Determinants of Performance on the PGA Tour

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Professional golf is an area that is particularly attractive to study because it models a perfectly competitive economy where payoffs are directly related to individual productivity (Scully 2002). Since one's earnings on the PGA Tour are based on individual performance, different skill factors and other variables such as tour experience and the number of events entered can be compared to determine which variables explain a tour player's performance. This question is interesting and relevant as tour players devote countless hours to practice focusing on different aspects of their golf game. For instance, time devoted to increasing driving length is time that a player will not be able to use to improve his accuracy with irons. Consequently, there is a high opportunity cost to practice. A player must choose the aspects of the game in which to specialize. This paper seeks to determine which skill factors offer the highest payoffs for golfers on the PGA Tour.

I. Background

The PGA Tour bases earnings on a prize system in which players receive compensation for how they place in tournaments. Golf tournaments consist of four rounds of eighteen holes played over four consecutive days. The player who takes the least number of strokes to finish wins the largest prize, the player who finishes second wins the second largest price, and so on. Therefore, a player's scoring average, the average number of strokes taken per round, is directly related to total earnings in dollars. Prize money is distributed in an uneven schedule where the top finisher usually receives 18 percent of the total purse, second 10.8 percent, third 6.8 percent, fourth 4.8 percent, fifth 4 percent, and sixth 0.2 percent (Scully). As is evident, the top five finishers generally take half of the total prize money offered.

PGA Tour professionals also have other sources of income such as corporate sponsorship, appearance fees, and golf course design contracts. In this study, the amount of other income is unknown and thus is not considered. The only earnings applied to this model are those made on the U.S. PGA Tour. Players may also win prize money on other tours such as the European Tour. Those earnings will not be considered. Over the past six years the size of PGA event purses has increased dramatically resulting from heightened interest in television broadcast rights and corporate sponsorship. In 2000, PGA Tour purses ranged between $2.8 and $6.0 million, whereas in 2005 purses could be as large as $10 million.

Previous studies in sports economics have used production relationships and labor market institutions to analyze skill factor payoffs. Unlike traditional human capital studies that can be contaminated by external factors, when considering PGA Tour players, it is known that they are among the best golfers in the world. Thus, there is little variation in player's innate physical abilities such as hand-eye coordination. Based on this assumption, a number of hypotheses can be used to test how various skills contribute to player performance (Alexander *et al.* 2005). Shmanske [1992] used production relationships to measure the individual's marginal revenue product on the PGA Tour, where a golfer's skill set was the explanatory variable. Alexander [2005] also used golfer skill variables to estimate how performance factors have changed over time. Alexander's research group concluded that putting is the most important skill factor in determining earnings; however, they found that driving distance is becoming a larger determinant of performance.

In professional golf, there has been a trend toward increased distance off the tee. Since 2002, the average driving distance on tour has increased by about 10 yards. This has led many in the golf world to place increased importance on driving distance. When asked what he thought the most overrated and underrated skills a golfer needs to play well, Hank Haney, Tiger Woods' swing coach responded by saying that power is "the single biggest thing that determines a player's potential…but (bunker play) is probably most overrated" (Golf Digest 2006). In response to increased driving distance, many courses that are used for PGA tournaments have been lengthened significantly. For example, Augusta National Golf Course, which hosts The Masters golf tournament, has been lengthened by 520 yards since 1997. Despite the fact that there is a greater emphasis on driving, a professional golfer will only use his driver a maximum of 14 times in a par 72 round. While roughly 40 percent of strokes taken are taken on the putting green (Alexander *et al.*). Thus, it was expected that putting will exhibit the greatest significance in determining a player's income out of all of the skill factors.

This paper differs from previous research in that it examines how a player's experience, the number of years on the PGA Tour, and the number of events played per year are correlated to scoring average and earnings. Experience is important especially when one is doing well in a golf tournament. When a victory is imminent and pressure is mounting, an experienced player is more equipped to deal with the stress than a less experienced player. However, it is thought that there is a certain point of diminishing marginal returns, when a player has been on tour for an extended period of time. As old age sets in, physical strength and flexibility diminish and reduce a player's skill. Scully [2002] found that there is a slight negative correlation between age and earnings; however, he only considered age as a single coefficient. In order to determine how a golfer's abilities are affected by experience, a regression was performed comparing the individual skill factors to experience and experience squared.

