4. Gender and skill convergence in professional golf

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4.1 INTRODUCTION

In golf, brute strength is not as important as it is in many other sports. Consequently, all else equal, women might be expected to compete effectively with men. However, with very few exceptions (for example, Babe Zaharias, Annika Sorenstam, and Michelle Wie) women have competed separately in women-only events. It is possible that separate competitions are an artifact of antique social mores that are slowly changing. As women, and society in general, become accustomed to the idea of women competing directly with men, women will be more willing to practice to develop the level of skills to compete in gender-neutral tournaments at the highest level. Many golf fans, including this author, eagerly await this day. However, Shmanske (2000, 2012) has shown that, at their current skill levels, women can earn more money by competing in women-only tournaments sponsored by the Ladies Professional Golf Association (LPGA) than they can by competing in the tournaments on the Professional Golfers' Association Tour (PGA TOUR), which are open to both genders.

Competitive professional golf in the United States is organized into annual 'Tours', in which the golf associations schedule tournaments. The associations determine which golfers are eligible to compete, and they negotiate with the golf courses and corporate sponsors for the right to stage the event. The PGA TOUR and its forerunner, the Tournament Players Division of the PGA of America, have organized the Tour since the 1930s, before which a less formal structure of the Tour was in place.

The LPGA was established in 1950, taking over from a short-lived association of women professional golfers called the Women's Professional Golf Association (WPGA), which staged the first professional Women's Open Championship in 1946. Although amateur women's golf had important women-only competitions as early as 1895, when the United States Golf Association (USGA) sponsored the first US Women's Amateur Championship, professional women's golf barely existed before the end of the Second World War. The WPGA ran the Women's Open for a few years; the LPGA took over in 1950, and the USGA took over in 1953.¹

One other major Tour, the Champions Tour (formerly called the SENIOR PGA TOUR), organizes competitions for participants over the age of 50. This Tour was formalized in 1980, at which time the PGA TOUR recognized that older golfers could not compete effectively on the regular Tour but still had the ability to attract fans and television coverage owing to their name recognition. There are also European and other foreign and 'minor' Tours. These have also been studied, but data have been most readily available for the three major North American professional Tours, which are the basis for this study.

This chapter compares men's and women's skill levels over the last 20 years by focusing on the skill of driving distance. Even though the skills of chipping, putting, and overall accuracy are also important, driving distance is especially interesting for three reasons. First, if women can catch up to men in driving distance, the skill most likely to be affected by overall size and brute upper-body strength, they can, with practice, match men in the other skills. The other skills require touch, hand-eye coordination, flexibility, balance, and timing, all developed by practice, and all theoretically gender neutral. Women's performance relative to men in driving distance should, therefore, be a prime determinant of women's ability to compete with men.

Second, the skill of driving distance has evolved rapidly with the growth of technology in golf equipment. Advances in materials and design for both balls and clubs have led to an increase in driving distance for golfers of all ages and abilities. If these new materials and designs differentially advantage women over men or men over women, they may advance or forestall, perhaps indefinitely, the day when women achieve parity with men.

Third, it is obvious to even casual observers of the sport that the skill of driving distance characterizes professional golfers. Even mediocre amateurs will occasionally have a great round, sink a long putt, chip in from off the green, or make a birdie, but most will never hit a drive over 300 yards. Even though more astute fans and more accomplished amateurs recognize that professionals are perhaps even farther ahead in the areas of spin rate, trajectory control, and consistency, than they are in pure distance, these more subtle aspects of the game lack the 'wow' factor that long drives engender. As the old adage says, 'Drive for show, putt for dough'. Because of the fans' appreciation of the prodigious distances that professionals can hit the ball, there are important linkages extending from driving distance to prize funds to professional golfers' earnings and back to the incentive to increase driving distance. These linkages may differ systematically between the PGA TOUR and the LPGA.

The remainder of this chapter is divided into four sections. Section 4.2

sets the stage for this research by reviewing the previous literature on professional golfers' earnings and the golf production function. The two following sections describe and carry out two separate analyses of the gender differences in driving distance. Section 4.3 examines whether women are catching up to men in the skill of driving distance. Section 4.4 performs a Granger (1969) causality test to determine the extent to which increasing prize funds bring forth greater driving distance, and the extent to which increases in driving distance provide fan enjoyment, ultimately leading to larger purses. Section 4.5 concludes.

4.2 LITERATURE REVIEW: THE GOLF PRODUCTION FUNCTION

The literature on women's golf is not as extensive as that on men's. There are only a few studies, and most of them do not statistically analyze a formal relationship between the input of the golfer's skills and the output of the golfer's score or earnings. For example, Shin and Nam (2004) examine a player's race and nationality, focusing on Korea, while Kalist (2008) looks at performance before and after childbirth. Early on, Marple (1983) compares men's and women's earnings in golf and tennis, showing that women might have been catching up but have a long way to go. More recently, Matthews et al. (2007) examine the link between purse size and performance, and Tirunch (2010) compares age and earnings profiles across gender. None of these studies estimates a production function *per se*.

