the winner of the tournament. Here, the contestants' effort levels increase incrementally from the beginning stages of the tournament to the final stage of the tournament. Rosen (1992) uses this same framework to describe the incentives faced by employees who compete in a promotion tournament in an institution with a triangular hierarchy. Providing disproportionately large prizes at the top of the hierarchy gives incentives to those vying for the top positions in the organization to continue to work hard.

Fudenberg and Tirole (1987) examines the decisions a contestant makes to continue playing in a tournament. Two types of rent-seeking contests are considered.

These differ in the amount of information that is available to the contestants throughout the tournament. One tournament is characterized as a “war of attrition” in which firms stare each other down and wait for the less efficient to exit, while the other assumes that competing firms acquire new technologies that enable them to gain an upper hand against their rivals.

The “war of attrition” model assumes that firms have no information regarding their rival’s technological capabilities. As this type of contest progresses, the least efficient firm will blink and drop out of the race once its costs of winning are so high that it is no longer profitable to continue. The remaining firm becomes the ex-post monopolist. In the other type of contest, firms adopt new technologies and learn about the technology that their rival has adopted, which allows the competitors to update their belief about the probability of victory throughout the contest. Eventually, one firm decides that playing has a negative expected profit and quits.

An example of the first type of contest is an athletic contest in which contestants make effort choices at various stages of the contest. Specifically, marathon runners often drop out if they cannot win because quitting and losing is more profitable than finishing and losing. (Scymanski 2004) On the other hand, markets in which intellectual property is important are an example of the second type of contest. Pharmaceutical firms “race” each other to gain new patents that can be used to manufacture patent-protected pharmaceuticals.

Perhaps Ferrall and Smith (1999), which provides a theoretical and empirical discussion of the behavior of professional hockey, baseball, and basketball teams in a series of postseason contests, is most closely related to this work. A theoretical model is

used to analyze factors that could lead to the existence of psychological momentum<sup>7</sup> in sequential contests and to describe the conditions necessary for a subgame perfect Nash equilibrium to exist in every contest of the sequence. Similar topics are analyzed in this dissertation. However, Ferrall and Smith do not identify the grand prize as the causal factor in creating psychological momentum nor do they explore the reasons for such momentum. In contrast, these ideas are central to this dissertation. The empirical tests of the existence of psychological momentum in Ferrall and Smith (1999) offer little support for the existence of a hot hand in the aforementioned sports. This finding is consistent with most of the other empirical studies which test for the existence of this phenomenon that are mentioned below.

Finally, Baik (1994) addresses the issue of how asymmetric abilities among participants in a tournament affect effort choices; an issue originally considered by Lazear and Rosen (1981). He considers not only the subgame perfect Nash equilibrium that exists in such tournaments, but also shows that the value that players place on the prizes can have as big an effect on the outcome of the tournament as skill levels. This might be defined as the *Rocky* effect because one player is “hungrier” for the prize than the other player.

## **B. Empirical Studies of Tournaments**

Substantial empirical work assesses the predictions of tournament theory. Most of the empirical work tries to estimate how the agents’ performances (or effort choices) are shaped by the incentive structure that the principal uses to provide incentives in the tournament. Obviously, the sporting world has been a fertile laboratory for this type of

---

<sup>7</sup> Psychological momentum is a term that is interchangeable with the hot hand effect. Farrell and Smith (1999) never discuss explicitly the hot hand effect, however.

study. The works most closely related to this dissertation are Ehrenberg and Bognanno (1990a, b) and Orszag (1994). These three papers analyze the performance of professional golfers from various leagues around the world. Ehrenberg and Bognanno (1990a, b) find that players performed better (worked harder) in the final rounds of golf tournaments in which they were near the top of field because of large differences between prizes in the upper echelons of golf tournaments. These studies are consistent with the theoretical predictions of Lazear and Rosen (1981). However, Orszag (1994) was unable to replicate the results of Ehrenberg and Bognanno (1990a, b) with data from a different year and a different golf league. It conjectured that golfers faced too much pressure from the growing value of the purses for which they were playing, which caused them to “choke” in the face of the chance to win a large amount of money in a tournament.

Other sports studies have used data from football, footraces, and motorcycle races to test the theoretical claims of tournament theory. Craig and Hall (1994) conclude that the competition between football players for spots on the rosters of National Football League teams is consistent with the predictions of tournament theory (and that the preseason matters). Maloney and McCormick (2000) find evidence supporting the claim that increased prize spreads cause runners to perform better, while Maloney and Terkun (2002) find that the tight distribution of the performances of the participants in motorcycle racing is affected by the rather small prize spreads that characterize the sport. On the other hand, Lynch and Zax (2000) found that selection effects from sorting are a more important component than effort induced by the prize spread in determining how strong performance is in a particular event as more talented contestants will select only the most lucrative events in which to compete.

Since tournaments are used outside the world of sports, the empirical study of tournaments has extended well beyond the white lines and playing fields of athletic contests. For instance, broiler chicken production was studied by Knoeber (1989) and Knoeber and Thurman (1994). The papers find evidence that is consistent with several of the tenets of tournament theory that are discussed in Lazear and Rosen (1981) and Green and Stokey (1983). First, broiler producers produce more as the spread between payments to producers are increased. Also, the contractor (principal) uses handicapping as a way to level the playing field and enhance incentives of the less efficient producers. Lastly, the tournaments that pit broiler producers against one another are in relatively tight geographic areas. This transfers much of the risk of the production shock away from producers to contractors (Knoeber and Thurman, 1995).

Tsoulouhas and Vukina (2001) also study tournaments in the poultry industry and compare welfare and grower income insurance under fixed performance standards and tournaments. It shows that an unregulated piece rate can decrease grower income insurance and keep grower welfare unchanged if a fixed performance standard is used as a compensation mechanism.

Tournaments serve two purposes in the financial service industry. First, incentives within an organization exist because a portfolio manager's compensation is based partially upon his relative performance to other managers in the organization. Second, incentives within the industry exist because it is quite easy to find rankings that compare the performance of portfolios. Both of these relative performance measures provide incentives to lower-ranked competitors to take more risks relative to higher-ranked competitors during the course of the competition in order to try to improve their

standing. Indeed, Brown, Harlow, and Stark (1996) and Chevalier and Ellison (1997) show that the portfolios of likely “losers” had higher volatility in the latter stages of the annual competition period compared to likely “winners” and that the pattern was more pronounced as the number of competitors and the ease of finding information about relative performance increased. Furthermore, James and Isaac (2000) shows that tournaments can provide incentives that distort prices in asset markets, which, in turn can lead to a misallocation of resources and macroeconomic difficulties. It cites the Federal Savings and Loan problems of the 1980s as an example of how these distorted incentives can lead to undesirable outcomes. On the other hand, Chevalier and Ellison (1999) shows that the portfolios of younger managers tend to be more homogenized and less volatile. This is attributed to the up-or-out promotion systems often used in this industry.

### **C. Hot Hand Studies**

This dissertation also predicts and finds evidence for the “hot hand” phenomenon, which can be defined as the existence of serial correlation between trials in sporting events. Gilovich, Vallone, and Tversky (GVT) (1985) is the seminal work on this subject and is drawn from Kahneman and Tversky (1974), which noted the tendency of humans to incorrectly infer statistical relationships from small sample sizes. GVT (1985) and Tversky and Vallone (1989a, b) find little evidence of serial correlation between results of shooting attempts in basketball and conclude that there is no statistical evidence in support of the hot hand.

Similarly, Clark (2003a) and Clark (2003b) found no evidence of streakiness amongst PGA Tour players, Senior PGA Tour players, or LPGA Tour players. Instead,

the perception of streakiness is attributed to the difficulty of the courses on which competitions were held.

Bowling is one sport in which evidence conflicts with GVT (1985). Dorsey-Palmateer and Smith (2004) and Smith (2003) question the methodology of GVT and find evidence strongly refuting the independence of separate trials (rolls) and of stationarity throughout a game in professional bowling.<sup>8</sup> These results suggest that bowlers' current attempts are affected by prior attempts and that performance is not consistent throughout a game. In other words, bowlers get on a roll more often than can be explained by luck.

As is discussed in the third chapter, a potentially key difference between GVT (1985) and Tversky and Vallone (1989a, b) and Dorsey-Palmateer and Smith (2004) is that there was no grand prize awarded in the studies that analyzed basketball shooting, but there was a grand prize given to the bowlers.

---

<sup>8</sup> The complaint voiced in Dorsey-Palmateer and Smith (2004) and Smith (2003) about GVT (1985) is that part of the study should be ignored because it studies streaky shooting within a basketball game, which is an act that is influenced by too many other variables that are difficult to consider.

#### **D. The Original Ideas of this Dissertation**

Although this dissertation draws closely from earlier work, there are many original ideas in this dissertation. First, this is the first work that identifies and theoretically discusses the grand prize as the cause of the hot hand effect in a season that consists of a sequence of tournaments. Similarly, this work is the first to show that optimal effort in a sequence of tournaments is constant in a sequence without a grand prize. (This assumes that the prize spread is constant in each tournament in the sequence.) The hot hand effect is created because a premium for winning the grand prize early can be earned by the player who is lucky early in the sequence. This premium causes the participants' optimal effort choices to diverge in the middle of the sequence because only the players with early good luck can win the grand prize early and avoid high effort costs associated with playing for the grand prize late in the sequence. In a season without a grand prize, there is no premium to be won, which makes the tournaments in the sequence independent from one another. (Ferrall and Smith (1999) discusses the possible existence of a hot hand effect in a sequence of tournaments, but does not identify the grand prize as the cause of this.) Second, this work is the first to analyze empirically the effect of a grand prize on performance and participation at various segments of a sequence of tournaments. The performance of PGA Tour golfers suggests that a hot hand effect arose between the early and middle tournaments of the PGA Tour season after the Tour Championship was added to the organization's schedule.

## Chapter III- Theory

### **Effort and Participation Decisions are Affected by a Grand Prize**

Many organizations award prizes to individuals based on their performances in a sequence of tournaments. A subset of these organizations not only award prizes for each tournament that is conducted, but also award a grand prize that is based on the participants' performances across all of the tournaments in a season.

For instance, all of the major professional sports organizations in North America not only offer "playoff" spots to a specific number of relatively well-performing teams in a season, but each league deems its champion to be the team that performs best during the playoffs, which is yet another series of tournaments. NASCAR awards the Nextel Cup (formerly the Winston Cup) to the driver who earns the most points in a season. Also, the Professional Golfers' Association (PGA) Tour offers its 30 leading money winners a spot in the Tour Championship, a lucrative season-ending event.

However, the promise of a grand prize at the end of a series of tournaments is not a phenomenon seen only in sports leagues. Salespeople often are given rewards or bonuses for outstanding relative performance over a period of time. Military personnel earn promotions based on their performance relative to other personnel in a series of evaluations. Academic prizes like the valedictorian title or admission to prestigious universities are rewarded to high school students who perform best in a series of semesters. Finally, the two major political parties in the United States determine who their presidential candidate will be based upon which potential candidate performs best in a series of primaries and caucuses.

These examples demonstrate that the use of a grand prize in a sequence of tournaments is a widely implemented incentive mechanism and deserves careful attention. Prior work that has analyzed these types of contests cite the participants' differing skill levels to explain who wins the grand prizes. This paper does not wish to cast this explanation aside. Instead, it proposes a complementary explanation. The incentives that participants face diverge after the early tournaments of the sequence are played.

The purpose of this chapter is to analyze how optimal effort decisions and participation decisions in a competition that is a sequence of tournaments are affected by a grand prize. It is shown that the addition of a grand prize not only causes optimal effort to increase at nearly every stage of a series of tournaments, but also causes the participants who have identical abilities to face unequal incentives to exert effort in the middle of the series. This divergence of incentives causes a "hot hand" effect, or serial correlation between the results of the early and middle portions of the series of tournaments. Thus, early success becomes more critical to success in the entire series when a grand prize is offered because a player's profit for the season is larger the sooner he wins the grand prize. The extent of the existence of this phenomenon can have important implications in human resources departments, in professional sports leagues, and in other organizations that use multiple stage tournaments as an incentive for agents.<sup>9</sup>

---

<sup>9</sup> Some sportswriters have debated the merits of winning a prize early in regular season. For instance, King and Zimmerman of *Sports Illustrated* claim that winning a regular season prize early can be detrimental to the team's playoff success because "they have nothing to play for and they'll get sloppy." In fact, in Week 12 of the 2004 NFL season, Zimmerman predicted that the Atlanta Falcons would lose in the first round of the playoffs because they would be rusty from having nothing to play for in the final stages of the regular season.

This chapter is divided into three parts. The first part presents a model that allows the optimal effort level of the participants to be characterized at all junctures of two types of seasons that consist of three tournaments. The first sequence that is discussed offers a prize to the winner of each tournament, but does not have a grand prize, while the second sequence offers a prize for each tournament and a grand prize. The second section of the chapter discusses the implications regarding participation when a grand prize is added to a sequence. The final section offers ideas for further study and summarizing remarks.

### **Section 1: Modeling Effort in Two Types of Seasons**

This section compares the optimal effort choices of participants at various junctures of two types of “seasons.” Each season consists of three tournaments contested by two agents with identical abilities. Let the three tournaments be identified as tournaments 1, 2, and 3 and the two players named Player A and Player B. Players are risk neutral and try to maximize expected profit for the season by choosing effort prior to each tournament.

The first type of season offers a prize of  $M$  to the winner of each tournament. The loser receives zero. (This is equivalent to saying that the difference between winning and losing is  $M$  in each tournament.) The second type of season offers a prize of  $M$  to the winner of each tournament, zero to the loser of each tournament, and a grand prize of  $G$  to the winner of the most tournaments, which is two tournaments in this instance.

The winner of each tournament is the player who produces the most output  $y$ . Define output to be an additive function of effort and a random “luck” component that has a mean of zero. Prior to tournament  $t$  each player chooses an effort level  $f_t$  for the tournament that maximizes his expected profit for the remainder of the season. In this

setting effort can be thought of as the amount of preparation (practice) in which a player chooses to invest prior to the start of play and/or how much effort a player will exert during a tournament. The random component for a player in tournament  $t$  is denoted as  $r_t$ . Thus, output for a player in tournament  $t$  is given by  $y_t = f_t + r_t$ .

After the players make an effort choice, a probability of victory can be calculated based on the difference between the players' optimal effort choices. Let  $P_{ti}$  denote the conditional probability of player  $i$  winning tournament  $t$ , which is assessed just prior to the playing of tournament  $t$  and is a concave function of effort. A player's cost of effort for tournament  $t$  is given by  $C(f_t)$ . Assume that the cost function is convex in current tournament effort and is the same for each tournament and for each contestant.

### **Section 1a: Effort in a Season with No Grand Prize**

First consider the effort choice of player A prior to the start of the third tournament. Regardless of the results of prior tournaments, he will try to maximize expected profit for the remainder of the season by choosing an effort level for the third tournament. From player A's perspective, expected profit is maximized by choosing  $f_{3A}$  conditional upon  $f_{3B}$  that satisfies

$$\max E(\pi_{3A}(f_{3A}|f_{3B})) = M \cdot P_{3A}(f_{3A} | f_{3B}) - C(f_{3A}).$$

The first-order condition necessary for maximization is

$$\partial \pi_{3A} / \partial f_{3A} = 0 = M \cdot P' - C'. \quad (1)$$

The Cournot-Nash outcome to this game sees player A choose an effort choice of  $f^*$  to satisfy (1). Call the corresponding cost of effort  $C^*$ . Because the players are identical and face the same incentives, it can be concluded that player B will choose the same effort level that player A chooses. Also, because of the nature of the players'

output function, both players have a chance of winning equal to  $\frac{1}{2}$ . Thus, expected future profit for both players prior to the beginning of the third tournament is

$$E(\pi_3) = (\frac{1}{2})M - C^*. \quad (1')$$

Of course, this is the result from Lazear and Rosen (1981) that states that effort will increase with  $M$  because the marginal benefit of effort increases at every effort level as  $M$  increases. This result acts as a benchmark and will be seen throughout much of the rest of the paper.

Backing up a contest to the start of the second tournament, the players make effort choices to maximize expected profit for the rest of the season. Thus, player A chooses an effort level that satisfies

$$\begin{aligned} & \max E(\pi_{2A}(f_{2A})) \\ & = M \cdot P_{2A}(f_{2A} \mid f_{2B}) - C(f_{2A}) + E(\pi_3). \end{aligned}$$

The first-order condition associated with this choice is

$$\partial \pi_{2A} / \partial f_{2A} = 0 = M \cdot P' - C'. \quad (2)$$

Note that equation (2) is identical to equation (1), the first-order condition that described both players' behavior in the third tournament. In this type of season, the effort choice for one tournament has no bearing on the effort choice for other tournaments nor does it affect the expected profit in the other tournaments.

From the above result three conclusions can be drawn. First, the optimal effort for the second tournament is the same as the optimal effort choice for the third tournament. Second, the effort choices made by both players prior to the second tournament are the same, which means that the probability of a player winning the second tournament is  $\frac{1}{2}$ . Finally, because optimal effort is the same for both players in this

tournament, the expected profit for the rest of the season prior to second tournament is given by

$$E(\pi_2) = 2[(1/2)M - C^*] = M - 2C^*. \quad (2')$$

The optimal effort choice for both players in the first tournament can be characterized in the same manner as the effort choices for the other two tournaments. The optimal effort choices for the players in the first tournament is again  $f^*$ , the same as for the other two tournaments. This implies that the expected profit for a player prior to the start of this type of season is

$$E(\pi_1) = (3/2)M - 3C^*. \quad (3)$$

Three conclusions can be drawn about optimal effort in seasons that offer only a prize for each tournament in the season. First, effort will be constant throughout the season. Second, because players are identical to each other and face identical incentives, they will make the same effort choices, and so, third, the probability of winning any of the tournaments in the series is  $1/2$ . All of this means that the results of each tournament in a sequence of tournaments without a grand prize are independent from each other.

### **Section 1b.1: Effort in the Third Tournament in a Season with a Grand Prize**

Now consider a season that offers not only a prize of  $M$  to the winner of each tournament, but also a grand prize of  $G$  to the winner of the most tournaments. Unlike the season previously described, the results of the previous tournaments play a part in determining the optimal effort choice for a player in this type of season.

If, prior to the third tournament, player A has won once and lost once in the previous two tournaments (which means that B is in the same position as A), then his problem is to find an effort level that satisfies

$$\max E(\pi_3^G(f_{3A})) = (M + G)P_{3A}(f_{3A} | f_{3B}) - C(f_{3A}).$$

The first-order condition is

$$\partial \pi_3^G / \partial f_{3A} = 0 = (M + G)P' - C'. \quad (4)$$

Call the effort choice that satisfies this equation  $f_{3H}$ .

The obvious conclusion that can be reached from equation (4) is that  $C_{3H} > C^*$  because the inclusion of the grand prize makes the marginal benefit of effort higher at all effort levels and is analogous to increasing the prize offered to the winner of the third tournament (Lazear and Rosen (1981) and Rosen (1986)).