This model was approached employing the hypothesis that the number of events a tour pro enters will exhibit a positive relationship on earnings. Not all players can participate in as many tournaments as they would like. Golfers qualify for tournaments by performing well on tour. However, there may be some point where a player enters too many tournaments and fatigue ensues. As a result, performance decreases and the player does not earn as much.

Implicit in this model is the fact that golf courses and golf technology have changed over time. It was previously mentioned that many golf courses have been lengthened recently, which is primarily a reaction to advances in golf technology. Club manufacturers continue to develop lighter clubs that hit the ball farther and straighter. New golf ball technology has also lead to enhanced performance. In this paper, technological change will be treated as neutral as done by Alexander [2005]. This follows from the assumption that all changes in equipment will confer the same benefits on all players, thus the relationship between performance and skill measures will be unchanged.

II. The Empirical Model

The sample that was used for regression analysis consisted of datasets for individual golfers on the U.S. PGA Tour from 2002 to 2005. The number of golfers in each cross-section varied from year to year (185 in 2002 to 203 in 2005). The composition of individual golfers on the PGA Tour varies each year due to factors such as injury, being new to the tour, or failing to qualify for next year's events. Several golfers were eliminated from the dataset due to incomplete statistical information. A representative cross-section of data includes players who were previously on tour and new entrants. The total number of observations for the sample was 778.

Comprehensive data on PGA Tour players is collected by the PGA Tour. Officials measure player's individual performance in many different skill areas. The tour also keeps track of player's total earnings per season as well as the number of years a player has been on tour. This paper uses three different models to assess player performance. The first model compares scoring average to skills. The second model compares earnings to tour experience, number of events participated in, and the skill factors. The third model compares individual skill factors to experience.

The first empirical model consists of two equations: the first equation relates a player's scoring average, which is the average number of strokes a player takes per round of competition, to various skill factors including driving accuracy, driving distance, the number of greens hit in regulation, the average number of putts per green, and the percentage of sand saves made. The second equation considers all the same variables as equation 1 and also introduces experience as a variable to test if it has a significant impact on a player's scoring average. The equations are as follows:

$$(1)\quad SCORING\ AVERAGE = \beta_0 + \beta_1\ DRIVING\ ACCURACY + \beta_2\ DRIVING\ DISTANCE + \beta_3\ GREENS\ HIT\ IN\ REGULATION\ \text{(percent)} + \beta_4\ AVERAGE\ NUMBER\ OF\ PUTTS\ PER\ GREEN + \beta_5\ SAND\ SAVES\ \text{(percent)} + \varepsilon_i$$

$$(2)\quad SCORING\ AVERAGE = \beta_0 + \beta_1\ DRIVING\ ACCURACY + \beta_2\ DRIVING\ DISTANCE + \beta_3\ GREENS\ HIT\ IN\ REGULATION\ \text{(percent)} + \beta_4\ AVERAGE\ NUMBER\ OF\ PUTTS\ PER\ GREEN + \beta_5\ SAND\ SAVES\ \text{(percent)} + \beta_6\ EXPERIENCE + \varepsilon_i$$

The dependent variable in this model is scoring average (Scoreavg) for PGA Tour professionals. This average only includes official PGA Tour events. Golfers included in the sample may have played other events, but in order to keep the sample standardized only earnings from the PGA Tour were included.

Player performance skills were included as explanatory variables. Since a player's scoring average is determined solely on how well he performs, players with better skills will score lower. The first player performance variable included in the model was driving accuracy (Drivacc), which measures the percentage of the time that a player's ball lands in the fairway when hit from the tee box. This variable should exhibit a negative correlation because higher driving accuracy will result in a lower scoring average, and it will be generally easier to hit a ball from the fairway than the rough. This is because the grass in the fairway is shorter and is evenly cut. A player is able to strike the ball flush and impart spin helping to keep the ball on the green.

The second performance category included was driving distance (Drivdist), which is the distance a ball travels when hit from the tee box. The PGA Tour measures driving distance by selecting two holes per round that are relatively flat and face in opposite directions to counteract the effect of the wind. Officials measure the distance from the tee box to where the ball comes to rest, whether or not the ball lands in the fairway (PGA Tour). This variable should exhibit a negative relationship because a shot farther from the tee means that a player will be closer to the green. As a result, a player can use shorter irons, making it easier to hit high spinning shots that stay on the green.

The third performance variable included was the percentage of greens hit in regulation (Greenreg). Greens in regulation is a measure of a player's accuracy with his irons because it takes a precise shot to land the ball on the green and have it to stay there. The PGA Tour measures greens hit in regulation by calculating the percentage of shots that stay on the green after a designated number of strokes (PGA Tour). To hit a green in regulation, one has three strokes to land the ball on the green on a par five, two on a par four, and one on a par three. This measurement is not a perfect representation of iron accuracy because a ball hit four inches from the hole counts the same as a ball hit forty feet away from the hole, as long as both balls are on the green. Nevertheless, percentage of greens hit in regulation should exhibit a negative correlation coefficient because a player with his ball on the green should have an easier time finishing the hole.

The fourth performance factor considered was the average number of putts hit per green (Puttavg). Putting performance is calculated by measuring the number of putts taken on greens hit in regulation. For these holes, the total number of putts is divided by the total number of holes played (PGA Tour). By using greens hit in regulation, the effects of chipping the ball close to the hole and one putting are eliminated. This variable should exhibit a positive correlation, because fewer putts taken will directly translate into a better score at the end of the round.

The fifth skill measurement used as a performance factor was the sand save percentage (Sandsave). The sand save percentage measures the percentage of the time a player is able to get the ball 'up and down' from a greenside bunker. This means that a player is allowed one stroke out of the bunker and one putt on the green to be considered a sand save. This statistic is calculated regardless of the total score on the hole (PGA Tour). Sand save percentage will likely exhibit a negative correlation to scoring because a player who is better able to extricate himself from trouble will score lower.

The final variable included in this model was experience. Experience was added to the second equation to establish if there is a negative correlation between a player's scoring average and the number of years spent on tour. This model only included the experience variable and not the experience squared term to avoid multicollinearity, which will be addressed later.

The second empirical model used compares a player's inflation adjusted earnings to all the skill factors included in the first model as well as the number of years on tour and the number of events participated in per year. Each variable was also regressed as an individual function of earnings to test for any significant correlation between the independent variables and the dependent variable. The equation used is as follows:

$$(3)\quad \mathit{LN(INFLATION\ ADJUSTED\ EARNINGS)} = \beta_0 + \beta_1\, \mathit{DRIVING\ ACCURACY} + \beta_2\, \mathit{DRIVING\ DISTANCE} + \beta_3\, \mathit{GREENS\ HIS\ IN\ REGULATION}\ (\text{percent}) + \beta_4\, \mathit{AVERAGE\ NUMBER\ OF\ PUTTS\ PER\ GREEN} + \beta_5\, \mathit{SAND\ SAVES}\ (\text{percent}) + \beta_6\, \mathit{EXPERIENCE} + \beta_7\, \mathit{EXPERIENCE}^2 + \beta_8\, \mathit{EVENTS} + \beta_9\, \mathit{EVENTS}^2 + \varepsilon_i$$

The dependant variable in consideration was the inflation-adjusted annual earnings for players on the U.S. PGA Tour, with a base year of 2002. These earnings only include prize money from official U.S. PGA Tour events. A player's experience (Experience), the number of years played on the PGA Tour, will likely demonstrate a positive correlation to earnings, but as a player ages his skills will decline so experience squared will demonstrate a negative correlation to earnings. The number of events in which a player participates per year (Events), should exhibit a positive correlation on earnings up until a point where a player enters too many events and becomes fatigued. Thus, the coefficient for events squared will likely be negative. All of the skill factors used in the second model are expected to have opposite signs from what was predicted for the first model. This is because better performance in the second model is demonstrated by greater earnings, whereas in the first model higher performance was indicated by a lower scoring average.