Also, because player B faces the same incentives as A, it can again be concluded that the effort levels the players choose prior to this tournament are equal. Thus, the probability of winning for each player is equal to 1/2 and the expected profit for both players prior to this tournament is

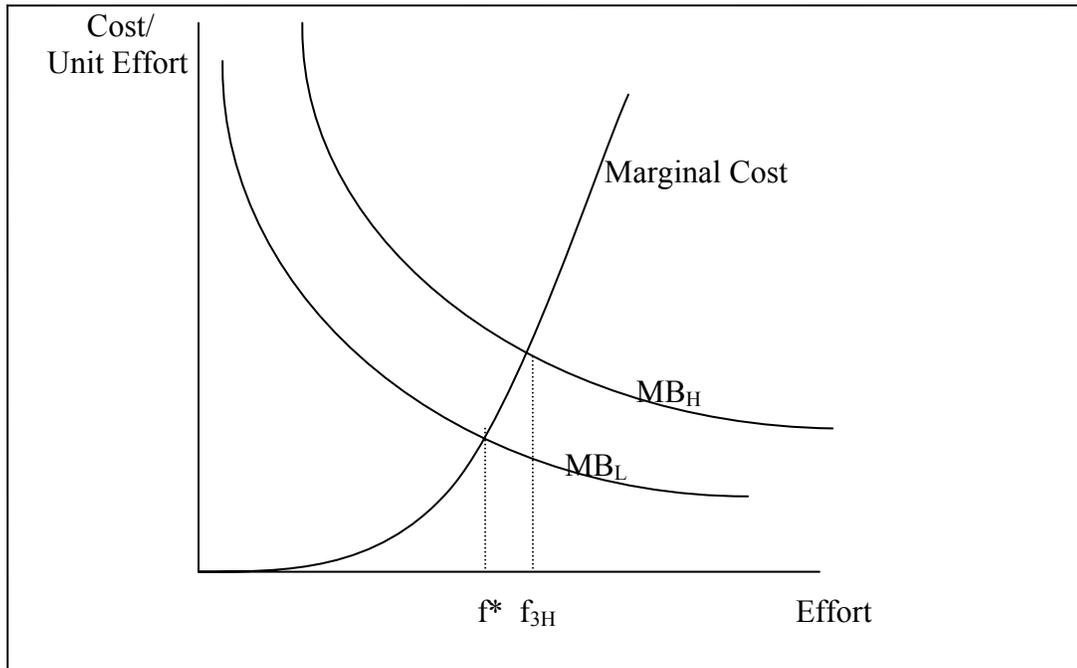
$$E(\pi_3^G) = (1/2)(M + G) - C_{3H}. \quad (4')$$

However, the analysis of the third tournament does not end here. There are two other possible scenarios in which a player could find himself prior to the third tournament. A player could have either won or lost both previous tournaments. It is only necessary to examine one because both scenarios yield the same result.

Assume that player A won both the first and second tournaments of the season. Thus, he has clinched the grand prize G and will contend for only M in the final tournament. Player A's view of this situation is identical to the view he would have if there was no grand prize. He would choose an effort level of  $f^*$  and his expected profit would be  $(1/2)M - C^*$ . (Of course, his effort would be the same if he lost the first two tournaments of the season.)

Figure 1 compares the two possible scenarios in which a player could find himself prior to the start of the third tournament. The marginal benefit of effort when the grand prize is undecided prior to the start of the third tournament is labeled as  $MB_H$ . The marginal benefit when the grand prize has already been won is  $MB_L$ , which is also the marginal benefit in the three tournaments in which no grand prize is offered.

**Figure 1: The grand prize's influence on third tournament effort**



**Section 1b.2: A Hot Hand Effect is Created-  
Second Tournament Effort is unequal in a Season with a Grand Prize**

A player can enter the second tournament having won or lost the first tournament. Players understand that the result of the second tournament determines the effort level they will choose in the third tournament. If the first tournament winner (assume this is player A) wins the second tournament, then third tournament effort for both players will be  $C^*$ . If the first tournament winner loses the second tournament, then third tournament effort will be  $C_{3H}$ . Thus, the prospect of avoiding high effort choices in the last

tournament acts as an *implicit incentive* in the second tournament for player A. By contrast, player B, the loser of the first tournament, is facing the prospect of high third tournament effort costs if he wins the second tournament. So, he faces an *implicit disincentive* to exert effort in this tournament. The difference in incentives causes the players to have different optimal effort choices, and since player A will choose greater effort than player B, the winner of the first tournament will be more likely to win the second tournament, as well. Thus, the first tournament winner appears to have a hot hand.

Player A's effort choice for the second tournament satisfies:

$$\begin{aligned}\max E(\pi_{2A}^{w1}(f_{2A} | f_{2B})) &= (M + G + E(\pi_3))P_{2A}(f_{2A} | f_{2B}) + E(\pi_3^G)(1 - P_{2A}(f_{2A} | f_{2B})) - C(f_{2A}) \\ &= (M + (\frac{1}{2})G + \Delta_3)P_{2A}(f_{2A} | f_{2B}) - C(f_{2A}) + E(\pi_3^G),\end{aligned}$$

where  $\Delta_3 = C_{3H} - C^*$ .

This implies an FOC of

$$\partial \pi_{2A}^{w1} / \partial f_{2A} = 0 = ((\frac{1}{2})(M + G) + \Delta_3)P' - C'. \quad (5)$$

Now, contrast the effort choice of player A to that of player B, the loser of the first tournament. Player B must find an effort level that satisfies

$$\begin{aligned}\max E(\pi_{2B}^{L1}(f_{2B} | f_{2A})) &= (M + E(\pi_3^G))P_{2B}(f_{2B} | f_{2A}) + E(\pi_3)(1 - P_{2B}(f_{2B} | f_{2A})) - C(f_{2B}) \\ &= (M + (\frac{1}{2})G - \Delta_3)P_{2B}(f_{2B} | f_{2A}) - C(f_{2B}) + E(\pi_3).\end{aligned}$$

This implies an FOC of

$$\partial \pi_{2B}^{L1} / \partial f_{2B} = 0 = (M + (\frac{1}{2})G - \Delta_3)P' - C'. \quad (6)$$

A comparison of (5) and (6) makes it apparent that  $f_{2A}^* > f_{2B}^*$ . In this tournament, the *explicit* prizes of M and G offer the players the same incentives to exert effort on the margins. It is the *implicit* incentive to exert effort, which is measured by the term  $\Delta_3$ , that causes the players to exert different effort levels in this tournament.

Although it is clear that player A, the winner of the first tournament, will compete in the second tournament, it is not clear that player B will compete. After all, player A has a larger incentive to prepare for the second tournament than does his opponent. If player B is going to agree to exert an effort level greater than zero in the second tournament, then a pure strategy Nash equilibrium must exist such that the expected profit he can earn from competing in the second tournament is greater than the opportunity cost he faces from not competing in the tournament. This is identical to saying that his incentive rationality constraint must be satisfied.

To explore this issue and the size of the hot hand effect, consider a simple case in which  $r_{2A}$  and  $r_{2B} \sim \text{uniform}(0, (1/2)v)$ . For player A,  $P_{2A} = P(y_{2A} > y_{2B})$   
 $= P(f_{2A} + r_{2A} > f_{2B} + r_{2B}) = P(f_{2A} - f_{2B} > r_{2B} - r_{2A}) = P(\beta > \delta)$ , where  $\beta = f_{2A} - f_{2B}$  and  $\delta = r_{2B} - r_{2A}$ . (Note: Given the assumption that the random component has a uniform distribution, the p.d.f. of  $\delta$  is  $z(\delta) = 1/v + (1/v^2)\delta$  for  $\delta < 0$  and  $1/v - (1/v^2)\delta$  for  $\delta > 0$ .)  
 Assume for both A and B that  $C(f_2) = (D/2)f_2^2$ , where  $D > 0$ .<sup>10</sup> This means player A's expected profit function is  $E(\pi_{2A}(f_{2A} | f_{2B}))$

$$= ((3/2)M + G - C^*) \left( \int_0^\beta [1/v - (1/v^2)\delta] d\delta + ((1/2)(M + G - C_{3H}) (1 - \int_0^\beta [1/v - (1/v^2)\delta] d\delta) - (D/2)(f_{2A})^2 \right)$$

$$= K_A \left( \int_0^\beta [1/v - (1/v^2)\delta] d\delta - (D/2)(f_{2A})^2 + (1/2)(M + G - C_{3H}) \right)$$

where  $K_A = M + (1/2)G + \Delta_3$  and  $\Delta_3 = (2MG + G^2)(vD)^{-2}$ .

For Player B,  $P_{2B} = P(f_{2B} - f_{2A} > r_{2A} - r_{2B}) = P(-\beta > -\delta) = 1 - P_{2A}$ . Thus, his expected profit function is

$$\max E(\pi_{2B}(f_{2B} | f_{2A}))$$

$$= ((3/2)M + (1/2)G - C_{3H}) \int_{-\beta}^0 [1/v + 1/v^2(\delta)] d\delta + ((1/2)M - C_{3H}) (1 - \int_{-\beta}^0 [1/v + 1/v^2(\delta)] d\delta) - D/2(f_{2B})^2$$

<sup>10</sup> If a pure strategy Nash equilibrium is to exist under the assumptions made for this tournament, then costs must be strictly increasing. The quadratic form given in the profit function above is just one of many functions that satisfy this necessary condition.

$$= K_B \int_{-\beta}^0 [1/v + (1/v^2)(\delta)] d\delta - (D/2)(f_{2B})^2 + (1/2)M - C_{3H}$$

$$\text{where } K_B = M + (1/2)G - \Delta_3.$$

Solving  $\partial\pi_{2A}/\partial f_{2A} = 0$  for  $f_{2A}$  and  $\partial\pi_{2B}/\partial f_{2B} = 0$  for  $f_{2B}$  gives

$f_{2A} = K_A(v + f_{2B})(v^2D + K_A)^{-1}$  and  $f_{2B} = K_B(v - f_{2A})(v^2D - K_B)^{-1}$ , the reaction functions for the two players.

These reaction functions bring to light an interesting necessary condition that must be satisfied in order for a pure strategy Nash equilibrium to exist--the variance of the random component must be large enough to induce a positive optimal effort from player B. (More specifically,  $v > f_{2A}$ .) Notice that Figure 3 shows that when this condition is satisfied, “large enough” means that player B could theoretically win the second tournament if  $f_{2B} = 0$ . However, an effort choice of zero cannot be considered a stable outcome for player B because it is not profit maximizing.

The necessity that luck play a big enough role for player B to find it worth his while to prepare should not be strange to someone who pays attention to the rhetoric often heard in athletic tournaments. Whenever a clear favorite exists in a match, one often hears the underdog of the match say things like “You never know what can happen,” or “Anything can happen in one game.” Indirectly, the players who participate in these tournaments are admitting that a relatively high degree of uncertainty exists in their contest. This uncertainty is what gives incentive to prepare to the player who has a relatively small chance to win.<sup>11</sup>

---

<sup>11</sup> The other necessary condition is  $Df_{2B} > K_B/v^2$ . If the variance is not large enough, then a corner solution exists in which  $f_B^* = 0$ . This result only exists here because it is assumed that the random component is distributed uniformly. If the random component has a different distribution (i.e. normal), then this solution does not exist and player B will always find it in his best interest to exert effort greater than zero.)

The role of uncertainty in tournaments has been discussed a number of times. Lazear and Rosen (1981) note two important effects. First, and no doubt most important, for a tournament to be used as an incentive mechanism, there must be enough uncertainty to induce participation in the tournament. Second, the pool of participants in the tournament can be affected by the size of uncertainty in the activity over which the contest is being contested. The less that effort affects performance in a tournament, the higher is the incentive for a lesser-skilled player to enter a tournament against more skilled competition (i.e. a minor leaguer versus a major leaguer). In this model, participation depends upon uncertainty because of the difference of *incentives* faced by the players rather than a difference in the *skill levels* possessed by the players.

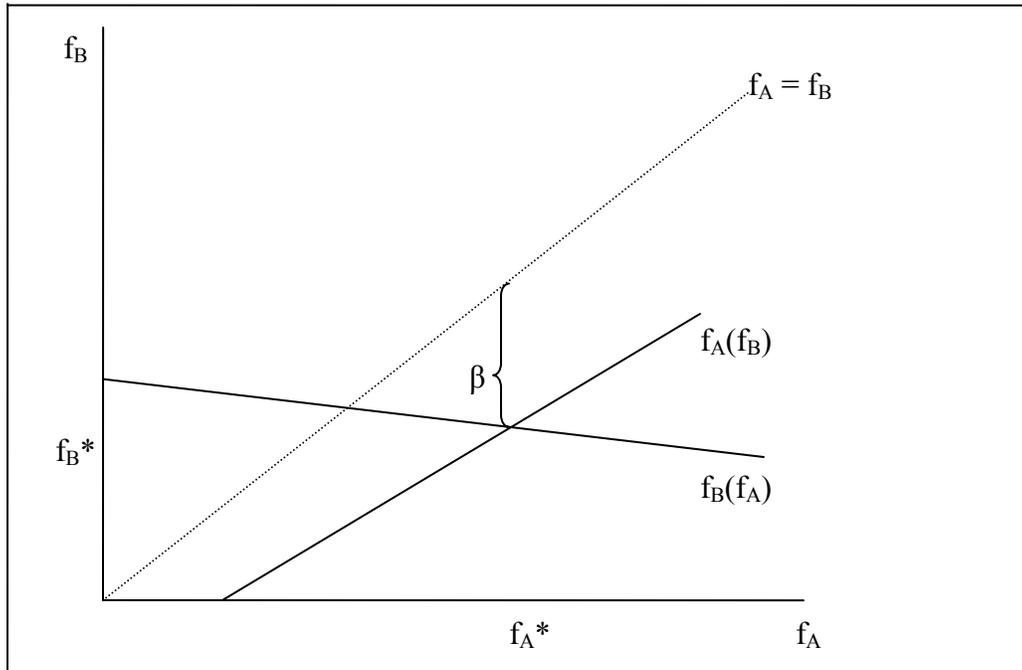
Substituting  $f_{2B}$  ( $f_{2A}$ ) into player A's (player B's) reaction function  $f_{2A}^*$  ( $f_{2B}^*$ ) gives  $f_{2A}^*$  ( $f_{2B}^*$ ), the explicit Nash-Cournot effort choice for player A (player B). These are  $f_{2A}^* = (vK_A)(v^2D + 2\Delta_3)^{-1}$  and  $f_{2B}^* = (vK_B)(v^2D + 2\Delta_3)^{-1}$ , which implies  $\beta = (2\Delta_3v)(v^2D + 2\Delta_3)^{-1}$ . This result is pictured in Figure 2.<sup>12</sup>

Figure 3 shows the optimal effort levels for both players. The marginal benefit of each unit of effort for player A is the vertical distance from the base to the legs of the isosceles triangle formed by points  $f_{2B} + v$ ,  $f_{2B} - v$ , and  $K_A/v$ . The same is done for player B with the triangle formed by  $f_{2A} + v$ ,  $f_{2A} - v$ , and  $K_B/v$ . The intersection of each triangle with the players' marginal cost functions defines the effort levels  $f_A^*$  and  $f_B^*$ .

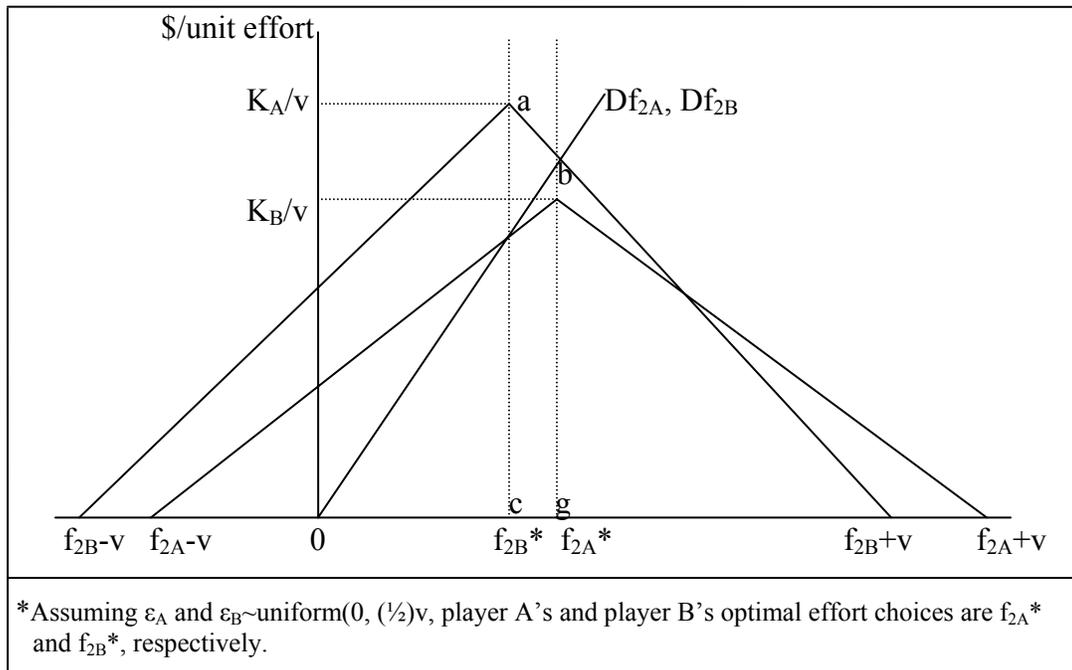
---

<sup>12</sup> The optimal effort choice in all the tournaments in a season without the grand prize is  $f^* = M(vD)^{-1}$ . If  $f_{2L} > f^*$ , then  $G$  must not exceed a certain critical value. This is discussed further in the appendix.

**Figure 2- Second Tournament Nash Equilibrium**



**Figure 3- Second Tournament Optimal Effort**



Using these effort choices, the probability of each player winning the second tournament can be determined. Further, the determinants of the size of the hot hand effect ( $P_{2A} > 1/2$ ) can be explored.

First, the probability of player A winning the second tournament is larger than  $1/2$  because his optimal effort is larger than player B's optimal effort. How much larger this probability is than  $1/2$  is equal to the area of the quadrilateral that is bounded by points a, b, c, and g divided by  $K_A$  in Figure 3. This is equal to  $2\Delta_3(\Delta_3 + v^2D)(2\Delta_3 + v^2D)^{-2}$ .

$$P_{2A} = \lambda = 1/2 + 2\Delta_3(\Delta_3 + v^2D)(2\Delta_3 + v^2D)^{-2} \text{ and}$$

$$P_{2B} = 1 - \lambda = 1/2 - 2\Delta_3(\Delta_3 + v^2D)(2\Delta_3 + v^2D)^{-2}.$$

Three variables influence the probability of a second tournament victory for either player. These are the marginal cost of effort, the size of the variance of the random component of output, and the size of the grand prize.

- The probability of A winning decreases (increases) as effort costs increase (decrease):  
 $\partial\lambda/\partial D = v^4D(D\Delta_3' - \Delta_3)(v^2D + 2\Delta_3)^{-3} < 0$ , where  
 $\Delta_3' = \partial\Delta_3/\partial D = -(2MG + G^2)(v^2D^3)^{-1}$
- The probability of A winning decreases (increases) as the variance of the idiosyncratic component increases (decreases) because the value of exerting effort falls as the importance of luck in deciding the tournament rises:  
 $\partial\lambda/\partial v = 2v^2D^2(\Delta_3'v^2 - 2\Delta_3v)/(v^2D + 2\Delta_3)^{-3} < 0$ , where  
 $\Delta_3' = \partial\Delta/\partial v = -(2MG + G^2)(v^3D)^{-1}$
- The probability of A winning increases (decreases) as the size of the grand prize increases (decreases):  
 $\partial\lambda/\partial G = 2\Delta_3'(v^2D)^2(v^2D + 2\Delta_3)^{-3} > 0$ , where  $\Delta_3' = \partial\Delta_3/\partial G = (M+G)(vD)^{-2}$

To conclude the analysis for the second tournament, the expected profit for the remainder of the season for player A is given by

$$E(\pi_{2A}) = (1/2 + \lambda)M + (1/2 + \lambda/2)G - C_{2H} + \lambda\Delta_3 - C_{3H} \quad (5')$$

The expected profit for player B is given by

$$E(\pi_{2B}) = ((3/2) - \lambda)M + (1/2 - \lambda/2)G - C_{2L} + \lambda\Delta_3 - C_{3H} \quad (6')$$

The most important result is that serial correlation exists across the first and second tournaments in the season. Often known as the hot hand, the idea of serial correlation in sports is discussed explicitly in Dorsey-Palmeteer and Smith (2004), and Gilovich, Vallone, and Tversky (1985), implicitly in Ferrall and Smith (1999), and was noted in the firm studied in Baker, Gibbs, and Holmstrom (1994a, b) and Gibbs (1994).

BGH (1994a, b) observe that a positive correlation exists between the number of promotions a worker receives and the worker's early success with a firm. While this certainly is explained by the sorting of heterogeneous workers, it may also reflect effort choices conditioned on past performance, which might be a function of luck. In other words, workers who have luck in their early tenure with a firm might be more willing to work hard than were workers who had a relative lack of luck. In fact, Baker, Jensen, and Murphy (1988) discuss the possibility of workers with the same position in a firm facing different incentives because of differing likelihoods for promotion.