III. Empirical Results

Table 1 includes summary statistics for the variables used in regression analysis and reveals some interesting facts about PGA Tour professionals. The average golfer earned $1,050,847 in 2002 dollars while participating in an average of 26.56 events per year. There was great variation from the average driving distance of 285.46 yards as the minimum average driving distance was 256.6 yards and the maximum average driving distance was 318.9 yards. The fairway was hit by golfers an average of 65.23 percent of the time from the tee with a maximum of 81.2 percent and a minimum of 45.4 percent. Professional golfers averaged 71.13 strokes per round and were able to hit greens in regulation 65.23 percent of the time with a maximum of 74 percent and a minimum of 55.5 percent. The table shows that players averaged 1.77 putts per green hit in regulation. Sand save percentage also varied highly from the average of 49.17 percent with a maximum of 64.9 percent and a minimum of 29.7 percent. As described, the results reported in Table 1 demonstrate that there is considerable variation in the skills and performance of golfers on the PGA Tour.

Table 1: Summary Statistics (n=778)

Variable	Mean	Standard Deviation	Maximum	Minimum
Inflation Adjusted Earnings	$1,050,847	1108082	$10,591,097	$40,025.05
Scoring Avg.	71.13	0.777	73.78	68.41
Driving Distance	285.46	9.085	318.9	256.6
Driving Accuracy (percent)	65.23	5.473	81.2	45.4
Greens in regulation (percent)	65.28	2.770	74	55.5
Putting Avg.	1.77	0.025	1.858	1.682
Sand Saves (percent)	49.17	5.977	64.9	29.7
# of Events	26.56	4.549	36	14
Years on Tour	13.27	6.372	33	0

Source: All variables were taken from the PGA Tour Statistics at http://pgatour.com (2006).

In Table 2, scoring average was used as the dependent variable (Scoreavg). The results show that the explanatory skill factors behaved as predicted. All of the variables are statistically significant at the 1% level except for driving accuracy (Drivacc), which was found to be insignificant in determining a player’s scoring average. In terms of practical significance, Table 2 shows that if a player was able increase his driving distance by 10 yards, scoring average would not even be improved by one-tenth of a stroke. But, if a player improved his putting average by 10 percent, his scoring average would improve by 2.3 strokes over one round. If a golfer was able to improve his iron accuracy and hit 10 percent more greens in regulation, then he would save 1.56 strokes per round. These results indicate that putting is the most significant skill factor.

Table 2: Scoring Average Regression Results

Variable	Coefficient	Std. Error	t-Stat
Constant	61.42	1.6582	37.04
Drivdist	-0.00883	0.00301	-2.933
Drivacc	-0.0009	0.005104	-0.1772
Greenreg	-0.15599	0.007806	-19.98
Puttavg	13.49	0.7399	18.23
Sandsave	-0.03023	0.00315	-9.597
Adj R^2	0.6238		
S.E.R.	0.4768		
N	778		
Durbin-Watson	1.876		
p-value	0.0001		

In Table 3, experience was added to the previous regression shown in Table 2 to test whether experience has a significant effect on a player's scoring average. Data analysis shows that experience is significant in determining a player's scoring average; however, the significance of experience is much less than some of the skill factors such as iron accuracy and putting, but experience is more significant than driving distance and driving accuracy. The coefficients for most of the skill factors did not change much when experience was added as an explanatory variable except for the coefficients for driving distance and driving accuracy, which changed by a factor of two and five, respectively. This may indicate some multicollinearity in the model, which will be addressed in detail later.