As in this dissertation, Ferrall and Smith (1999) theoretically discuss the possibility that incentive effects diverge for players in a sequence of tournaments as the sequence progresses. The empirical results, which were based upon championship series results in professional hockey, baseball, and basketball, do not show evidence of serial correlation in teams' performances. Most importantly, the paper does not identify the possible source that drives the incentive difference, the grand prize.<sup>13</sup>

---

<sup>13</sup> The model presented in Ferrall and Smith (1999) has dynamics that are very similar to the model presented above. In fact, the model presented above would yield the exact results of the Ferrall and Smith model if  $M = 0$ , which is the same as all of the payoffs used in the study.

Dorsey-Palmeteer and Smith (2004) reports that results from the 2002-2003 Professional Bowlers' Association seasons support the hypothesis that bowlers experience hot and cold streaks during competition. On the other hand, Gilovich, Vallone, and Tversky (1985) argued against a hot hand by observing that the shooting attempts of two types of basketball players are independent from one another.

One set of players in the Gilovich, Vallone, and Tversky (1985) study were professionals playing in a game situation, which, Dorsey-Palmeteer and Smith (2004) point out, is a rather questionable data set to use in an experiment considering all of the variables that cannot be controlled in a game situation. However, Tversky and Vallone (1989) also studied players who were shooting free throws in a non-game situation and found no serial correlation between the attempts of those players.

So, what is the difference between the findings of these papers?

The reason is possibly found in the existence of a grand prize. BGH (1994a, b) and Gibbs (1994) observed workers who have careers with a firm and Dorsey-Palmeteer and Smith (2004) studied bowlers who are in a competition against other bowlers. The workers studied in BGH and the bowlers who were analyzed are either trying to achieve the best positions within the firm or are trying to win a grand prize in the tournament. Meanwhile, Gilovich, Vallone, and Tversky (1985) observe no correlation between free throws attempted by basketball players who faced no grand prize. Thus, one of the explanations as to why these results differed in their conclusions regarding serial correlation is that one set being observed was striving for a grand prize, while the other was not.

Ultimately, it must be recognized that a hot hand can be *engineered* by the season organizer in a setting such as the one described above. When it might be in the best interest of the organizer to do this is not clear. At first glance, it seems odd to think that a principal would want to engineer a contest so that the agents who compete in the contest have different incentives to exert effort. However, the attraction of streaks can be viewed over and over again in the sports sections of newspapers. It is in the best interest of a principal to create contests that have participants facing unequal incentives to exert effort. Perhaps it is a way to keep media or fan attention focused on players who got “lucky” and are vying for new and larger prizes. However, discussing an organizer’s motives for creating situations in which disparate incentives exist and inducing streaks is beyond the scope of this dissertation.

### **1b.3- First Tournament Effort in a Season with a Grand Prize**

Because both players begin the season with identical records and abilities they will make identical effort choices in the first tournament. Think of this in terms of player A’s problem, but keep in mind that player B’s problem is identical.

Player A picks an effort level to satisfy

$$\begin{aligned} & \max E(\pi_{1A}(f_{1A} \mid f_{1B})) \\ & = (M + E(\pi^{W1}_2))P_{1A}(f_{1A} \mid f_{1B}) + E(\pi^{L1}_2)(1-P_{1A}) - C(f_{1A}) \\ & = (M + E(\pi^{W1}_2) - E(\pi^{L1}_{2A}))P_{1A} + E(\pi^{L1}_2) - C(f_{1A}), \end{aligned}$$

where  $E(\pi^{W1}_2)$  = expected profit for the season prior to tournament 2 given player A wins the first tournament and  $E(\pi^{L1}_2)$  = expected profit for season prior to tournament 2 given player A loses the first tournament.

The FOC that must be satisfied is:

$$\partial\pi_1/\partial f_1 = (M + E(\pi^{W1}_2) - E(\pi^{L1}_2))P' - C' \quad (7).$$

Call  $f_1^*$  the effort level that satisfies (7) and let  $C(f_1^*) = C_1$ .

Since the difference between winning and losing this tournament is the same for both players, we can conclude that both players have an equal chance of winning the first tournament. Also, both players recognize at the start of this tournament that there is an advantage to winning the first tournament. The size of this advantage is positively related to how large the difference is between the two expected profit levels a player faces prior to the beginning of the second tournament. Thus, the larger is the size of the hot hand, the more effort will be exerted in the first tournament of the season.

The expected profit each player will earn for an entire season with a grand prize is

$$E(\pi_1) = (3/2)M + (1/2)G - C_1 - (1/2)(C_{2H} + C_{2L}) - (C_{3H} - \lambda\Delta_3). \quad (7')$$

### **Section 1c- Comparing Effort in the Two Types of Seasons**

The preceding analysis shows that a grand prize affects the incentives to exert effort in a sequence of tournaments in two important ways. First, except in the case of the second tournament effort choice of the player who lost the first tournament, as long as the grand prize has not been clinched by one of the players and the prize offered for winning a tournament is unchanged, the optimal effort exerted by both players will be larger in a tournament in a season with a grand prize than it is at the same tournament in a season without a grand prize. A principal could induce similar increased incentives to exert effort by increasing the difference between winning and losing a tournament. However, by not using a grand prize, the principal sacrifices the chance to link the early and middle stages of the sequence together and create a hot hand effect. This hot hand effect exists because the incentives that the participants face to exert effort diverge in the middle of the sequence. The player with early success in the sequence has a larger

incentive to exert effort in the middle of the sequence because only he can win the grand prize early and avoid the high effort costs associated with winning the grand prize late in the sequence. The size of the hot hand effect is positively related to size of the grand prize and negatively related to the size of the variance of the random component of the players' output functions and the marginal cost of exerting effort.

## **Section 2 – The participation decision changes when a grand prize is awarded**

Introducing a grand prize not only changes the players' optimal effort choices, but it also changes their participation decisions. In a season with a grand prize, the expected profit that is lost when a player decides not to compete in a tournament is increased at nearly every point of the season because a player not only gives up a chance of the prize that is awarded for winning a tournament, but he also decreases the chance that he wins the grand prize. Thus, the calculus that governs a player's decision to compete in a tournament is altered when a grand prize is awarded.

If participants have a choice of not competing in any given tournament in the series, a player will not compete if his incentive rationality constraint is violated. Calculating the opportunity cost of not competing at each point of the season allows generalizations to be made regarding the probability of a player not participating in any one tournament of the season.

Define the opportunity cost of not participating in a tournament to be equal to the difference between the expected profit earned by a player who competes in all the remaining tournaments in a season and the expected profit he would earn if he skipped this tournament and then participated in the rest of the tournaments in the season. The

larger is the opportunity cost of not participating, the more likely it becomes for a player to participate in a tournament.

First, consider a season without a grand prize. Prior to the third tournament, a player expects to earn  $E(\pi_3) = (\frac{1}{2})M - C^*$ . If he does not participate in the third tournament, then he forsakes this expected profit. The same calculation made prior to the second tournament yields the same result as  $E(\pi_2) - E(\pi_3) = (\frac{1}{2})M - C^*$ . Indeed, just as the optimal effort level is constant across all the tournaments in a season without a grand prize, the opportunity cost of not competing in a tournament also is constant. Thus, in seasons without a grand prize, the participation rate should be constant for all of the tournaments in the season because the opportunity cost of not participating is constant.

Calculating the opportunity cost of not competing in a season with a grand prize is a bit more involved. The intuition behind the results is simple--a player who does not compete in a tournament in a season with a grand prize has not only given up a chance at the prize that is awarded for winning the tournament, but he also has diminished his chances of winning the grand prize. Thus, there is higher cost to be paid for skipping a tournament in a season with a grand prize.

Two extreme examples of this are seen in the third tournament and the second tournament of the season. First, if a player decides not to participate in the final tournament when the grand prize has not been won, then he relinquishes any chance of winning the grand prize. At that point in the season, he had a 50/50 chance of winning the grand prize. So, skipping this tournament would be an expensive decision. Similarly, a player who loses the first tournament and decides not to play in the second tournament forfeits any chance of winning the grand prize. (Although this decision is not as

expensive as the decision to skip the third tournament in which the grand prize has not been won.)

Not playing in any of the other tournaments of the season does not carry the penalty of giving up all chance of winning the grand prize, but, because the player diminishes his chances of winning the grand prize when he forfeits a tournament, he does pay a larger price for doing so. Table 1 shows the expected profit prior to each tournament given that he participates or does not participate in a given tournament. For all of the tournaments in the season with a grand prize, the expected profit that is sacrificed by not playing in a tournament is equal to or larger than the expected profit that is sacrificed by not playing in same tournament in a season with a grand prize because the decision to forfeit diminishes the chances of a player winning the grand prize

**Table 1- Opportunity Cost of Not Participating in a Season with a Grand Prize**

Tournament That is Forfeited	Expected Profit given Participation	Expected Profit given no Participation	Opportunity Cost of not Participating
3 <sup>rd</sup> (G not won)	$E(\pi_{3H})$ $= (\frac{1}{2})(M + G) - C_{3H}$	0	$(\frac{1}{2})(M + G) - C_{3H}$
3 <sup>rd</sup> (G won)	$E(\pi^*) = (\frac{1}{2})M - C^*$	0	$(\frac{1}{2})M - C^*$
2 <sup>nd</sup> (Won 1 <sup>st</sup> )	$E(\pi_{2H})$ $= (\frac{1}{2} + \lambda)M + (\lambda/2 + \frac{1}{2})G$ $- C_{2H} - C_{3H} + \lambda\Delta_3$	$E(\pi_{3H})$ $= (\frac{1}{2})(M + G) - C_{3H}$	$\lambda M + (\lambda/2)G - C_{2H}$ $+ \lambda\Delta_3$
2 <sup>nd</sup> (Lost 1 <sup>st</sup> )	$E(\pi_{2L})$ $= ((3/2) - \lambda)M +$ $((1 - \lambda)/2)G - C_{2L}$ $- C_{3H} + \lambda\Delta_3$	$E(\pi_3)$ $= (\frac{1}{2})M - C^*$	$(1 - \lambda)M + ((1 - \lambda)/2)G$ $- C_{2L} - (1 - \lambda)\Delta_3$
1 <sup>st</sup>	$E(\pi_1)$ $= (3/2)M + (\frac{1}{2})G - C_1$ $- (\frac{1}{2})(C_{2H} + C_{2L})$ $- C_{3H} + \lambda\Delta_3$	$E(\pi_{2L})$ $= ((3/2) - \lambda)M +$ $((1 - \lambda)/2)G - C_{2L}$ $- C_{3H} + \lambda\Delta_3$	$\lambda M + (\lambda/2)G - C_1$ $- (\frac{1}{2})\Delta_2$

Three conclusions regarding participation can be drawn from the above results. First, participation rates, just like optimal effort, will be constant in a season without a grand prize. Second, except for the second tournament of the first tournament loser,

participation rates in seasons with a grand prize should be at least as large as participation rates in a season without a grand prize. Only when the grand prize has been clinched early in a season with a grand prize will the probability of participation equate across the two seasons. Lastly, participation in mid-season events should increase more for players with early success relative to players with a lack of early success in seasons with a grand prize because mid-season events are more valuable to the player with early luck than to the player with a relative lack of early luck.

### **Section 3- Conclusion**

This chapter shows how the incentives that players face in a multiple tournament season are altered by the introduction of a grand prize. The optimal effort and the opportunity cost of playing in two different types of three tournament seasons are compared. One season offers a prize to the winner of each tournament while the other season does this and also gives a grand prize to the winner of the most tournaments. The comparison between the incentive regimes yields a number of conclusions that can be used to empirically analyze performance and participation. First, the effort levels exerted by players remain constant in a season without a grand prize. Second, the players' optimal effort levels are larger in nearly every tournament in a season with a grand prize. Third, a hot hand effect is created by the addition of the grand prize because the player who has early success in the season has a larger incentive to exert effort compared to a player without early success. Fourth, the probability of participating is constant in a season without a grand prize. Fifth, the probability of players participating in any of one of the tournaments is almost always at least as large as when a grand prize is awarded.<sup>14</sup>

---

<sup>14</sup> The exception to this is if the grand prize has been won prior to the third tournament. In this situation, the probability of participating is equal under both regimes.

Finally, players who have early luck in a season with a grand prize are more likely to participate in a mid-season tournament compared to players who did not.

## Chapter IV- Empirical Analysis

### **Empirical Tests of the Theory with PGA Tour Data**

In 1987, the Professional Golfers' Association (PGA) Tour changed the organization of its season by including the Tour Championship, an end-of-season event that qualifies as a grand prize. The introduction of the Tour Championship into the PGA Tour's schedule changed the league's season from a sequence of tournaments without a grand prize to a sequence of tournaments with a grand prize in a manner consistent with the theoretical framework of the previous chapter. The PGA Tour data are used to test the previously discussed theoretical predictions regarding player performance and player participation.

This chapter consists of six sections. The first section describes the PGA Tour before and after the Tour Championship was introduced. The second section describes the data that are used to analyze golfer performance and participation in seasons with and without the Tour Championship. The third and fourth sections present results of tests that show mixed support for the theoretical predictions in the previous chapter. The fifth section discusses possible sources of error in the measurement sections. The sixth and final section summarizes the chapter.

#### **Section 1: The PGA Tour and the theory's predictions**

The American PGA Tour's season starts in mid-January and ends in early-November. Every year, tournaments are played throughout the United States and Canada. Most PGA Tour events operate similarly. A field of 156 players begins each four round tournament. (A "round" comprises 18 holes, which means that each tournament is usually 72 holes.) After two rounds, the field is cut to approximately 70

players. These players compete for two more rounds to determine how the purse will be divided. Although purse sizes vary from week to week, the way purses are allocated to players does not vary. The winner of a tournament receives 18% of the tournament's total purse, the second place finisher receives 10% of the total purse, the third place finisher 6.8%, fourth place 4.8%, and so on to 70<sup>th</sup> place, who receives 0.2% of the total purse. In the 2004 season, the Players' Championship's \$8 million purse was the largest offered by a tournament on the PGA Tour, while the smallest purse, which was offered by three tournaments, was \$3 million. (pgatour.com)

The PGA Tour's money list ranking is calculated after each tournament and ranks players based upon the total amount of money won so far during the season. At the end of the season, the top 125 players on the money list earn full membership rights into the PGA Tour for the next season. The 125 players who earn full membership rights can play in any "typical" PGA Tour event in the following season.<sup>15</sup> Because of the exemption given to PGA Tour members, the players are truly free agents who can pick which events to play during the season. The money list rankings are also used to determine which players receive an invitation to play in elite tournaments. Many tournaments, like the British Open, the Masters, and the US Open offer spots in their fields to golfers who are ranked above some threshold value on the money list at a particular point in a season. However, the Tour Championship is the only tournament on the PGA Tour's schedule that relies *solely* on the money list rankings to determine its field. This tournament, which debuted in 1987 as the Nabisco Championship, offers the

---

<sup>15</sup> As with any rule, there are exceptions. There are a few tournaments that are on the PGA Tour's schedule that are operated by a different organization and have different entry procedures. An example is the U.S. Open, which is operated by the United States Golf Association. There also are golfers who earn stronger exemptions for performance over a career or earn weaker tournament-by-tournament exemptions based upon their performance in a particular tournament.

season's top 30 money winners an invitation to play in the season-ending event.

(Nabisco Championship invitations were based on a point system that was closely related to the amount of money a player earned.)

A spot in the Tour Championship is a prize to most golfers, as making the field can not only be quite lucrative, but it also signals to the golfing world that a golfer is at the top of his profession. For instance, the purse of the 2004 Tour Championship was \$6 million, which is in the upper quarter of purses. The player who wins the Tour Championship earns slightly over \$1 million, which was approximately 50% of the total prize money earned by the 30<sup>th</sup> ranked player on the money list that season. In addition, unlike a typical PGA Tour event that cuts the field in half after the first two rounds, all of the players in the Tour Championship are guaranteed prize money. The last place finisher in the 2004 Tour Championship received approximately \$90,000, or 5% of the earnings of the money list's 30<sup>th</sup> ranked golfer in that season. (pgatour.com)

Perhaps Joey Sindelar, a perennial PGA Tour player, summed up the incentive of getting into the Tour Championship the best following his 1987 B.C Open win when he responded to a question from a reporter about his desire to get into the Nabisco Championship by telling him simply, "I'm going to go hard after it." (Golf Weekly, 1987)

In short, the nature of the PGA Tour season was changed after the Nabisco Championship was created. Prior to 1987, placing in the top 30 on the money list at season's end was not of great importance. There were a few elite tournaments that used the money list to award spots to players, but often these tournaments used the money list rankings from points in mid-season to determine who played in a tournament. Otherwise,

the only incentives that PGA Tour players faced were the purses offered by each individual tournament. Some tournaments offered a relatively large amount of prize money (i.e. The Las Vegas Invitational) or the added prestige of winning a major tournament like the Masters or the U.S. Open. However, there was little to tie together the events of the season for the players. In a season such as this, the model from Chapter III suggests that the level of effort exerted by a player in a given tournament was essentially a function of the purse for that tournament.

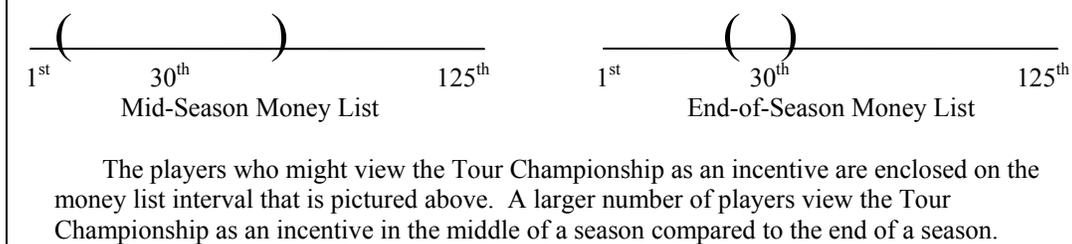
The addition of the Tour Championship to the PGA Tour's schedule changed the organization's season to one with a grand prize like the one modeled in the third chapter. Golfers now participate in a series of tournaments for both individual tournament purses and a grand prize, entry to the Tour Championship. Thus, the incentives that golfers faced changed. The level of effort they exert is now a function of not only the size of a purse offered by a tournament, but also their chance of gaining entry to the Tour Championship. Generally, as seasons with the Tour Championship progress, players separate themselves into three different categories- players who clinch their spot in the Tour Championship early, players who no longer have a realistic chance to get into the Tour Championship, and players who are on the cusp of qualifying for the Tour Championship during the final tournaments of the season.

Pinpointing exactly when a player has qualified for the Tour Championship or has been eliminated from qualifying for the tournament is an exceedingly difficult calculation to make. However, a player's money earnings and/or his ranking on the money list at any given point in the season can be used as an estimate of the probability of a player gaining a spot in the Tour Championship. For instance, in 2000, Tiger Woods earned enough

money in just three events to all but guarantee himself a spot in the Tour Championship (PGA Tour, 2001). Thus, the grand prize of a spot in the Tour Championship ceased being an incentive for Woods very early in that season. On the other extreme, in 1993 Craig Stadler was the runner-up in the season's final event, the Las Vegas Invitational, and jumped twelve positions on the money list to earn an invitation to the Tour Championship (Golf Week, 1993). For Stadler, a spot in the Tour Championship provided an incentive up to the very last hole of the last round of the season. So, even if the exact probability of a player gaining entry into the Tour Championship cannot be calculated, the week-by-week collection of money lists and the consistent nature of how prizes are awarded allows one to approximate the relative size of the incentives provided by the Tour Championship for a player in a particular spot on the money list at a particular point in the season.

Figure 3 illustrates that the number of players who are still in the running for the Tour Championship declines as the season progresses. At the beginning of a season, there are many players who have a legitimate chance of winning a spot in the Tour Championship. However, as the season progresses and as players either clinch or are eliminated from the Tour Championship, the number of players who see the Tour Championship as an incentive to exert effort is reduced. These differing incentives should help explain performance.

**Figure 4- The number of players who see the Tour Championship as an incentive decreases as the season progresses.**



## Section 2: Description of Data

The data consist of six seasons of PGA Tour results: 1983, 1984, 1986, 1987, 1993, and 2000. The first three seasons do not have the Tour Championship and the last three seasons include the Tour Championship. Two pooled sets of results were created from these results. The data were taken from *Golf World*, a weekly publication that publishes the results of golf tournaments from around the world, and from the *PGA Tour Media Guide*, which is published by the PGA Tour prior to the beginning of each season and which contains results of PGA Tour tournaments from the prior season. The results from each tournament allowed an approximate re-creation of the money list for each week of the six seasons.<sup>16</sup>

Each season's top 125 money winners were followed for four of the six seasons. The exceptions to this are 1987, which has 121 players, and 2000, which tracked 130 players. Constraints in the data collection process caused this discrepancy.

The average score for each tournament a player entered was calculated by dividing the player's total score for a tournament by the number of rounds he played in a tournament. For example, if Francis Ouimet's score was 280 in a four round tournament,

<sup>16</sup> The re-creation is approximate because there were players who were in the top 125 on the money list at various times of the season, but were not in the top 125 at the end of the season.

then his average score was  $280/4 = 70$ . Alternatively, if Tommy Bolt's score was 152 for two rounds and he was cut from the field, then his average score is  $152/2 = 76$ . If a player did not finish (DNF) a tournament because of injury or bad temperament, then his average score is not reported.

The length of the six PGA Tour seasons is roughly 35 tournaments. Each season started in the middle of January and continued to late October or early November. The only tournaments that the PGA Tour sanctions that are not included in the dataset are tournaments that have entry procedures that differ from "typical" PGA Tour events. Thus, events like The Masters, the US Open, the British Open, the World Series of Golf, the Tournament of Champions (or the Mercedes Championship), any event that runs concurrently with aforementioned events, and any event that is part of the World Golf Championships are not included in the dataset. However, the money winnings for players who competed in these events or any other events are included in the construction of a money list for the season.

The data allow the creation of two independent variables that measure the size of the incentive effect provided by the Tour Championship for a player at a given point in a season. The first, *ranking distance*, determines how many spots on the money list a player is from 30<sup>th</sup> place prior to a tournament. It is calculated as the absolute value of the difference between a player's ranking on the money list prior to a tournament and 30. Thus, if Carl Petterson is ranked 23<sup>rd</sup> on the money list prior to the Shell Houston Open, then his ranking distance is  $|23 - 30| = 7$ . The second metric used to estimate the size of the incentives provided by the Tour Championship is *money distance*, which is the absolute value of the difference between the amount of money a player has earned prior

to a tournament and the amount of money earned by the 30<sup>th</sup> ranked golfer prior to a tournament. Example: If, prior to the PGA Championship, Rob Kinney had earned \$225,000 and the 30<sup>th</sup> ranked golfer had earned \$400,000, then Kinney's ranking distance is  $|\$225,000 - \$400,000| = \$175,000$ .

In the empirical specifications, money distance and ranking distance are interacted with two dummy variables which indicate whether a player was in or out of the top 30 on the money list prior to a tournament and at what time in the season a tournament was played. The top 30 dummy is included because a player who had performed well may face different incentives from the Tour Championship than a player who has performed poorly. For instance, the theory predicts that players who have a good start to the season are more likely to play well in the middle of a season in order to clinch their spot in the Tour Championship relatively early in the season. The time period dummy is used because, as a season progresses, the meaning of a player's ranking distance and money distance change because the chance of a player moving significantly up or down the money list rankings falls due to the dwindling amount of money yet to be awarded on the PGA Tour. In the analysis below, the season is split into quarters, which is an arbitrary choice. Ranking distance and money distance for top 30 and not top 30 players in all four quarters of the two types of seasons are summarized below in Tables 2a-2d.<sup>17</sup>

---

<sup>17</sup> The mean and standard deviation of money distance is different in the seasons with the Tour Championship because the value of purses in absolute and real terms increased dramatically from the early 1980s to the late 1990s. In real terms, the value of the purse of a typical tournament increased by about 250% during this time period.

<b>Table 2a: Ranking Distance in seasons without the Tour Championship</b>								
Top 30 (N = 1668)					Not Top 30 (N = 6162)			
Mean	S.D.	Min	Max	Quarter	Mean	S.D.	Min	Max
14.96	4.25	0	29	1	43.21	21.06	0	95
14.80	3.96	0	29	2	46.78	22.27	0	95
14.19	3.26	0	29	3	49.46	22.22	0	95
14.71	3.38	0	29	4	51.62	23.16	0	95

<b>Table 2b: Ranking Distance in seasons with the Tour Championship</b>								
Top 30 (N = 1588)					Not Top 30 (N = 6363)			
Mean	S.D.	Min	Max	Quarter	Mean	S.D.	Min	Max
14.73	4.07	0	29	1	43.78	21.18	0	98
14.32	3.76	0	29	2	48.63	23.22	0	100
13.82	3.43	0	29	3	49.68	23.49	0	100
13.07	2.72	0	29	4	51.41	23.33	0	100

<b>Table 2c: Money Distance in seasons without the Tour Championship</b> (In thousands of 1983 dollars)								
Top 30 (N = 1668)					Not Top 30 (N = 6162)			
Mean	S.D.	Min	Max	Quarter	Mean	S.D.	Min	Max
28.47	11.63	0	477	1	18.57	9.84	0	64
57.51	18.25	0	336	2	41.46	19.69	0	174
74.85	20.33	0	400	3	69.97	30.78	0	295
80.57	22.90	0	406	4	91.66	41.24	0	223

<b>Table 2d: Money Distance in seasons with the Tour Championship</b> (In thousands of 1983 dollars)								
Top 30 (N = 1588)					Not Top 30 (N = 6363)			
Mean	S.D.	Min	Max	Quarter	Mean	S.D.	Min	Max
116.49	56.24	0	2294	1	66.95	41.43	0	351
217.51	95.71	0	3007	2	155.62	87.85	0	696
247.39	120.19	0	4880	3	234.38	126.98	0	826
297.25	125.24	0	6586	4	376.88	204.74	0	1505

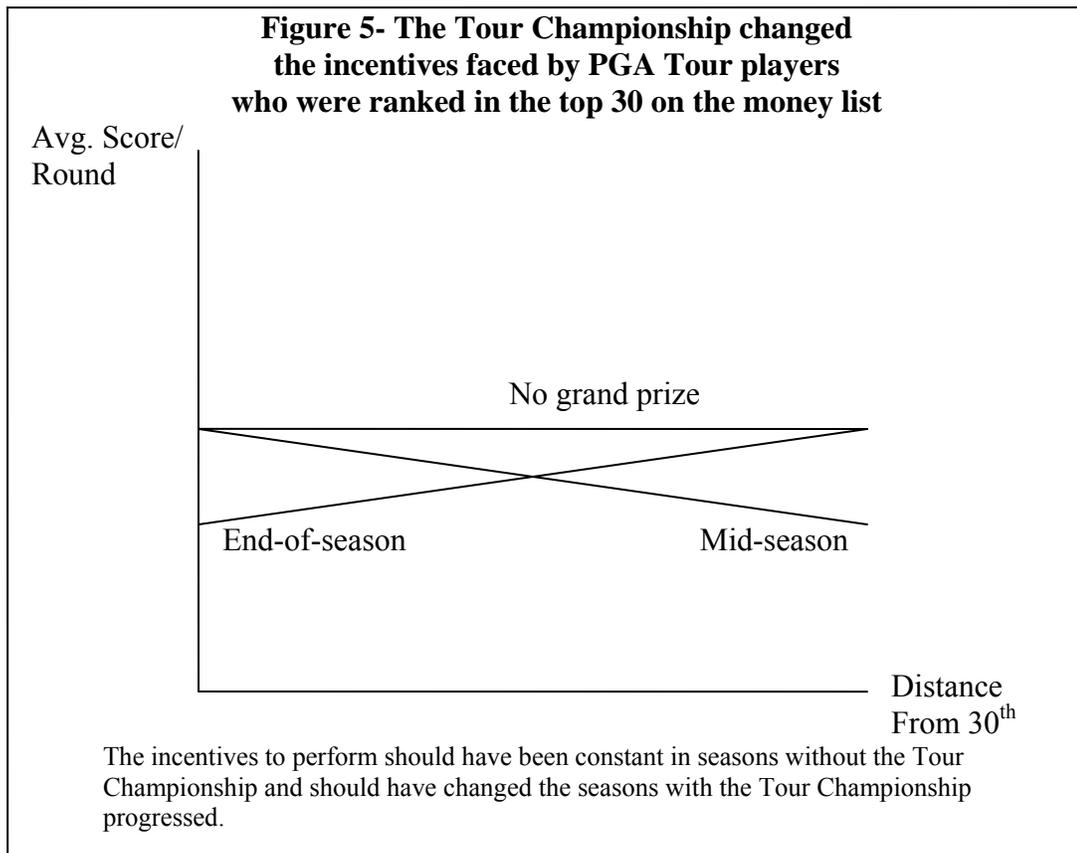
### Section 3: Analyzing Performance

The model in Chapter III provides four testable predictions about a golfer's performance during PGA Tour seasons with and without a Tour Championship.

- Prediction 1: Performance will be better (scores *lower*) for top 30 players in seasons with the Tour Championship because there is more benefit to exerting effort at nearly every juncture of these seasons.
- Prediction 2: In seasons without a Tour Championship, performance will not be related to a player's position on the money list at any time in the season. Instead, incentives to perform should only depend on the size of the tournaments' purses.
- Prediction 3: Holding constant ability, in the middle of a season with the Tour Championship, players who are ranked in the top positions on the money list (i.e. the "lucky" players) will perform better than players who are ranked lower. Because higher ranked players were closer to clinching a spot in the Tour Championship compared to lower ranked players, the higher ranked players have the added incentive of avoiding the high late season effort costs that are associated with trying to gain a spot in the top 30 on the money list. (This is the "hot hand" effect described in Chapter III.)
- Prediction 4: At the end of a season with the Tour Championship, players who are on the cusp of qualifying for the Tour Championship will be the players who perform best because they are the only players who are being incentivized by both the prizes a late season tournament offered and by the chance to gain an invitation to the Tour Championship. Players who have clinched a spot to the Tour Championship and those who have no chance of gaining an invitation to the Tour Championship are incentivized only by the prizes a tournament offered.

Taken together, the third and fourth predictions assert that for players in the top 30 on the money list the slope of the line that describes the relationship between player score and distance from 30<sup>th</sup> place on the money list is negative in the middle of the season and become positive at the end of the season. (See Figure 5 below.)

The four predictions regarding performance are assessed in two different ways. One tests the first prediction by comparing the average scores carded by PGA Tour players in the two different types of seasons. The second uses OLS to develop tests of the second, third, and fourth hypotheses and to explore the relationship between a player's performance and a player's ranking on the money list.



The summary statistics of the players' scores are reported in Tables 3a-b and support the theory's first prediction-- players who are in the top 30 (or are lucky) will perform better in seasons with a grand prize. Note that these golfers performed better in absolute terms at all stages of the seasons with the Tour Championship. Table 4 reports the results of differences in means tests for the two types of seasons. The left column of

Table 4 shows the null hypotheses tested. For instance, the null hypothesis of the first test that is reported,  $N_0: \text{Top30Q1}^w = \text{Top30Q1}^{wo}$ , tests if the performance of players who were in the Top 30 in the first quarter of seasons with the Tour Championship was equal to the performance of players who were in the same position in the same quarter of the seasons without the Tour Championship. The t-statistic that is reported for this test is 4.88, which rejects the null hypothesis at very low significance levels.

These results should be taken with a caveat for two reasons. First, technological developments likely made players in the seasons with the Tour Championship more able golfers. Although course design and tournament set-up decisions often tried to mitigate the technological advancements being made by equipment manufacturers, scores would still be lower if course design changes failed to keep pace with technological changes. Second, the real value of purses increased in the years following the creation of the Tour Championship. Thus, all players had an incentive to work harder because the marginal benefit of exerting effort increased due to the rise in purse values.<sup>18</sup>

<b>Table 3a: Top 30 Performance In Seasons Without Tour Championship</b>			
	# Observations	Avg. Score	Standard Deviation
Quarter 1	524	71.79	2.28
Quarter 2	464	71.77	2.10
Quarter 3	328	71.73	2.09
Quarter 4	352	70.71	2.08
Total	1668	71.56	2.19

<sup>18</sup> It is probably true that the rising purse values and the rapid accumulation of technology are probably behind these findings. Consider that the average score for top 30 players in 1987 was 71.34. By 1993, this value had fallen to 71.13 and in 2000 it was 70.51. More than likely, the rapid advancement of technology was causing average score to fall throughout the 1990s.

<b>Table 3b: Top 30 Performance In Seasons With Tour Championship</b>			
	# Observations	Avg. Score	Standard Deviation
Quarter 1	497	71.31	2.27
Quarter 2	438	70.87	2.16
Quarter 3	385	71.27	2.72
Quarter 4	268	70.29	2.17
Total	1588	71.01	2.37

<b>Table 4: Prediction 1 is supported. Average scores are better with the Tour Championship</b>	
Test	Result (t-statistics)
Top 30Q1 <sup>w</sup> = Top30Q1 <sup>wo</sup>	4.88
Top30Q2 <sup>w</sup> = Top30Q2 <sup>wo</sup>	12.55
Top30Q3 <sup>w</sup> = Top30Q3 <sup>wo</sup>	4.67
Top30Q4 <sup>w</sup> = Top30Q4 <sup>wo</sup>	7.58
Total Top30 <sup>w</sup> = Total Top30 <sup>wo</sup>	13.63

### OLS Procedure

Four different equations are estimated for each pooled dataset (seasons with and without the Tour Championship). Estimation is by ordinary least-squares. The purpose of this is to test the second and third hypotheses regarding performance.<sup>19</sup>

#### Equation 1:

$$\begin{aligned}
\text{score}_{it} = & \text{constant} + \sum_{q=1}^4 \delta_q \text{Quarter}^q_{it} \text{Distance}_{it-1} R_{it-1} \\
& + \sum_{q=1}^4 \eta_q \text{Quarter}^q_{it} (\text{Distance}_{it-1})^2 R_{it-1} \\
& + \sum_{q=1}^4 \delta^N_q \text{Quarter}^q_{it} \text{Distance}_{it-1} (1-R_{it-1}) \\
& + \sum_{q=1}^4 \eta^N_q \text{Quarter}^q_{it} (\text{Distance}_{it-1})^2 (1-R_{it-1}) \\
& + \sum_{s=1}^{T-1} \beta_s \text{Tourney}^s_{it} + \sum_{j=1}^{N-1} \gamma_j \text{Player}^j_{it} + \varepsilon_{it}
\end{aligned}$$

where

- $\text{score}_{it}$  = average score/round for player  $i$  in tournament  $t$
- $\delta_q$  and  $\eta_q$  are coefficients that describe the relationship between ranking distance and average score and between the square of ranking distance and

<sup>19</sup> Although there is no specific variable that controls for purse, the tournament dummy variable implicitly holds purse (and a host of other tournament specific characteristics) constant.

score for players who were in the top 30 on the money list prior to tournament  $t$ .  $\delta_q^N$ , and  $\eta_q^N$  do the same for players who were not in the top 30 prior to tournament  $t$ .

- $\text{Quarter}_{it}^q = 1$  if tournament  $t$  is in quarter  $q$   
 $= 0$  otherwise
- $\text{Distance}_{it-1} =$  ranking distance prior to tournament  $t$
- $R_{it-1} = 1$  if player in top 30 on money list prior to tournament  $t$   
 $= 0$  otherwise
- $\text{Player}_{it}^j = 1$  if  $j = i$   
 $= 0$  otherwise
- $\text{Tournament}_{it}^s = 1$  if  $s = t$   
 $= 0$  otherwise
- $\varepsilon_{it} =$  mean zero error term.

Equation 1a:

$$\begin{aligned} \text{score}_{it} = & \text{constant} + \sum_{q=1}^4 \delta_q \text{Quarter}_{it}^q \text{Distance}_{it-1} R_{it-1} \\ & + \sum_{q=1}^4 \eta_q \text{Quarter}_{it}^q (\text{Distance}_{it-1})^2 R_{it-1} \\ & + \sum_{q=1}^4 \delta_q^N \text{Quarter}_{it}^q \text{Distance}_{it-1} (1-R_{it-1}) \\ & + \sum_{q=1}^4 \eta_q^N \text{Quarter}_{it}^q (\text{Distance}_{it-1})^2 (1-R_{it-1}) \\ & + \sum_{s=1}^{T-1} \beta_s \text{Tourney}_{it}^s + \varepsilon_{it} \end{aligned}$$

Player identity is not held constant in Equation 1a. All other variable definitions match those in Equation 1.

Equation 2:

$$\begin{aligned} \text{score}_{it} = & \text{constant} + \sum_{q=1}^4 \rho_q \text{Quarter}_{it}^q \text{Mondistance}_{it-1} R_{it-1} \\ & + \sum_{q=1}^4 \tau_q \text{Quarter}_{it}^q (\text{Mondistance}_{it-1})^2 R_{it-1} \\ & + \sum_{q=1}^4 \rho_q^N \text{Quarter}_{it}^q \text{Mondistance}_{it-1} (1-R_{it-1}) \\ & + \sum_{q=1}^4 \tau_q^N \text{Quarter}_{it}^q (\text{Mondistance}_{it-1})^2 (1-R_{it-1}) \\ & + \sum_{s=1}^{T-1} \beta_s \text{Tourney}_{it}^s + \sum_{j=1}^{N-1} \gamma_j \text{Player}_{it}^j + \varepsilon_{it} \end{aligned}$$

where

- $\text{Mondistance}_{it-1} =$  money distance prior to tournament  $t$
- $\rho_q$  and  $\tau_q$  are coefficients which describe the relationship between money distance and average score and the square of money distance and average score for players in the top 30 on the money list prior to tournament  $t$ .  $\rho_q^N$  and  $\tau_q^N$  do the same for players who were not in the top 30 prior to tournament  $t$ .

Equation 2a:

$$\begin{aligned} \text{score}_{it} = & \text{constant} + \sum_{q=1}^4 \rho_q \text{Quarter}_{it}^q \text{Mondistance}_{it-1} R_{it-1} \\ & + \sum_{q=1}^4 \tau_q \text{Quarter}_{it}^q (\text{Mondistance}_{it-1})^2 R_{it-1} \\ & + \sum_{q=1}^4 \rho_q^N \text{Quarter}_{it}^q \text{Mondistance}_{it-1} (1-R_{it-1}) \\ & + \sum_{q=1}^4 \tau_q^N \text{Quarter}_{it}^q (\text{Mondistance}_{it-1})^2 (1-R_{it-1}) \\ & + \sum_{s=1}^{T-1} \beta_s \text{Tourney}_{it}^s + \varepsilon_{it} \end{aligned}$$

Equations 1a and 2a are estimated to determine the importance of player heterogeneity. Because equations 1a and 2a are nested models of equations 1 and 2, a global F-test can be used to assess the effect of player heterogeneity.

The number of players in the pooled dataset with the Tour Championship is  $N = 376$ . The number of players in the pooled dataset without the Tour Championship is  $N = 375$ .<sup>20</sup> One player from each of the six years was dropped in order to avoid multicollinearity. The number of tournaments in the three seasons with the Tour Championship is  $T = 108$ . The number of tournaments in the three seasons without the Tour Championship is  $T = 103$ . One tournament in each pool must be dropped in order to avoid multicollinearity.

### **Interpreting the Results**

The estimation results for equation 1 are reported in Table 5; those for equation 1a in Table 7, equation 2 in Table 8, and equation 2a in Table 10. These results permit a predicted score to be calculated at any point in the season given a player's position on the money list prior to a tournament.

---

<sup>20</sup> There are two ways to account for player identity. The first is to create one player dummy for every player and to use this for every season in the dataset. The second way is to treat player identity as being different for each season. The reason the second method is used is because players and the incentives they face *are* different from season to season. One only needs to compare the Tiger Woods of 2000 to the Tiger Woods of 2004 for an example that illustrates this point.