Table 3: Scoring Average Regression Results

Variable	Coefficient	Std. Error	t-Stat
Constant	62.62	1.639	38.21
Drivdist	-0.01459	0.003111	-4.692
Drivacc	-0.00487	0.005055	-0.9637
Greenreg	-0.1486	0.007749	-19.17
Puttavg	13.72	0.7258	18.9
Sandsave	-0.02986	0.003086	-9.677
Experience	-0.01578	0.002815	-5.605
Adj R^2	0.6383		
S.E.R.	0.467		
N	777		
Durbin-Watson	1.873		
p-value	0.0001		

The data shown in Table 4 include the regression statistics where the natural logarithm of inflation adjusted earnings (Infearn) was used as the dependent variable. Each variable was considered as an individual function of earnings and then was considered collectively to explain earnings. The collective regression results show that experience, experience squared, events, events squared, and driving accuracy are not significant determinants of earnings on the PGA Tour. The regressions considering those same variables as individual determinants of earnings also indicate that these factors are not significant in determining a player's income on the PGA Tour. This was unexpected and may be due to multicollinearity. Table 4 does validate some of the predications made earlier that driving distance, iron accuracy, putting average, and sand save percentage are significant at the 1 percent level and the signs are as expected.

Table 4: Regression of Ln(Earnings)

Variable				Regression Coefficient (t-Statistic)						
Constant	13.43	13.44	13.39	13.44	8.028	13.2	2.665	46.21	11.087	23.81
	(66.28)	(120.6)	(169.0)	(256.0)	(7.587)	(32.26)	(3.76)	(21.66)	(40.99)	(9.878)
Events	3.75E-04									6.58E-03
	(4.99E-02)									(0.1333)
Events^2		-1.08E-06								-5.93E-05
		(-7.41E-03)								(-6.19E-02)
Experience			3.43E-03							9.69E-03
			(6.38E-01)							(6.49E-01)
Experience^2				2.35E-05						-3.69E-05
				(1.28E-01)						(-7.14E-02)
Drivdist					1.90E-02					1.55E-02
					(5.12)					(3.47)
Drivacc						3.73E-03				-4.21E-03
						(5.96E-01)				(-5.83E-01)
Greenreg							1.65E-01			0.1633
							(1.52)			(14.71)
Puttavg								-18.45		-15.31
								(-15.36)		(-14.73)
Sandsave									4.79E-02	3.60E-02
									(8.78)	(8.16)
Adj. R^2	-1.29E-03	-1.29E-03	-7.64E-04	-1.27E-03	3.14E-02	-8.30E-04	0.2293	0.2322	8.91E-02	0.5111
S.E.R.	0.9539	0.9539	0.9543	0.9545	0.9382	0.9537	0.8369	0.8353	0.9098	0.667
N	778	778	777	777	778	778	778	778	778	777
Durbin-Watson	1.886	1.886	1.886	1.888	1.892	1.886	1.912	1.832	1.83	1.788
p-value	0.9694	0.9694	0.9831	0.9718	0.3815	0.9815	0.0001	0.0001	0.0129	0.0001

The findings included in Table 5 consist of five separate regressions that were performed to determine if there was any specific correlation between individual skill factors and performance. It was found that driving distance is significantly higher when a player is less experienced. This corresponds with predictions made that younger players are stronger and more flexible, thus they can swing a driver faster. The regression of the natural logarithm of driving accuracy and the natural logarithms of experience and experience squared is also significant and shows that as players age, they loose driving distance and either become more accurate as a result or they try to compensate for their lack of distance by improving accuracy. The regressions run on the remaining skill factors, iron accuracy (Greenreg), putting average (Puttavg), and sand save percentage (Sandsave) show that experience is not a significant determinant of performance.

Table 5: Regression of Ln of Individual Skill Factors

	Drivdist	Greenreg	Puttavg	Sandsave	Greenreg
Variable	Regression Coefficient (t-Statistic)				
Constant	5.642	4.159	0.5828	3.855	4.159
	(623)	(323.7)	(136.8)	(100.5)	(323.7)
Ln(Experience)	0.03508	0.01549	-0.00837	0.01322	0.01549
	(4.11)	(1.279)	(-2.085)	(0.3657)	(1.279)
Ln(Experience)^2	-0.0117	-0.00315	0.001904	0.000153	-0.00315
	(-5.909)	(-1.121)	(2.044)	(0.01823)	(-1.121)
Adj. R^2	0.1105	0.000021	0.003027	0.00173	0.000021
S.E.R.	0.0299	0.04243	0.01406	0.1266	0.04243
N	775	775	775	775	775
Durbin-Watson	1.736	2.049	2.069	2.133	2.049
p-value	0.0021	0.9995	0.9329	0.9616	0.9995