Consider the following example, which calculates the predicted score for a player who was ranked 20<sup>th</sup> on the money list prior to a tournament in the third quarter of a season with the Tour Championship. Prior to this third quarter tournament, this player had a ranking distance of 10 because he was 10 places from 30<sup>th</sup> on the money list. The results from Table 5 show that this player's score should have been approximately  $-0.04995 \text{ strokes/round} * 10 + 0.00272 \text{ strokes/round} * 10^2 = -0.23 \text{ strokes/round}$  lower than the sum of the estimated constant, the tournament specific effect, and the player specific effect. The same calculations can be done using the results from Table 8 and substituting a player's money distance for ranking distance.<sup>21</sup>

Table 6 and Table 9 show the results of hypothesis tests of the theory's predictions regarding performance, which test a pair of hypotheses jointly. In each case, the hypothesis tested is that the effect of distance from 30<sup>th</sup> place on the money list on player score is the same at different times of the season. For instance, to assess whether the relationship between the top 30 players' scores and their ranking distance from 30<sup>th</sup> place on the money list remained the same across all of the quarters of the seasons without the Tour Championship, look at the fourth row of the right-most column of Table 6 to see that the value of the F-test is 0.50. Equal effects across time can only be rejected at fairly high significance levels.

### **Ranking Distance Results**

Results in Table 5 and 7 based on rank distance from 30<sup>th</sup> on the money list are generally consistent with predictions. Consistent with prediction three, there is evidence of a hot hand in seasons with the Tour Championship. Table 5 and Figure 6b show that

---

<sup>21</sup> This effect is measured in strokes/round. A -0.23 strokes/round effect adds up to nearly 1 stroke lower per tournament for a player in this position on the money list for the season.

in the second and third quarters of the seasons with the Tour Championship, the players who were ranked around 20<sup>th</sup> on money list performed best in that period of the season. For example, Table 5 shows that in the second quarter of the seasons with the Tour Championship,  $\delta_2 = -0.068$  and  $\eta_2 = 0.00284$ . In the second quarter of the seasons with a Tour Championship a player's score declined as his rank improved relative to 30<sup>th</sup> place on the money list until roughly 18<sup>th</sup> place on the money list.<sup>22</sup> From approximately 18<sup>th</sup> place to 1<sup>st</sup> place on the money list, player score rose as the ranking improved. (See Figure 6b below.) The theory predicts that players in a position to clinch their spot in the Tour Championship relatively early in the season had the largest incentive to exert effort. These players ranked higher than 18<sup>th</sup> on the money list were increasingly likely to have already clinched their spot in the Tour Championship and so were incentivized by the Tour Championship.

Compare these second quarter results to fourth quarter results for the top 30 players. The value  $\delta_4 = 0.03721$  and  $\eta_4 = -0.0001$ . Taken together, these coefficient estimates imply that player score rose along with distance from 30<sup>th</sup> place on the money list along the entire interval from 30<sup>th</sup> place to 1<sup>st</sup> place. (See Figure 6b below.) This is consistent with the fourth prediction since players who were closest to 30<sup>th</sup> place on the money list in the fourth quarter performed best at the season's end.

The performance of golfers who were ranked lower than 30<sup>th</sup> place on the money list in seasons with the Tour Championship is less consistent with the theoretical predictions. The fourth quarter results for these players is consistent with the fourth prediction since score rise with distance from 30<sup>th</sup> place on the money list to

---

<sup>22</sup> In order to calculate the money list rank that corresponds to the minimum score in the second quarter, the minimum of  $\delta_2 \text{Distance} + \eta_2 \text{Distance}^2$  needs to be calculated. This occurs at  $\text{Distance} \approx 12$ , which corresponds to a money list ranking of  $30 - 12 = 18$ .

approximately 75<sup>th</sup> place on the money list. (See Figure 6d.) Earlier season results are puzzling. Here, too, scores should rise with distance from 30<sup>th</sup> on the money list. Score fell (performance improved) as rank declined, however.

A possible explanation for these odd results might be traced to the PGA Tour's policy of awarding single season exemptions to the top 125 ranked golfers on the money list. Because of this rule, the strength of incentives to exert effort in the fourth quarter of seasons for players ranked below 30<sup>th</sup> place on the money list might be non-monotonic. At one end of the spectrum, there are players who are fighting to get into the Tour Championship and at the other end of the spectrum there are players who are fighting to remain exempt for next season. In between, there are players who have little or no chance of getting into the Tour Championship and have safely earned their exemption for the next season. Player performance is consistent with these declining incentives.

For the seasons without the Tour Championship, the results in Tables 5 and 6 and Figures 6a and 6c show that no clear relationship existed between score and ranking distance. For instance, the rather low values of the F-tests in Table 6 make it unreasonable to reject the hypothesis that the relationship between score and a player's ranking distance is unchanged over the course of a season. Also, all of the p-values for the coefficients listed on the right side of Table 5 are uniformly high.

Comparing results of the two types of seasons suggests that the addition of the Tour Championship gave the players ranked in the top 30 on the money list an incentive to increase their effort in the middle of the season. In Figure 6a, which depicts the case prior to the introduction of the Tour Championship, the top 30 players' scores were rise with distance from 30<sup>th</sup> place in every quarter of the season. Figure 6b shows that this

relationship changed dramatically in seasons with the Tour Championship. In the middle of these seasons, players who ranked around 17<sup>th</sup> performed the best. By the middle of these seasons, these players were close to clinching a spot in the Tour Championship, but were unlikely to already have done so. Thus, there is evidence supporting the theory's prediction that a grand prize (the Tour Championship) gives rise to a hot hand effect in the middle of a season that consists of a series of tournaments.

Finally, the results in Table 7, which deletes player fixed effects, are consistent with the notion that the best players shoot the lowest scores. The (mostly) negative values of  $\delta_q$  and the (mostly) positive values of  $\delta^N$  should not be surprising because player identity was not accounted for in this regression. Therefore, it is to be expected that the lowest scores should have been shot by the best players, who occupy the highest rankings on the money list.

<b>Table 5:</b> OLS Results using Equation 1 <sup>23 24</sup>				
With Tour Championship (R <sup>2</sup> = 0.4209 , N = 7951)			Without Tour Championship (R <sup>2</sup> = 0.4193 , N = 7825)	
Coefficient Value	Standard Error	Name	Coefficient Value	Standard Error
-0.05426**	0.02762	$\delta_1$	0.02944	0.02638
-0.06800***	0.03039	$\delta_2$	0.00876	0.01001
-0.04995	0.03256	$\delta_3$	0.03994	0.03282
0.03721	0.03597	$\delta_4$	0.01660	0.01574
0.00231**	0.00109	$\eta_1$	-0.00082	0.00103
0.00284***	0.00121	$\eta_2$	-0.00128	0.00100
0.00272**	0.00129	$\eta_3$	-0.00070	0.00128
-0.00001	0.00148	$\eta_4$	-0.00008	0.00038
-0.01187*	0.00666	$\delta_1^N$	-0.00086	0.00677
-0.01887***	0.00666	$\delta_2^N$	0.00132	0.00664
-0.01083	0.00700	$\delta_3^N$	0.00330	0.00760
0.01122	0.00726	$\delta_4^N$	-0.00340	0.00670
0.00011	0.00007	$\eta_1^N$	$-9.16 \times 10^{-6}$	0.00008
0.00012*	0.00007	$\eta_2^N$	-0.00010	0.00007
0.00004	0.00007	$\eta_3^N$	-0.00013	0.00008
-0.00020***	0.00007	$\eta_4^N$	-0.00009	0.00007
69.10416	0.78020	Constant	73.53526	0.8621641

<sup>23</sup> A coefficient with significance level of  $p < 0.10$  is designated with a \*,  $p < 0.05$  by \*\*, and  $p < 0.01$  by \*\*\*. This notation is also used later tests.

<sup>24</sup>  $H_0: \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_1^N = \delta_2^N = \delta_3^N = \delta_4^N = 0$  can be rejected at any reasonable significance level as the test statistic yields a value of  $F(7, 7454) = 2.85$  ( $p > 0.0037$ ).

Figures 6a-6d- The relationship between performance and ranking distance changes after the Tour Championship was created

Figure 6a

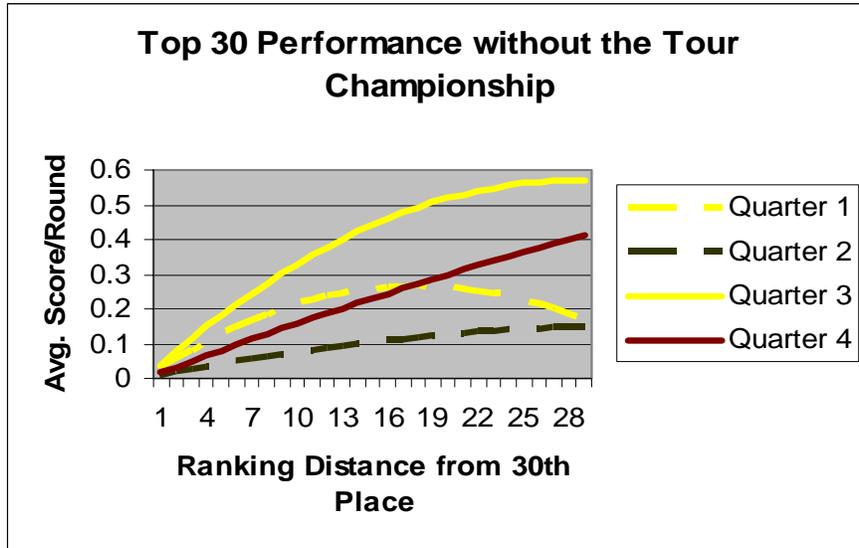


Figure 6b



Figure 6c

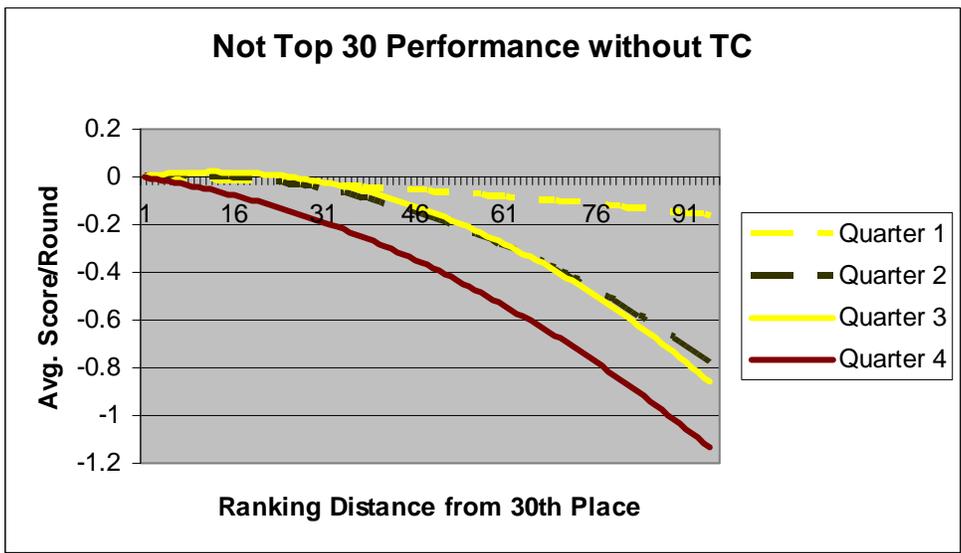
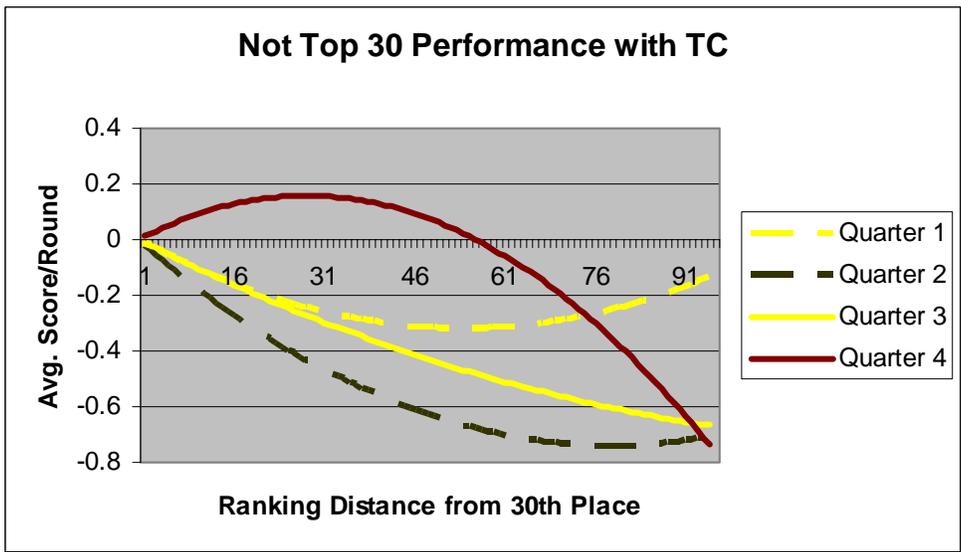


Figure 6d



<b>Table 6:</b> Predictions 2 and 4 are accurate when ranking distance is used		
Test	With Tour Championship (All tests are F(2, 7454) or F(6, 7454))	Without Tour Championship (All are F(2, 7339) or F(6, 7339))
$H_0: \delta_1 = \delta_2$ & $\eta_1 = \eta_2$	0.06 (0.9443)	0.26 (0.7698)
$H_0: \delta_2 = \delta_3$ & $\eta_2 = \eta_3$	0.81 (0.4471)	1.15 (0.3169)
$H_0: \delta_3 = \delta_4$ & $\eta_3 = \eta_4$	2.44 (0.0873)	0.30 (0.7394)
$H_0: \delta_1 = \delta_2 = \delta_3 = \delta_4$ & $\eta_1 = \eta_2 = \eta_3 = \eta_4$	2.05 (0.0559)	0.50 (0.8120)
$H_0: \delta_1^N = \delta_2^N$ & $\eta_1^N = \eta_2^N$	2.65 (0.0710)	3.25 (0.0388)
$H_0: \delta_2^N = \delta_3^N$ & $\eta_2^N = \eta_3^N$	0.44 (0.6431)	0.04 (0.9592)
$H_0: \delta_3^N = \delta_4^N$ & $\eta_3^N = \eta_4^N$	3.15 (0.0428)	1.04 (0.3534)
$H_0: \delta_1^N = \delta_2^N = \delta_3^N = \delta_4^N$ & $\eta_1^N = \eta_2^N = \eta_3^N = \eta_4^N$	3.20 (0.0039)	2.55 (0.0180)

With Tour Championship (R <sup>2</sup> = 0.3427, N = 7951)			Without Tour Championship (R <sup>2</sup> = 0.3507, N = 7830)	
Coefficient Value	Standard Error	Name	Coefficient Value	Standard Error
-0.04663**	0.02646	$\delta_1$	0.01103	0.02535
-0.08920***	0.02815	$\delta_2$	-0.02350***	0.00867
-0.04911**	0.02984	$\delta_3$	0.04105	0.03104
0.00827	0.03360	$\delta_4$	-0.03175**	0.01463
0.00072	0.00102	$\eta_1$	-0.00104	0.00097
0.00180*	0.00110	$\eta_2$	-0.00010	0.00010
0.00062	0.00117	$\eta_3$	-0.00217**	0.00121
-0.00097	0.00137	$\eta_4$	0.00073*	0.00038
-0.00335	-0.00641	$\delta_1^N$	0.01828***	0.00645
-0.00566	0.00616	$\delta_2^N$	0.02072***	0.00592
0.00353	0.00634	$\delta_3^N$	0.02849***	0.00682
0.02156***	0.00654	$\delta_4^N$	0.01861***	0.00598
0.00010	0.00007	$\eta_1^N$	-0.00007	0.00007
0.00011*	0.00006	$\eta_2^N$	-0.00012*	0.00007
0.00002	0.00006	$\eta_3^N$	-0.000017***	0.00007
-0.00014**	0.00007	$\eta_4^N$	-0.00012**	0.00006
70.99679	0.22887	Constant	68.93812	0.30992

### Money Distance Results

Equations 2 and 2a employ money as a metric to describe the distance from 30<sup>th</sup> place on the money list. Estimates of these equations provide results that are less consistent with the predictions than when rank is used as a metric. The results are presented in Tables 8 and 9. Here and in Figure 7b there is little support for the third prediction, but there is support for the fourth prediction.

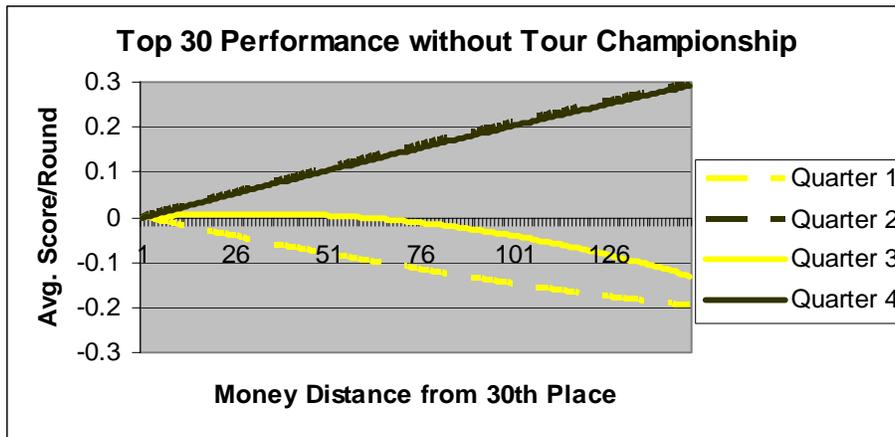
<sup>25</sup> Player effects matter when ranking distance is used. The values of the global F-tests that compare the OLS results using equation 1 (the complete model) to equation 1a is 2.39 in the pool with the Tour Championship and 2.41 in the pool without the Tour Championship.

First, player scores rise with money distance from 30<sup>th</sup> place in the second and third quarters of the seasons with the Tour Championship. This is inconsistent (and nearly opposite) with prediction three. There is no evidence, here, of a hot hand in seasons with the Tour Championship. Second, the results in Table 9 show that the relationship between score and money distance is essentially the same, and therefore inconsistent with the predictions, over the course of a season for top 30 players.

On the other hand, the positive relationship between score and money distance in the fourth quarter of seasons with the Tour Championship is in itself consistent with prediction four.

With Tour Championship (R <sup>2</sup> = 0.4187 , N = 7951)			Without Tour Championship (R <sup>2</sup> = 0.4200, N = 7825 )	
Coefficient Value	Standard Error	Name	Coefficient Value	Standard Error
0.00158	0.00097	$\rho_1$	0.00179	0.00367
0.00062	0.00067	$\rho_2$	0.00228	0.00195
0.00118**	0.00052	$\rho_3$	0.00585**	0.00262
0.00101**	0.00050	$\rho_4$	0.00214	0.00337
$-1.10 \times 10^{-6}$ *	$6.29 \times 10^{-7}$	$\tau_1$	$-3.45 \times 10^{-6}$	0.000012
$-3.85 \times 10^{-7}$	$3.30 \times 10^{-7}$	$\tau_2$	$-1.83 \times 10^{-6}$	$3.04 \times 10^{-6}$
$-2.65 \times 10^{-7}$	$1.39 \times 10^{-7}$	$\tau_3$	-0.00001	0.00001
$-1.95 \times 10^{-7}$ **	$8.71 \times 10^{-8}$	$\tau_4$	$1.08 \times 10^{-6}$	0.00001
-0.00248	0.00251	$\rho^N_1$	-0.00556	0.01009
-0.00288**	0.00131	$\rho^N_2$	-0.00265	0.00425
-0.00108	0.00098	$\rho^N_3$	-0.00099	0.00304
-0.00050	0.00063	$\rho^N_4$	-0.00278	0.00346
$-2.09 \times 10^{-6}$	$9.18 \times 10^{-6}$	$\tau^N_1$	0.00012	0.00022
$2.64 \times 10^{-6}$	$2.53 \times 10^{-6}$	$\tau^N_2$	$-3.99 \times 10^{-6}$	0.00004
$-1.11 \times 10^{-7}$	$1.42 \times 10^{-6}$	$\tau^N_3$	-0.000023	0.00002
$-3.03 \times 10^{-7}$	$5.21 \times 10^{-7}$	$\tau^N_4$	-0.00001	0.00002
69.10416	0.78020	Constant	70.47789	0.69795

**Figure 7a-7d: The Relationship between Score and Money Distance changes after the Tour Championship was created**  
**Figure 7a**



<sup>26</sup> H<sub>0</sub>: H<sub>0</sub>:  $\delta_1=\delta_2=\delta_3=\delta_4=\delta^N_1=\delta^N_2=\delta^N_3=\delta^N_4 = 0$  cannot be rejected at any reasonable significance level as the test statistic yields a value of  $F(7,7454) = 1.16$  ( $p > 0.0019$ ).

Figure 7b

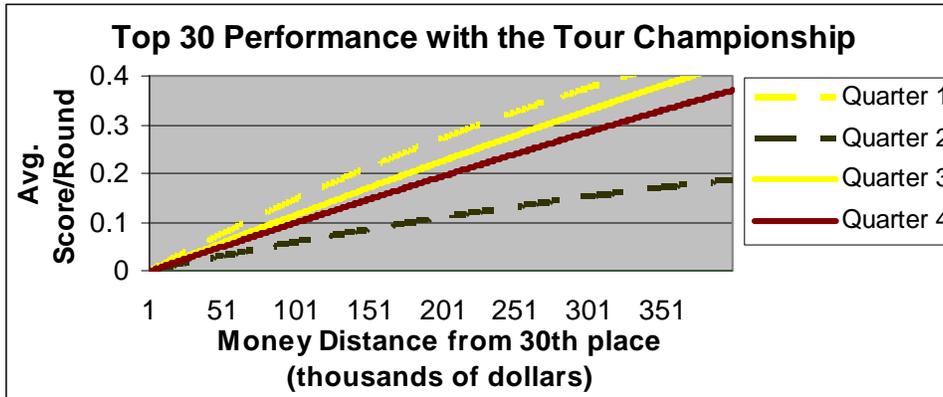


Figure 7c

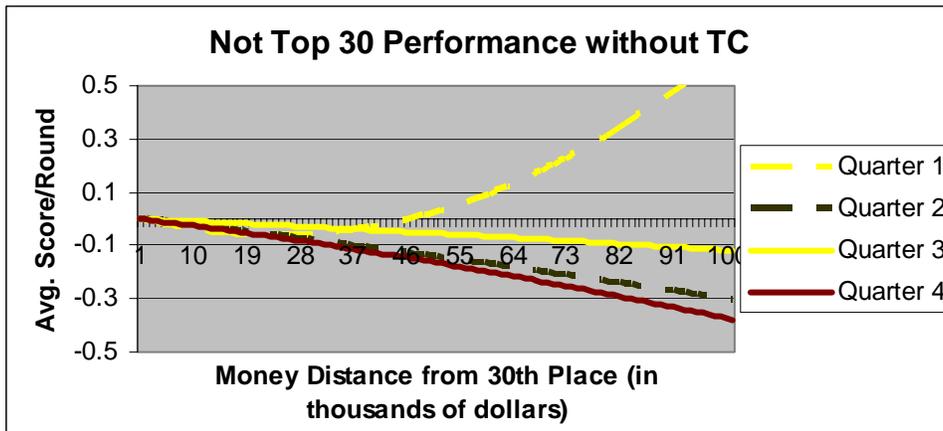
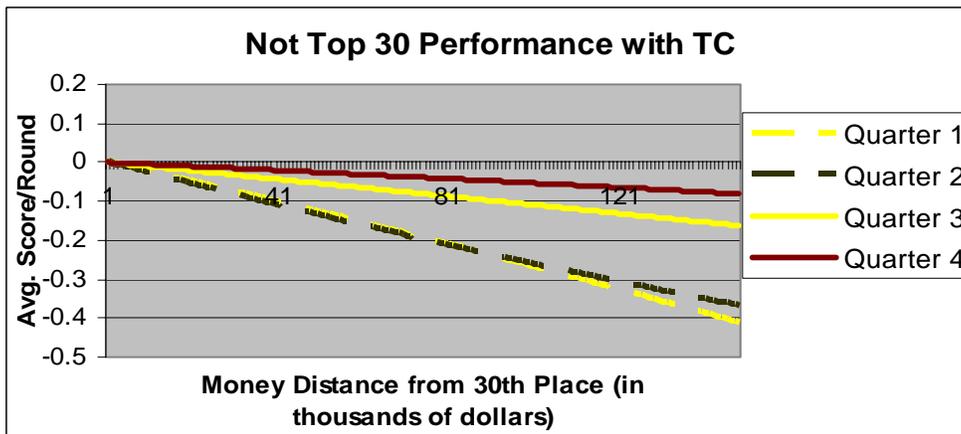


Figure 7d



<b>Table 9: Prediction 2 is supported</b>		
Test	With Tour Championship (All tests are F(2, 7454) or F(6, 7454))	Without Tour Championship (All tests are F(2, 7339) or F(6, 7339))
$H_0: \rho_1 = \rho_2$ & $\tau_1 = \tau_2$	0.69 (0.5001)	0.06 (0.9381)
$H_0: \rho_2 = \rho_3$ & $\tau_2 = \tau_3$	2.57 (0.0767)	0.67 (0.5112)
$H_0: \rho_3 = \rho_4$ & $\tau_3 = \tau_4$	0.18 (0.8386)	1.58 (0.2063)
$H_0: \rho_1 = \rho_2 = \rho_3 = \rho_4$ & $\tau_1 = \tau_2 = \tau_3 = \tau_4$	1.07 (0.3803)	0.31 (0.9306)
$H_0: \rho_1^N = \rho_2^N$ & $\tau_1^N = \tau_2^N$	0.34 (0.7136)	0.31 (0.6898)
$H_0: \rho_2^N = \rho_3^N$ & $\tau_2^N = \tau_3^N$	0.79 (0.4560)	0.10 (0.9060)
$H_0: \rho_3^N = \rho_4^N$ & $\tau_3^N = \tau_4^N$	0.43 (0.6525)	0.37 (0.5417)
$H_0: \rho_1^N = \rho_2^N = \rho_3^N = \rho_4^N$ & $\tau_1^N = \tau_2^N = \tau_3^N = \tau_4^N$	1.08 (.3736)	0.16 (0.9864)

<b>Table 10: OLS Results using Equation 2a</b>				
With Tour Championship ( $R^2 = 0.3425$ , $N = 7951$ )			Without Tour Championship ( $R^2 = 0.3424$ , $N = 7825$ )	
Coefficient Value	Standard Error	Name	Coefficient Value	Standard Error
-0.00181**	0.00084	$\rho_1$	-0.00234	0.00226
-0.00145***	0.00054	$\rho_2$	-0.00482***	0.00158
-0.00035	0.00045	$\rho_3$	0.00236	0.00300
-0.00014	0.00045	$\rho_4$	-0.00018	0.00028
$5.76 \times 10^{-8}$	$5.40 \times 10^{-7}$	$\tau_1$	$6.06 \times 10^{-7}$	$6.79 \times 10^{-7}$
$1.85 \times 10^{-7}$	$2.68 \times 10^{-7}$	$\tau_2$	$3.16 \times 10^{-6}$ **	$1.47 \times 10^{-6}$
$-1.34 \times 10^{-8}$	$1.13 \times 10^{-7}$	$\tau_3$	-0.00002**	0.00001
$-5.69 \times 10^{-8}$	$7.68 \times 10^{-8}$	$\tau_4$	$4.38 \times 10^{-9}$	$7.49 \times 10^{-9}$
0.00355	0.00235	$\rho^N_1$	0.05450***	0.00916
0.00384	0.00235	$\rho^N_2$	0.01889***	0.00564
0.00398***	0.00085	$\rho^N_3$	0.01730***	0.00410
0.00282***	0.00058	$\rho^N_4$	0.00044**	0.00020
$-8.97 \times 10^{-6}$	$8.81 \times 10^{-6}$	$\tau^N_1$	-0.00057***	0.00021
$-4.33 \times 10^{-6}$ *	$2.28 \times 10^{-6}$	$\tau^N_2$	-0.00001	0.00007
$-3.28 \times 10^{-6}$ ***	$1.25 \times 10^{-6}$	$\tau^N_3$	-0.00007***	0.00003
$-1.45 \times 10^{-6}$	$4.97 \times 10^{-7}$	$\tau^N_4$	$-2.43 \times 10^{-8}$	$1.39 \times 10^{-8}$
70.85666	0.19974	Constant	71.93962	0.11174

27

#### Section 4: Participation

As shown in Chapter 3, the inclusion of a grand prize alters the opportunity cost of not participating in a tournament. This alters the probability that a player will participate in a tournament. Four testable predictions are implied for participation in seasons with and without the Tour Championship.

- Prediction 1: For players ranked in the top 30, the probability that a player participates in a tournament will increase at all stages of a season after the Tour Championship is added because the opportunity cost of not playing in a tournament has increased. This effect may or may not be true for players who were not ranked in the top 30.

<sup>27</sup> Player effects still matter: The value of the global F-tests that compare the efficacy of OLS results of equations 2 and 2a in seasons with and without the Tour Championship are F(2.62) and F(2.53).

- Prediction 2: The probability that a player participates in a tournament prior to the creation of the Tour Championship will be a function of the purse for that tournament. A player's position on the money list will have no bearing on whether or not he participates in a tournament.
- Prediction 3: The probability that a player who is high on the money list participates in a mid-season tournament will be larger than the probability that a lower ranked player participates in a mid-season tournament, all else equal.
- Prediction 4: The probability that a player on the cusp of qualifying for a spot in the Tour Championship late in the season participates in a late season tournament will be higher than that for a player who has either clinched a spot in the Tour Championship or has no chance of gaining an invitation to the Tour Championship.

These four predictions are analyzed with summary statistics and with a logit model using ranking distance and money distance as proxies for position on the money list. The logit model generates a battery of hypothesis tests that address these four predictions.

Tables 11a-11d summarize the participation rates of players in the dataset for the two types of seasons. As the table indicates, the participation rates for both types of players changed after the creation of the Tour Championship. However, participation did not become larger in every quarter. Tables 11a and 11b show that players who were ranked in the top 30 of the money list participated at lower rates in all but the third quarter after the Tour Championship was created. Overall, these players' participation rates fell nearly 4% after 1987. On the other hand, the players who were ranked between 31<sup>st</sup> and 125<sup>th</sup> on the money list participated more often in all but the first quarter of the three seasons after the creation of the Tour Championship. So, it can be said that the first prediction was half right (or half wrong) on this point.

<b>Table 11a: Top 30 Participation In Seasons Without Tour Championship</b>		
	# Chances to Participate	Participation Rate
Quarter 1	810	0.6716
Quarter 2	810	0.5753
Quarter 3	810	0.4272
Quarter 4	780	0.4179
Total	3210	0.5240

<b>Table 11b: Top 30 Participation In Seasons With Tour Championship</b>		
	# Chances to Participate	Participation Rate
Quarter 1	840	0.5917
Quarter 2	810	0.5418
Quarter 3	810	0.4753
Quarter 4	810	0.3309
Total	3270	0.4859

<b>Table 11c: Not Top 30 Participation Without Tour Championship</b>		
	# Chances to Participate	Participation Rate
Quarter 1	2565	0.6838
Quarter 2	2475	0.7087
Quarter 3	2475	0.5749
Quarter 4	2385	0.5836
Total	9900	0.6206

<b>Table 11d: Not Top 30 Participation With Tour Championship</b>		
	# Chances to Participate	Participation Rate
Quarter 1	2574	0.6465
Quarter 2	2484	0.6566
Quarter 3	2484	0.6449
Quarter 4	2389	0.6132
Total	9931	0.6407

<b>Table 12: Participation <u>does</u> change after the Tour Championship is created (but the theory is only half right)</b>	
Test	Result (t-statistic)
$H_0: \text{Top } 30Q1^w = \text{Top}30Q1^{wo}$	-2.39
$H_0: \text{Top}30Q2^w = \text{Top}30Q2^{wo}$	-0.96
$H_0: \text{Top}30Q3^w = \text{Top}30Q3^{wo}$	1.38
$H_0: \text{Top}30Q4^w = \text{Top}30Q4^{wo}$	-2.54
$H_0: \text{Total Top}30^w = \text{Total Top}30^{wo}$	-3.06
$H_0: \text{NoTop}30Q1^w = \text{NoTop}30Q1^{wo}$	-2.00
$H_0: \text{NoTop}30Q2^w = \text{NoTop}30Q2^{wo}$	-2.78
$H_0: \text{NoTop}30Q3^w = \text{NoTop}30Q3^{wo}$	3.58
$H_0: \text{NoTop}30Q4^w = \text{NoTop}30Q4^{wo}$	1.48
$H_0: \text{Total Not Top}30^w = \text{Total Not Top}30^{wo}$	2.93

Table 12 reports the results of the null hypothesis tests for prediction one. For example,  $H_0: \text{Top}30Q1^w = \text{Top}30Q1^{wo}$  tests whether the first quarterly participation rates were equal for players who were in the top 30 on the money list across both types of seasons. The value of the t-statistic is -2.39, which means that this null hypothesis can be rejected at rather low significance levels. The problem with this result is that the participation rate in the season without the Tour Championship is significantly larger, which runs counter to the first prediction. Indeed, this is the case for many of the results that are reported in Table 12.

The lack of predictive punch regarding participation rates across the two types of seasons for the players who were ranked in the top 30 on the money list is not easily explained. Perhaps the most reasonable explanation is that wealth effects from the increased real value of purses might have altered the labor/leisure decision of golfers in a way that caused them to choose more leisure in the seasons with the Tour Championship. The explanation seems more legitimate when one considers that in the seasons after the Tour Championship the participation rates for players in the top 30 mostly fell while the

participation rates for players out of the top 30 mostly rose. It is possible that the wealthiest golfers participated less because they could afford to do so.

A second explanation for the decreased participation rates is that golf became internationalized in the 1980s. The expansion of golf into global markets spawned greater opportunities in overseas events. The increase in the reward for not participating in a PGA Tour event could outweigh the opportunity cost, would also overturn prediction one. There is much anecdotal evidence to support this explanation. During the 1980s and 1990s, players like Seve Ballesteros of Spain, Bernhard Langer of Germany, Greg Norman of Australia, and Nick Faldo of England won or were perennial contenders in many of the most important golf tournaments played throughout the world. Also, Tze-Chung Chen of Taiwan and Isao Aoki of Japan nearly won the US Open in 1985 and 1980, respectively. Finally, in 1987, the European Ryder Cup team defeated the US Ryder Cup in the biennial matches for the first time on US soil at Muirfield Village Golf Club in Dublin, OH. All of these triumphs or near-triumphs (especially in Norman's case) helped increase the popularity of golf in foreign countries where, in turn, many American players had opportunities to earn more playing in select events. Therefore, it should not be surprising to see participation for the elite players fall after 1987.

### **Logit Analysis**

More complex analytical tools are needed in order to test the second, third, and fourth predictions. The framework used to study golfer participation is similar to that in other studies that analyze participation decisions. (See Oettinger 1999 for an example of such a study.) It is assumed that when a golfer participates in a tournament, he implicitly

states that the profit he expects to earn from participating in the tournament is larger than the profit he would have received from not participating.

Although the golfers' opportunity cost vector is unobservable, every player has a host of observable characteristics that allow for an estimate of the value relative to that of not participating. In particular, a player's ranking distance or money distance may affect the value of participating. The information available for both of these metrics allow for the creation of two vectors of characteristics. Call the vectors of observable player and tournament characteristics that affect the probability of a player participating in a tournament  $\mathbf{D}_{it}$  if ranking distance is used and  $\mathbf{M}_{it}$  if money distance is used. These vectors contain player specific dummy variables, the values of the purses that each tournament offered in terms of 1983 dollars, and, as in the previous section, the ranking or money distance interacted with a quarter dummy variable and a top 30 dummy variable. Thus, two different logit models can be used to estimate players' participation decisions.

#### Equation 3: Ranking Distance Logit

$\text{Prob}(\text{Participation}_{it} = 1 | \mathbf{D}_{it}) = \Phi(\mathbf{D}_{it}, \varepsilon_{it})$ , where  $\mathbf{D}_{it}$  = vector containing player specific characteristics, purse values for every tournament, and players' ranking distances from 30<sup>th</sup> on money list and where  $\varepsilon_{it}$  = mean zero error term.

#### Equation 4: Money Distance Logit

$\text{Prob}(\text{Participation}_{it} = 1 | \mathbf{M}_{it}) = \Omega(\mathbf{M}_{it}, \varepsilon_{it})$ , where  $\mathbf{M}_{it}$  = vector containing player specific characteristics, purse values for every tournament, and players' money distances from 30<sup>th</sup> on the money list and where  $\varepsilon_{it}$  = mean zero error term.

### **Interpreting the Results**

Results are presented in Tables 13-16 and in Figures 8a-d and 9a-d. To interpret these results, use the results from Table 13 that describe the relative likelihood of

participation for top 30 players first quarter tournaments in seasons with the Tour Championship,  $\delta_1 = -0.00384$  and  $\eta_1 = -0.00021$  as a guide. Taken together, the coefficients can be used to estimate how the likelihood of participation in a first quarter tournament changed as a player moved away from 30<sup>th</sup> place on the money list. Since a logistic distribution is used to estimate these effects and because the likelihood of participation is normalized around 30<sup>th</sup> place on the money list, the calculation  $x_i\beta = (\text{Distance}_{it-1})\delta_1 + (\text{Distance}_{it-1})^2\eta_1$  can be performed for each player to determine how much more or less likely it would have been for them to participate in a tournament at this point in the season had they been ranked 30<sup>th</sup> on the money list.

For example, if a player was ranked 20<sup>th</sup> on the money list prior to a first quarter tournament in a season with the Tour Championship, then the results from Table 13 show that  $x_i\beta = -0.0594$ . This result can then be used to conclude that the 20<sup>th</sup> ranked golfer was  $e^{-0.0594} \approx 0.94$  times more likely to play in a tournament at this stage of the season than had he been ranked 30<sup>th</sup> on the money list at this point in the season. (The same calculations can be done using money distance and the results from Table 15.)<sup>28</sup>

Tables 14 and 16 show the results for a battery of hypothesis tests which examine the relationship between the probability of a player participating in a tournament and his ranking distance or money distance across the quarters of a season. The tests for equality are  $\chi^2$  values with two or six degrees of freedom. Almost all of the null hypotheses are rejected at the 5% level, which means that the second prediction, that participation rates will be unchanged across quarters in a season without the Tour Championship, is not supported by the data.

---

<sup>28</sup> The logistic distribution states that the probability of a player participating in a tournament relative to him not playing in a tournament when he is ranked 30<sup>th</sup> is  $e^0 = 1$ . Thus, if  $x\beta > 0$ , then a player was more likely to play in a tournament than if were ranked 30<sup>th</sup> on the money list.

### **Ranking Distance Results**

The results of logit estimation of equation 1 are reported in Table 13 and are depicted in Figures 8a-8d. The hypotheses tests from this estimation are reported in Table 14. The results strongly support the third and fourth predictions but not the second.

First, the participation pattern of players who were in the top 30 in seasons with the Tour Championship was consistent with the third and fourth predictions regarding participation. For instance, Figure 8b shows that players who ranked furthest from 30<sup>th</sup> place (highest in the money list) were more likely to play in the second quarter tournaments than were players who were ranked lower on the money list, which is consistent with the third prediction. Also, the probability that a player ranked high on the money list participated in a tournament decreased relative to players who were on the cusp of qualifying for the Tour Championship late in the season, consistent with the fourth prediction. (The relative likelihood of participation in a season with the Tour Championship given Ranking Distance = 10 in quarter 1 = 0.94, quarter 2 = 1.06, quarter 3 = 0.65, and quarter 4 = 0.49.) Finally, the hypotheses tests in Table 15 show that players' participation decisions changed as the seasons with the Tour Championship progressed. Note the relatively large  $\chi^2$  values in Table 14.