Multicollinearity was a significant concern in the analysis of the determinants of player performance. Since many of the skill factors were expected to affect performance in the same direction (i.e. driving accuracy and driving distance) the presence of multicollinearity was expected. Table 6 shows a correlation matrix that was constructed to determine if any of the variables considered were significantly related to each other. Typically, a value of 0.8 and higher indicates a significant correlation between two explanatory variables. The matrix below shows that there was some negative correlation between driving distance and driving accuracy. This indicates that as a player drives the ball farther, accuracy declines. The matrix also shows that there is minor correlation between experience, driving distance, and driving accuracy as discussed earlier. There was also a slight correlation between driving accuracy and iron accuracy. This fact is not unexpected as it is logical that a player who controls the ball better off the tee will also control the ball better onto the green.

The problem that arises with multicollinearity is that error terms are larger than normal because several variables are being used to account for the same phenomenon. This may explain why driving accuracy is not significant, as iron accuracy may explain the same effect of accuracy on performance. Also, multicollinearity may explain why experience is not significant in the earnings model since experience is correlated to driving distance and driving accuracy and may already be implicit in the model. Heteroscedasticity and autocorrelation were also tested for and are not present in the regression analysis conducted. The Durbin-Watson values for the regression analyses performed are close to 2.0, which indicate that autocorrelation is not a problem.

Table 6: Correlation Matrix

	EVENTS	EXPERIENCE	DRIVACC	DRIVDIST	PUTTAVG	GREENREG	SANDSAVE
EVENTS	1.000000	-0.159698	0.090060	-0.019412	0.041452	0.062285	-0.062740
EXPERIENCE	-0.159698	1.000000	0.152487	-0.315471	0.010332	0.014550	0.066676
DRIVACC	0.090060	0.152487	1.000000	-0.639268	0.039058	0.310756	-0.010009
DRIVDIST	-0.019412	-0.315471	-0.639268	1.000000	0.047196	0.202191	-0.174398
PUTTAVG	0.041452	0.010332	0.039058	0.047196	1.000000	-0.014420	-0.365719
GREENREG	0.062285	0.014550	0.310756	0.202191	-0.014420	1.000000	-0.103788
SANDSAVE	-0.062740	0.066676	-0.010009	-0.174398	-0.365719	-0.103788	1.000000

IV. Conclusion

This paper is consistent with other golf economics research in that it found that putting is the most important component of player performance. If a player were to improve his putting average by one putt per round (approximately 5 percent), he would earn an average of $0.75 million more per year. Iron accuracy, as measured by greens hit in regulation, was determined to be the second most important explanatory variable in PGA Tour performance. If a player were to improve the number of greens he hit in regulation by 1 percent, then he would win an average of $160,000 more per year. Thus, it can be concluded if a player wishes to maximize performance and practice time, the most effort should be devoted to improving putting and iron accuracy.

The data also show that driving distance, sand save percentage, and experience are small determinants of scoring average. Surprisingly, when experience was included in the regression of earnings it was found to be insignificant. It was expected that if experience improves scoring average, then experience should also improve player earnings. Multicollinearity may explain this inconsistency as experience may be implicit in other skill factors such as driving distance and driving accuracy. It was also surprising that the number of events that a professional golfer participated in was not a significant determinant of player earnings. In future studies, it would be useful if the performance factors used could be adjusted to avoid correlation. For example, if data were available on the average distance from the hole a player's ball is when they hit a green in regulation, then the distance could be factored into the putting average statistic in the hope of eliminating the multicollinearity between some of the skill variables.

Results from the regression analysis also show that experience may affect many of the skill factors where experience is an indicator of a player's relative age on tour. The data generated shows that as players age, they loose distance off the tee, however, they gain accuracy. This factor along with the dominance of putting may explain why older golfers are able to compete with young golfers, which is a phenomenon unique to golf. The results of this study disprove Hank Haney's statement that "power is the single biggest thing that determines a player's potential" and demonstrates that putting remains the single most important skill in determining a player's performance on the PGA Tour.

V. References

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