The participation patterns for players who were not in the top 30 on the money list in seasons with the Tour Championship also are consistent with the fourth prediction. The results shown in Table 13 and Figure 8d show that as the seasons with the Tour Championship progressed, the relative likelihood of a player participating in a

tournament decreased the further that a player was from 30<sup>th</sup> place on the money list from 30<sup>th</sup> place to roughly 60<sup>th</sup> place on the list. The decrease in the probability of participating is consistent with the fourth prediction because the opportunity cost of not entering a late-season tournament declines the further a player is from 30<sup>th</sup> place on the money list.<sup>29</sup>

PGA Tour players' participation decisions in seasons without the Tour Championship were not consistent with the second prediction. Results shown in Tables 13 and 14 show the players' rankings on the money list did affect their participation decisions and this effect differed between season quarters. This does not square with the second prediction, as it suggests that a player's position on the money list should have no bearing on his decision to participate in a tournament in a season without the Tour Championship and that the relative likelihood of a player participating in a tournament should remain constant over the course of the season.

---

<sup>29</sup> The results in Figure 8d also are consistent with the incentive to maintain full exemption by being in the top 125 on the money list because the probability of a player ranked near 125<sup>th</sup> on the money list playing in a late season tournament is relatively high.

With Tour Championship		Name	Without Tour Championship	
Coefficient Value	Standard Error		Coefficient Value	Standard Error
-0.00384	0.02038	$\delta_1$	0.01782	0.02074
0.01636	0.02175	$\delta_2$	-0.03701*	0.02137
-0.03914*	0.02214	$\delta_3$	-0.11085***	0.01722
-0.06721***	0.02269	$\delta_4$	-0.11233***	0.02242
0.00021	0.00086	$\eta_1$	-0.00052	0.00089
-0.00099	0.00093	$\eta_2$	0.00062	0.00090
0.00043	0.00094	$\eta_3$	0.00244***	0.00066
0.00038	0.00098	$\eta_4$	0.00304***	0.00093
0.00817*	0.00447	$\delta^N_1$	0.02138***	0.00058
0.00982**	0.00453	$\delta^N_2$	0.00058	0.00378
-0.01040**	0.00450	$\delta^N_3$	-0.01188***	0.00262
-0.01776***	0.00447	$\delta^N_4$	-0.00038***	0.00011
-0.00010**	0.00005	$\eta^N_1$	-0.00037***	0.00015
-0.00004	0.00005	$\eta^N_2$	-0.00008	0.00006
0.00024***	0.00005	$\eta^N_3$	0.00009***	0.00003
0.00038***	0.00005	$\eta^N_4$	$2.61 \times 10^{-8}$ ***	$9.77 \times 10^{-9}$
0.97305***	0.07489	Purse	3.12966***	0.18017
-1.30014	0.37706	Constant	-0.03706	0.02458

**Figure 8a-8d: The Relationship between Ranking Distance and Participation**

**Figure 8a**

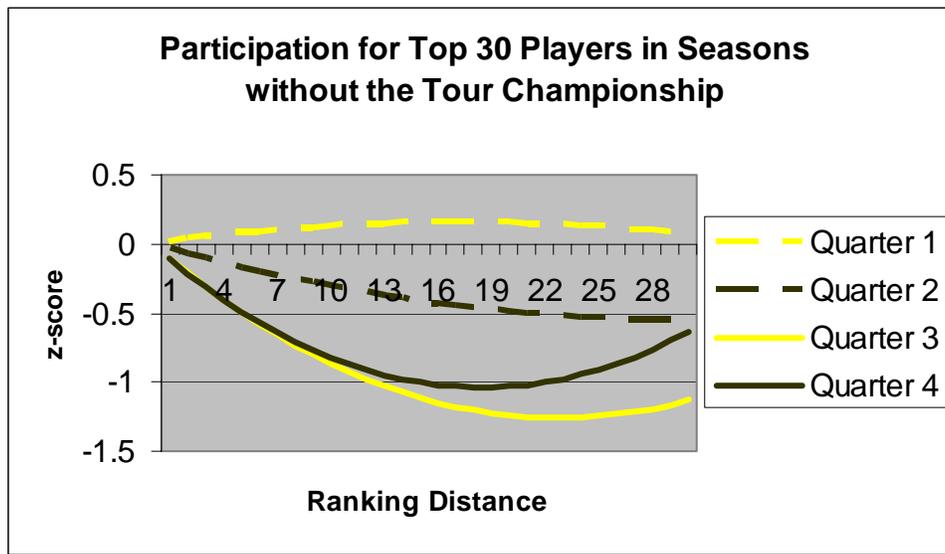


Figure 8b

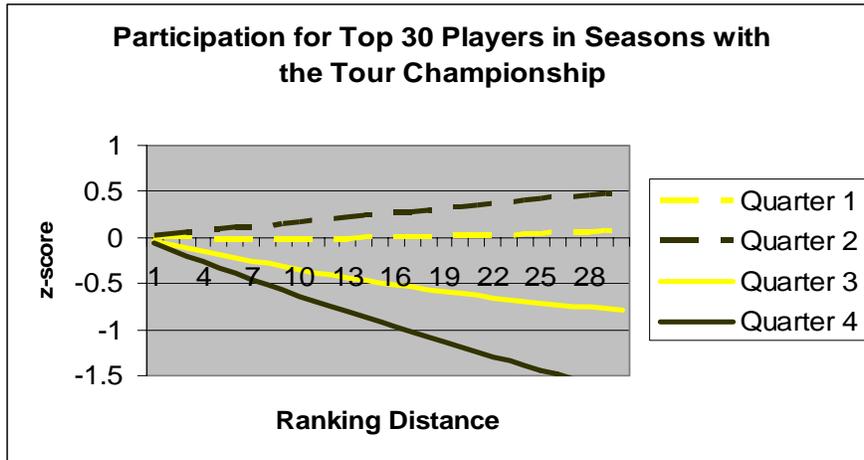


Figure 8c

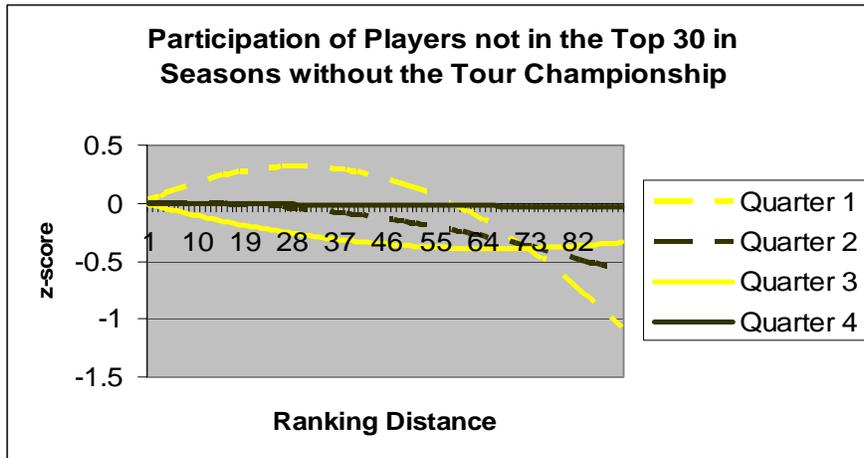
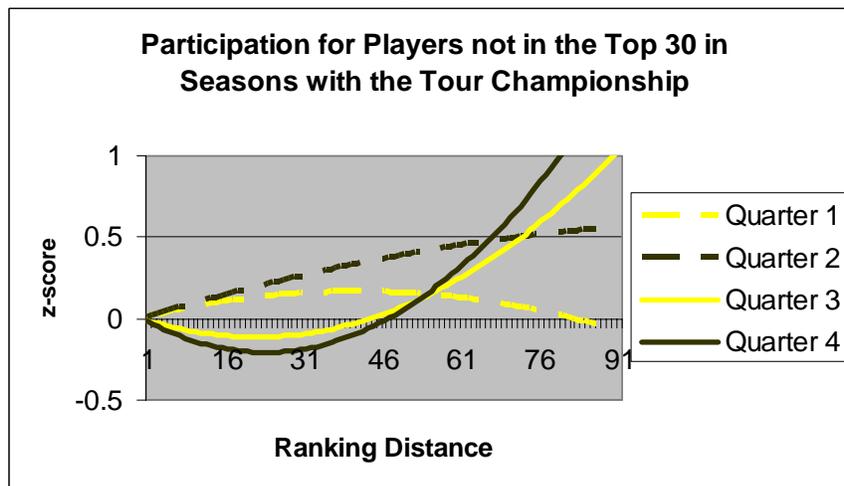


Figure 8d



<b>Table 14: Participation decisions changed as both types of seasons progressed<sup>30</sup></b>		
Test	With Tour Championship (All tests are $\chi^2(, 2)$ or $\chi^2(, 6)$ )	Without Tour Championship (All tests are $\chi^2(, 2)$ or $\chi^2(, 6)$ )
$H_0: \delta_1 = \delta_2$ & $H_1 = \eta_2$	2.01 (0.3669)	20.14 (0.0000)
$H_0: \delta_2 = \delta_3$ & $H_2 = \eta_3$	15.83 (0.0004)	28.27 (0.0000)
$H_0: \delta_3 = \delta_4$ & $H_3 = \eta_4$	19.63 (0.0001)	3.62 (0.1640)
$H_0: \delta_1 = \delta_2 = \delta_3 = \delta_4$ & $\eta_1 = \eta_2 = \eta_3 = \eta_4$	94.80 (0.0000)	105.95 (0.0000)
$H_0: \delta_1^N = \delta_2^N$ & $\eta_1^N = \eta_2^N$	23.98 (0.0000)	16.48 (0.0003)
$H_0: \delta_2^N = \delta_3^N$ & $\eta_2^N = \eta_3^N$	21.05 (0.0000)	9.86 (0.0073)
$H_0: \delta_3^N = \delta_4^N$ & $\eta_3^N = \eta_4^N$	10.03 (0.0066)	23.50 (0.0000)
$H_0: \delta_1^N = \delta_2^N = \delta_3^N = \delta_4^N$ & $\eta_1^N = \eta_2^N = \eta_3^N = \eta_4^N$	103.94 (0.0000)	76.13 (0.0000)

### Money Distance Results

The results of the logit estimation using the specification in equation 2 are shown in Table 15 and in Figures 9a-9d. These results are consistent with the results from above in that the players' participation decisions were consistent with the third and fourth predictions regarding participation and not the second prediction.

First, the third prediction is supported because the probability of a top 30 player participating in a mid-season tournament was positively related to a player's money distance. Second, the strong negative relationship between the probability of a player participating in a late season tournament and his money distance is supportive of the fourth prediction. Finally, Table 16 shows that the hypothesis that the relationship

<sup>30</sup> A  $\chi^2_{0.05,2} = 5.991$  and  $\chi^2_{0.05,6} = 12.592$ .

between the probability of a player participating in a tournament and money distance was static across the season can only be roundly rejected. Thus, in seasons with the Tour Championship, the participation decisions of players who were ranked in the top 30 on the money list were consistent with the theoretical predictions no matter which metric was used to measure the incentives that were provided by the Tour Championship.

Once again, the second prediction regarding participation is not supported by the data. The results of the hypothesis tests which test if the relationship between the probability of a player participating in a tournament and his relative money earnings changed throughout the season are shown in Table 16. The results show that regardless of whether a player was ranked in or out of the top 30 on the money list, his money distance and his decision to participate did not have a constant relationship throughout the season as the theory predicts.

With Tour Championship		Name	Without Tour Championship	
Coefficient Value	Standard Error		Coefficient Value	Standard Error
0.00049	0.00073	$\rho_1$	0.00010	0.00155
$1.96 \times 10^{-6}$	0.00047	$\rho_2$	-0.00124	0.00082
-0.00118***	0.00034	$\rho_3$	-0.0104***	0.00191
-0.00195***	0.00031	$\rho_4$	-0.00068***	0.00026
$-5.83 \times 10^{-7}$	$5.59 \times 10^{-7}$	$\tau_1$	$-1.51 \times 10^{-7}$	$5.60 \times 10^{-7}$
$-2.55 \times 10^{-7}$	$2.36 \times 10^{-7}$	$\tau_2$	$7.97 \times 10^{-8}$	$2.36 \times 10^{-7}$
$2.18 \times 10^{-7}$ **	$1.03 \times 10^{-7}$	$\tau_3$	0.00002***	$8.00 \times 10^{-6}$
$2.41 \times 10^{-7}$ ***	$5.25 \times 10^{-8}$	$\tau_4$	$1.80 \times 10^{-8}$	$6.93 \times 10^{-9}$
0.00605***	0.00189	$\rho^N_1$	0.02730***	0.00616
0.00549***	0.00090	$\rho^N_2$	0.00279	0.00372
0.00158***	0.00062	$\rho^N_3$	-0.01078***	0.00258
0.00136***	0.00037	$\rho^N_4$	-0.00035***	0.00011
-0.00002	$8.67 \times 10^{-6}$	$\tau^N_1$	-0.00047***	0.00015
$-8.84 \times 10^{-6}$ ***	$2.17 \times 10^{-6}$	$\tau^N_2$	-0.00010**	0.00005
$-8.76 \times 10^{-8}$	$1.07 \times 10^{-6}$	$\tau^N_3$	0.00009***	0.00003
$-8.56 \times 10^{-8}$	$3.45 \times 10^{-7}$	$\tau^N_4$	$2.42 \times 10^{-8}$ ***	$9.76 \times 10^{-9}$
1.01237***	0.07512	Purse	3.15763***	0.17976
-1.59973	0.42980	Constant	-0.08448	0.24576

**Figures 9a-d: The Relationship between Money Distance and Participation**

**Figure 9a**

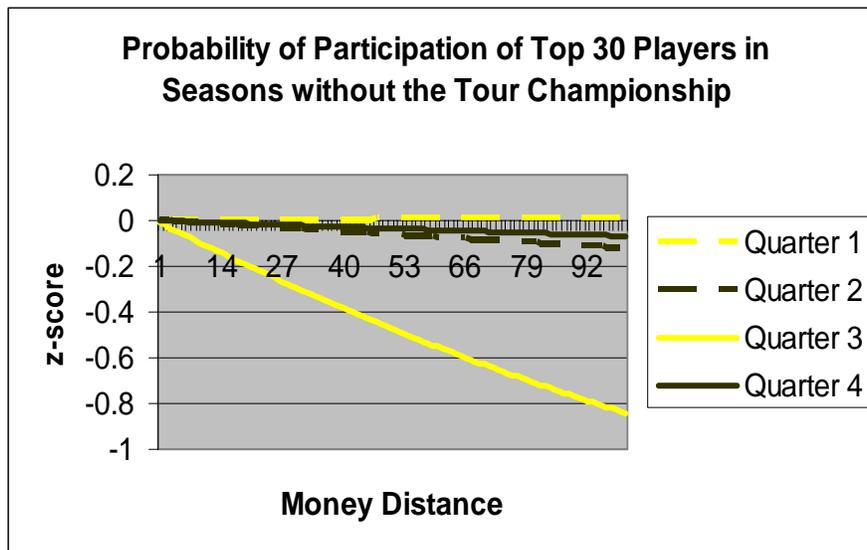


Figure 9b

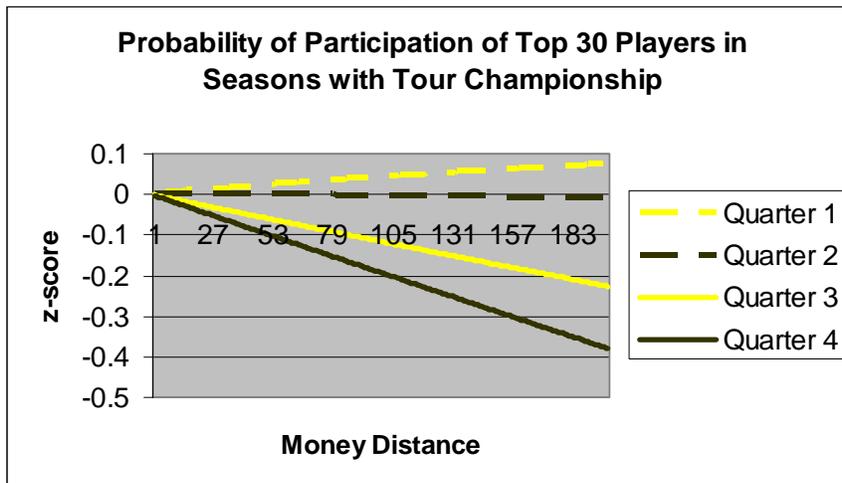
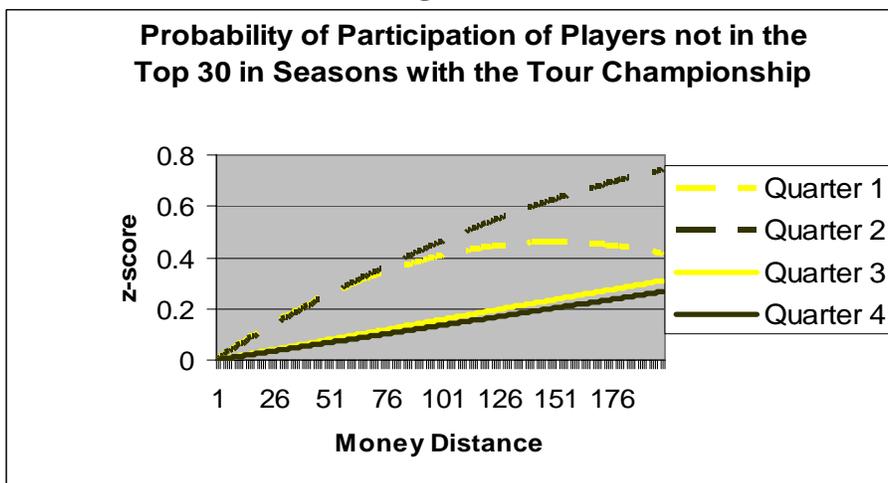


Figure 9c



Figure 9d



<b>Table 16: Participation decisions changed as both types of seasons progressed</b>		
Test	With Tour Championship (All tests are $\chi^2(, 2)$ or $\chi^2(, 6)$ )	Without Tour Championship (All tests are $\chi^2(, 2)$ or $\chi^2(, 6)$ )
$H_0: \rho_1 = \rho_2$ & $\tau_1 = \tau_2$	0.54 (0.7662)	3.75 (0.1534)
$H_0: \rho_2 = \rho_3$ & $\tau_2 = \tau_3$	7.92 (0.0191)	26.48 (0.0000)
$H_0: \rho_3 = \rho_4$ & $\tau_3 = \tau_4$	12.19 (0.0023)	39.49 (0.0000)
$H_0: \rho_1 = \rho_2 = \rho_3 = \rho_4$ & $\tau_1 = \tau_2 = \tau_3 = \tau_4$	33.04 (0.0000)	47.42 (0.0000)
$H_0: \rho_1^N = \rho_2^N$ & $\tau_1^N = \tau_2^N$	4.57 (0.1018)	20.42 (0.0000)
$H_0: \rho_2^N = \rho_3^N$ & $\tau_2^N = \tau_3^N$	23.96 (0.0000)	11.76 (0.0028)
$H_0: \rho_3^N = \rho_4^N$ & $\tau_3^N = \tau_4^N$	1.14 (0.5649)	19.29 (0.0001)
$H_0: \rho_1^N = \rho_2^N = \rho_3^N = \rho_4^N$ & $\tau_1^N = \tau_2^N = \tau_3^N = \tau_4^N$	32.79 (0.0000)	82.48 (0.0000)

## **Section 5: Sources of Error**

Not all measurement is perfect. In the case of the above measurements, there are many outside influences that could lead to erroneous results. Chief among these are the unknown or too-difficult-to-measure incentives that could skew how powerful the incentives provided by the Tour Championship are. For instance, players receive endorsement contracts that stipulate their level of compensation as a function of relative performance in tournaments. The existence of these incentives could alter the effort and/or participation decisions of golfers in a way that could bias coefficient measurements. Second, there are other elite tournaments that offer invitations based on money list rankings. The US Open, the Masters, and the more modern World Golf Championships all fill a portion of their tournament fields by using the money list and/or the World Golf Rankings. To some degree, the determination of these fields overlaps with the determination of the Tour Championship field, which, no doubt, leads to biased measurements regarding the magnitude of the incentive provided by the Tour Championship. Finally, as previously mentioned, the PGA Tour grants special privileges to players who are ranked in the top 125 on the money list in the prior season. If a player does not make it into the top 125, then he does not have full membership status on the Tour and may not gain entry to as many tournaments as he would wish. This can be potentially costly as a player might be forced to play golf on one of the “minor league” tours, which have purses that are a fraction of the size of the purses of the PGA Tour. The incentive to maintain a spot in the top 125 on the PGA Tour’s money list is a concern about the estimates as it is certainly debatable whether the incentive to gain access to the

Tour Championship is more or less powerful than the incentive to maintain full membership status on the PGA Tour. Thus, the assumption that the incentive to exert effort decreases as the distance from 30<sup>th</sup> place on the money list increases might not be entirely true.

A second problem is that wealth effects might be influencing PGA Tour players' decisions about practicing for and participating in events. It was documented earlier that from 1983 to 2000, the value of the average first place prize in a PGA Tour event rose by 800% after inflation was accounted for. It is entirely plausible that players' labor/leisure decisions changed due to this dramatic rise in prize money in the past 20 years. If this did, then the veracity of the measurements of performance and participation should be questioned.

### **Section 6: Conclusion**

The introduction of the Tour Championship, a grand prize for PGA Tour golfers, allows a test of the theoretical predictions about the effects of a grand prize developed in the third chapter. These tests examine player performance and participation on the PGA Tour and often support the theory, especially when a player's ranking on the money list is used as a metric to measure distance from 30<sup>th</sup> place on the money list.

Most important, when ranking distance is used as a metric, a hot hand effect is observed after the Tour Championship was introduced. Holding constant player ability, players who performed well early (were lucky) tend to perform better in mid-season, as well. Also, as predicted, among players who were ranked in the top 30 on the money list late in the season, those who were closest to 30<sup>th</sup> place played best in events that were

late in the season. Prior to the Tour Championship, the theory predicts that the incentive to perform should be unrelated to earlier performances and it is not.

Results with the money distance metric are not as strong. Indeed, here a hot hand effect is not observed. However, the fourth prediction regarding performance is consistent with the results.

Predictions about player participation receive substantial support. For instance, after the Tour Championship was introduced, participation rates for player who were not in the top 30 increased, the incentive to participate in mid-season events became stronger for players who were on the cusp of qualifying for the Tour Championship, and, of the players who were in the top 30 on the money list near the end of the season, those closest to 30<sup>th</sup> place were more likely to participate in late season events.

On the other hand, the empirical findings did not always support the theory's predictions about participation. First, participation rates for players in the top 30 fell after the Tour Championship was introduced. Second, for players who were not in the top 30 in seasons with the Tour Championship, those furthest from 30<sup>th</sup> place and not in the top 30 on money list were more likely to play in an event at nearly any point in the season. Finally, prior to the introduction of the Tour Championship, the relation between participation and a player's distance from 30<sup>th</sup> place varied throughout the season.

Overall, there is evidence that the addition of the Tour Championship changed players' effort and participation decisions. Perhaps the most important empirical finding is evidence that supports the theory's prediction that a hot hand can be induced with a grand prize. Future studies could include more attention to the PGA Tour or another professional golfers' tour. However, many sports leagues have prize structures that are

similar to the PGA Tour. Perhaps data from these leagues can shed further light on the incentives that grand prizes offer participants.

## Chapter V- Conclusion

This dissertation theoretically discusses the effect that the addition of a grand prize in a sequence of tournaments has on the effort and participation choices of the participants in the sequence. Among the places in which these kinds of contests can be observed are in professional sports leagues, in many organizational hierarchies, and in the primaries for the presidential nomination of the two major political parties in the United States. The predictions from the theoretical discussion are empirically tested with six seasons of results from the Professional Golfers' Association (PGA) Tour.

The theoretical model builds largely upon Lazear and Rosen (1981), Rosen (1986), and Ferrall and Smith (1999) and makes three conclusions regarding the use of a grand prize in a sequence of tournaments. First, it shows that the awarding of a grand prize in a sequence of tournaments causes serial correlation to exist across the early and middle tournaments of the sequence. This "hot hand effect" exists because only the player with early success in the sequence can win the grand prize early and avoid the high effort costs associated with winning the grand prize late in the sequence. The player who has less early success does not face this incentive and, therefore, will choose an effort level that is lower compared to the effort choice of his more successful (lucky) counterpart. The size of the hot hand effect is increasing with the size of the grand prize and decreasing with the size of the marginal cost of exerting effort and the variance of the random component of the players' output functions. Second, the theoretical model shows that the effort exerted by players in a season with a grand prize is larger in nearly every tournament in the sequence because the difference between winning and losing a tournament is larger in a season with a grand prize. Finally, the analysis shows that in a

sequence of tournaments without a grand prize, the participants' effort choices are unrelated to the results of prior tournaments in the sequence and are only a function of the prize awarded for winning an individual tournament in the sequence. Thus, if the prizes awarded in the sequence do not change, then the effort exerted by the participants will be constant across every tournament in the sequence.

The theoretical predictions regarding participation are analogous to the effort predictions. First, a player who has early success in the sequence has a larger opportunity cost of not competing in a tournament in the middle of the sequence compared to a player with less early success, which means that it is more likely that a player with early success will participate in a mid-sequence tournament. Second, in a season with a grand prize, players will be more likely to participate in nearly every tournament in the sequence because the opportunity cost of not participating in any one of the tournaments increases when a grand prize is awarded. Finally, the likelihood of a player participating in a tournament is constant in a season without a grand prize because the opportunity cost of not playing in a tournament is constant as long as the prize that is awarded in each tournament does not change.

The results from six PGA Tour seasons are used to test the predictions of the model. The Tour Championship, an elite season-ending event that was added to the PGA Tour's schedule in 1987, is treated as the PGA Tour's grand prize. The results offer evidence in support of the theoretical predictions. For instance, the performance of players in the mid-season tournaments suggests that a hot hand effect was created after the Tour Championship was added to the PGA Tour's schedule in 1987. Also, the

incentives to exert effort changed as the seasons with the grand prize progressed and were constant in seasons without the Tour Championship.

The model makes two correct predictions regarding golfers' voluntary participation in PGA Tour tournaments. First, in seasons with the Tour Championship, players who had a good start in a season were more likely to participate in a mid-season tournament relative to players who had a slower start to the season. Second, players on the cusp of earning an invitation to the Tour Championship were more likely to participate in late season events compared to players who had already earned a spot in the tournament. On the other hand, the model predicts incorrectly that the incentive to participate in a tournament would be constant in seasons without the Tour Championship

The model's success in predicting the relationship between the performance and participation of PGA Tour players after the Tour Championship was added to the organization's schedule warrants further study of the effects that grand prizes have on the incentives players face in contests that can be characterized as a sequence of tournaments. There are many professional sports leagues that have seasons that are structured in this manner. Studying the results of these leagues and comparing across leagues would be a possible avenue for further research. Additionally, the use of the grand prize from the principal's perspective is a natural extension of this dissertation. The rise of the use of additional play-off spots in professional baseball, football and basketball, the creation of elite tournaments in tennis and golf, and the changes NASCAR made in the awarding of its season championship, the Nextel Cup, all offer opportunities to explore reasons why organizations are using the grand prize as an incentive and how much success each organization had for doing so.

## Appendix

### I. The relationship between $f^*$ and $f_{2L}$

If the principal wants the first tournament loser's effort in the second tournament to be larger than  $f^*$ , then the grand prize must not exceed a certain critical value.

So, we need to find the grand prize  $G$  that makes  $f^* < f_{2L}$ .

$$f^* = M(vD)^{-1} \text{ and } f_{2L} = vK_B(v^2D + 2\Delta_3)^{-1} \text{ implies that } M(vD)^{-1} < vK_B(v^2D + 2\Delta_3)^{-1}.$$

Some algebraic manipulation leads to

$0 < 2(2M-1)G^2 + 2(2M+vD)(2M-1)G - 2Mv^{-1}(v^2D - 1) = aG^2 + bG + c$ . The roots of this quadratic are  $G = (-b \pm (b^2 - 4ac)^{0.5})(2a)^{-1}$ . From this, it can be inferred that if

$$G > -b + (b^2 - 4ac)^{0.5}(2a)^{-1}, f^* \text{ will be larger than } f_{2L}.$$

### II. Derivations of comparative statics results from page 36:

a) There is a positive relationship between  $G$  and  $\lambda$ , the implicit incentive that the players face in the second tournament.

$$P(\text{A winning}) = \frac{1}{2} + \lambda = \frac{1}{2} + 2\Delta(v^2D + \Delta)(v^2D + 2\Delta)^{-2}, \text{ where } \Delta = (2MG + G^2)(2vD)^{-2}.$$

This implies that

$$\begin{aligned} \partial P(\text{A winning})/\partial G &= [(v^2D + 2\Delta)^2(2\Delta'(v^2D + 2\Delta) - 2\Delta(v^2D + \Delta)2(v^2D+2\Delta)(2\Delta'))](v^2D + 2\Delta)^{-4} \\ &= 2\Delta'[(v^2D + 2\Delta)^2 - 4\Delta(v^2D + \Delta)](v^2D + 2\Delta)^{-3} \\ &= 2\Delta'(v^2D)^2(v^2D + 2\Delta)^{-3} > 0 \quad (\Delta' = \partial\Delta/\partial G = (M+G)(vD)^{-2}) \end{aligned}$$

b) There is a negative relationship that exists between  $D$ , the marginal cost of exerting effort, and  $\lambda$ .

$$\begin{aligned} \partial P(\text{A winning})/\partial D &= [(v^2D+2\Delta)^2(2(2\Delta\Delta'+\Delta v^2+v^2D\Delta'))-2(v^2+2\Delta')(v^2D+2\Delta)(2\Delta)(v^2D+\Delta)](v^2D+2\Delta)^{-4} \\ &= 2[(v^2+2\Delta)(2\Delta\Delta' + \Delta v^2 + v^2D\Delta') - 2\Delta(v^2 + 2\Delta')(v^2D + \Delta)](v^2D + 2\Delta)^{-3} \\ &= v^4D(D\Delta' - \Delta)(v^2D + 2\Delta)^{-3} < 0 \quad (\Delta' = -(2MG + G^2)(2v^2D^3)^{-1}) \end{aligned}$$

c) There is a negative relationship between the variance of the idiosyncratic component of output ( $v$ ) and  $\lambda$ .

$$\partial P(\text{A winning})/\partial v =$$

$$\begin{aligned} & (v^2D+2\Delta)^2[2\Delta'(v^2D+\Delta)+2\Delta(2vD+\Delta')]-2\Delta(v^2D+\Delta)[2(v^2D+2\Delta)(2vD+2\Delta')](v^2D+2\Delta)^{-4} \\ & = 2[(v^2D + 2\Delta)(\Delta'v^2D + 2\Delta vD + 2\Delta\Delta') - 4\Delta(v^2D + \Delta)(vD + \Delta')](v^2D + 2\Delta)^{-3} \\ & = 2(v^2D^2(\Delta'v^2 - 2\Delta v))/v^2D + 2\Delta)^{-3} < 0, (\Delta' = -(2MG + G^2)(v^3D)^{-1} \end{aligned}$$

## References

- Asch and Warner, "A Theory of Compensation and Personnel Policy in Hierarchical Organizations with Applications to the United States Military", *Journal of Labor Economics*, July 2001, p. 523-562.
- Baik, "Effort Levels in Contests with Two Asymmetric Players", *Southern Economic Journal*, 1994, p. 367-378.
- Baker, Jensen, and Murphy, "Compensation and Incentives: Practice vs. Theory", *The Journal of Finance*, July 1988, p. 593-616.
- Baker, Gibbs, and Holmstrom, "The Internal Economics of the Firm: Evidence from the Personnel Data", *Quarterly Journal of Economics*, November 1994, p. 881-919.
- Baker, Gibbs, and Holmstrom, "The Wage Policy of a Firm", *Quarterly Journal of Economics*, November 1994, p. 921-955.
- Bebchuk, Fried, Walker, "Executive Compensation in America: optimal contracting or extraction of rents?" John M. Olin Center for Law, Economics, and Business. Discussion paper no. 338.
- Bognanno, "Corporate Tournaments", *Journal of Labor Economics*, April 2001, p. 290-315.
- Brown, Harlow, and Starks, "Of Tournaments and Temptations: An Analysis of Managerial Incentives in the Mutual Fund Industry", *Journal of Finance*, March 1996, p. 85-110.
- Burns, "The Hot Hand in Basketball: Fallacy or Adaptive Thinking?", In J.D. Moore & K. Stenning (Eds.), *Proceedings of the Twenty-third Annual Meeting of the Cognitive Science Society*, 2001, p. 152-157.
- Chevalier and Ellison, "Risk Taking by Mutual Funds as a Response to Incentives", *Journal of Political Economy*, December 1997, 1167-1200.
- Chevalier and Ellison, "Career Concerns of Mutual Fund Managers", *The Quarterly Journal of Economics*, May 1999, 389-432.
- Clark, "An analysis of streaky performance on the LPGA Tour", *International Journal of Sport Psychology*, October 2003, 365-370.
- Clark, "Streakiness among professional golfers. Fact or fiction?", *International Journal of Sport Psychology*, Jan-Mar 2003, 63-79.

- Craig and Hall, "Trying Out for the Team: Do Exhibitions Matter? Evidence from the National Football League", *Journal of the American Statistical Association*, September 1994, p. 1091-1099.
- Dorsey-Palmateer and Smith, "Bowlers' Hot Hands", *The American Statistician*, February 2004, p. 38-45.
- Ehrenberg and Bognanno, "Do Tournaments Have Incentive Effects?", *Journal of Political Economy*, December 1990, p. 1307-1324.
- Ehrenberg and Bognanno, "The Incentive Effects of Tournaments Revisited: Evidence from the European PGA Tour", *Journal of Industrial and Labor Relations Review*, February 1990, p. 74S-84S(a).
- Ferrall and Smith, "A Sequential Game Model of Sports Championship Series: Theory and Estimation", *Review of Economics and Statistics*, November 1999, p. 704-719.
- Erickson, "Executive Compensation and Tournament Theory: Empirical Tests on Danish Data", *Journal of Labor Economics*, April 1999, p. 262-280.
- Fudenberg, Levine, and Tirole, "Incomplete Information Bargaining with Outside Opportunities", *Quarterly Journal of Economics*, February 1987, p. 37-50.
- Fudenberg and Tirole, "Understanding Rent Dissipation: On the Use of Game Theory in Industrial Organization", *American Economic Review*, May 1987, p. 176-183.
- Gibbs, "Incentive compensation in a corporate hierarchy," *Journal of Accounting and Economics*, March-May 1995, 247-277.
- Gibbons, "Incentives in Organizations", *The Journal of Economic Perspectives*, Autumn, 1998, p. 115-132.
- Gilovich, Vallone, and Tversky, "The Hot Hand in Basketball: On the misperception of random sequences", *Cognitive Psychology*, October 1985, p. 295-314.
- Golf World*, Golf World, Inc., Pinehurst, NC, v. 36.
- Golf World*, Golf World, Inc., Pinehurst, NC, v. 37.
- Golf World*, Golf World, Inc., Pinehurst, NC, v. 39.
- Golf World*, Golf World, Inc., Pinehurst, NC, v. 40.
- Golf World*, Golf World, Inc., Pinehurst, NC, v. 41.

- Golf World*, Golf World, Inc., Pinehurst, NC, v. 47.
- Green and Stokey, “A Comparison of Tournaments and Contracts”, *Journal of Political Economy*, June 1983, 349-365.
- Greene, *Econometric Analysis*, Prentice Hall, 5<sup>th</sup> ed., 2002.
- Grossman and Hart, “An analysis of the principal-agent problem”, *Econometrica*, January 1983, p. 7-46.
- Holmstrom, “Moral Hazard and Observability”, *Bell Journal of Economics*, Spring 1979, p. 74-91.
- Hvide, “Tournament Rewards and Risk Taking”, *Journal of Labor Economics*, October 2002, p. 877-898.
- Ichniowski, Shaw, and Prenzushi, “The Effects of Human Resource Managements Practices on Productivity: A Study of Steel Finishing Lines”, *American Economic Review*, June 1997, p. 291-313.
- James and Isaac, “Asset Markets: How They Are Affected by Tournament Incentives for Individuals”, *The American Economic Review*, Sep. 2000, p. 995-1004.
- Kahneman and Tversky, “Judgment under uncertainty: Heuristics and biases”, *Science*, September 27, 1974, p. 1124-1131.
- Kennedy, *A Guide to Econometrics*, The MIT Press, 4<sup>th</sup> ed., 1998.
- King, “Unbridled”,  
[http://sportsillustrated.cnn.com/2004/writers/peter\\_king/11/29/mmqb.colts/index.html](http://sportsillustrated.cnn.com/2004/writers/peter_king/11/29/mmqb.colts/index.html),  
 November 29, 2004.
- Kmenta, *Elements of Econometrics*, The University of Michigan Press, 2<sup>nd</sup> ed., 1997.
- Knoeber “A Real Game of Chicken”, *Journal of Law, Economics, and Organization*, Fall 1989, p. 271-292.
- Knoeber and Thurman, “An Empirical Analysis of Broiler Production”, *Journal of Labor Economics*, April 1994, p. 155-179.
- Knoeber and Thurman, “Don’t Count Your Chickens: Risk and Risk Shifting in the Broiler Industry”, *American Journal of Agricultural Economics*, August 1995, p. 486-496.
- Laffont and Martimort, *The Theory of Incentives: The Principal-Agent Model*, Princeton University Press, 2001.

- Lazear, *Personnel Economics*, Wiley, 1997.
- Lazear and Rosen, "Rank Order Tournaments Optimal Labor Contracts", *Journal of Political Economy*, October 1981, p. 841-864.
- Malcomson, "Incentive Contracts in Labor Markets", *Handbook of Labor Economics*, Vol. III and IV. North Holland Publishing, New York City, 1998.
- Maloney and McCormick, "The Response of Workers to Wages in Tournaments: Evidence from Footraces", *Journal of Sports Economics*, 2000, p. 99-123.
- Maloney and Terkun, "Road Warrior Booty: Prize Structures in Motorcycle Racing", *Contributions to Economic Analysis and Policy*, Vol. 1, Article 3, 2002.
- Mendenhall and Sincich, *A Second Course in Statistics*, 5<sup>th</sup> ed., Prentice Hall, 1996.
- Nalebuff and Stiglitz, "Towards a General Theory of Compensation and Competition", *Bell Journal of Economics*, Spring 1983, p. 21-43.
- Neale, "The Peculiar Economics of Professional Sport", *Quarterly Journal of Economics*, February 1964, p. 1-14.
- Oettinger, "An Empirical of the Daily Labor Supply of Stadium Vendors", *Journal of Political Economy*, April 1999, p. 360-392.
- Orszag, "A New Look at Incentive Effects and Golf Tournaments", *Economics Letters*, September 1994, p. 77-88.
- 2000 PGA Tour Media Guide*, PGA Tour, Inc., Ponte Vedre Beach, FL, 1999.
- Rosen, "The Economics of Superstars", *American Economic Review*, December 1981, p. 845-858.
- Rosen, "Prizes and Incentives in Elimination Tournaments", *American Economic Review*, September 1986, p. 701-715.
- Scymanski, "The Economic Design of Sporting Contests", *Journal of Economic Literature*, December 2003, p. 1137-1187.
- Smith, "Horseshoe Pitchers' Hot Hands", *Psychonomic Bulletin and Review*, October 2003, p. 753-758.
- Taylor and Demick, "A multidimensional model of momentum in sports", *Journal of Applied Sport Psychology*, March 1994, p. 51-70.

Tsoulouhas and Vukina, "Regulating Broiler Contracts: Tournaments versus Fixed Performance Standards", *American Journal of Agriculture Economics*, issue 3, 2001, p. 1062-1073.

Tversky and Gilovich, "The Cold Hands about the Hot Hand in Basketball", *Chance*, Winter 1989, p.16-21.

Vergin, "Winning streaks in sports and the misperception of momentum", *Journal of Sport Behavior*, June 2000, p. 181-197.

Zimmerman, "Immovable Objects",  
[http://sportsillustrated.cnn.com/2004/writers/dr\\_z/12/08/power.rankings/index.html](http://sportsillustrated.cnn.com/2004/writers/dr_z/12/08/power.rankings/index.html), December 8, 2004.