At the simplest level, golfers use their skills in a variety of dimensions as inputs to earn prize money based on rank-order performance in tournaments. This suggests estimating a production function as a reduced-form regression of golfer earnings on a vector of skills, such as: driving distance, driving accuracy, accuracy with approach shots, putting proficiency, and ability to play from sand bunker hazards. Numerous studies of this relationship have been undertaken, differing slightly based on the year and Tour of the sample, the format of the dependent variable, the functional form, and the skill and control variables included on the right-hand side.

Early studies (Davidson and Templin, 1986 and Nix and Koslow, 1991) came from the exercise, sport, and body mechanics literature, as opposed to the economics of sports. Using data from 1983 and 1987, respectively, these researchers were interested in discovering which skills were statistically important in determining earnings, but they did not systematically control for other determinants of earnings. Therefore, they used stepwise regression and dropped multiple dimensions of skill from the analysis. The

results confirm the importance of several golf skills, but they are hard to generalize due to the *ad hoc*, stepwise nature of the statistical calculations.

A paper from the exercise and sport literature (Shaffer et al., 2000) expands this analysis to include the top 50 golfers from the Champions Tour, the LPGA, and the PGA TOUR for the 1998 season. This chapter confirms that driving distance is important, but I do not estimate the full golf production function.

The earliest economic study is Shmanske (1992), who uses data on 60 top money earners in 1986. He regresses levels and natural logarithms of earnings per year and earnings per tournament on the five skills mentioned above, a calculated measure of short game skill, and a measure of experience. In the levels specification, the coefficient estimates are interpreted as value of the marginal product (VMP) of the various skills. Thus, an additional yard of driving distance is worth \$6,775 per year or \$341.10 per tournament. Shmanske also uses survey data on the golfers' practice routines to develop an estimate of the VMP of practice for each skill. He finds a return of between \$200 and \$300 per hour for practice on driving and a return of \$300–\$600 per hour for practice on putting.

Sommers (1994) uses the full set of 183 PGA TOUR golfers for 1992. The dependent variable is the natural logarithm of earnings per tournament. He finds that one yard of driving distance increases earnings by 3.8 percent. See Table 4.1 for a listing of the various parameter estimates for driving distance that appear in the economics literature, as well as a transformation of these estimates into elasticities for ease of comparison. For example, in this case, the average driving distance was 260.4 yards, so one additional yard is actually an increase in driving distance of $1/260.4 = 0.384$ percent. Transforming these calculations yields an elasticity of earnings per tournament with respect to driving distance of 9.90.

Several other studies examine variations on the above theme. They use different samples or include different control variables in addition to the usual five skills of driving distance, driving accuracy, greens in regulation, sand saves, and putts per green. Moy and Liaw (1998) develop separate estimates of the parameters for the PGA TOUR, the Champions Tour, and the LPGA for the 1993 season. Driving distance is statistically significant on the PGA TOUR and the Champions Tour but not in the LPGA Tour. Nero (2001) uses the highest 130 earners in 1996 to estimate a parameter that implies an elasticity of earnings per year with respect to driving distance of 13.34. Alexander and Kern (2005) use 10 years of PGA TOUR data in an unbalanced panel to track changes in the VMPs of golfer skills over the 1992–2001 period. The return to driving distance roughly tripled over this period, almost exactly matching an approximate tripling in purse sizes.

Table 4.1 Studies of professional golf production and earnings

Author and date	Sample	Descriptive statistics ^a	Impact of 1 added yard	Elasticity ^b
Nix and Koslow (1991)	PGA TOUR 1987	\$267,000/year 263.4 yards	Estimates not reported	
Shmanske (1992)	PGA TOUR 1986	\$256,000/year 262.1 yards	\$6,775**/year	6.94
Sommers (1994)	PGA TOUR 1992	260.4 yards	0.038***ln\$/event	9.90
Wiseman et al. (1994)	PGA TOUR 1992	70.9 strokes/round	-0.18*strokes/rd	-0.66 ^c
	SPGA ^d 1992	261 yards	Estimates not reported	
	LPGA 1992		Estimates not reported	
Moy and Liaw (1998)	PGA TOUR 1993	\$265,000/year 260.2 yards	Reports elasticities	9.28***
	SPGA 1993	\$329,000/year		3.14**
	LPGA 1993	254.1 yards \$91,000/year		4.07
Berry (1999)	PGA TOUR 1999	226.9 yards 71.84 strokes/round	-0.175strokes/rd	-0.66 ^c
Shaffer et al. (2000)	PGA TOUR 1998 SPGA 1998 LPGA 1998	272.2 yards	Estimates not reported	

Table 4.1 (continued)

Author and date	Sample	Descriptive statistics ^a	Impact of 1 added yard	Elasticity ^b
Shmanske (2000)	PGA TOUR 1998	\$623,000/year	0.036***ln\$/event	9.76
	LPGA 1998	271.25 yards \$139,440/year 236.6 yards	0.016ln\$/event	3.79
Rishe (2001)	PGA TOUR 1999	\$923,000/year	0.015ln\$/event	4.10
	SPGA 1999	273.2 yards \$567,000/year 265.9yards	0ln\$/event	0
Nero (2001)	PGA TOUR 1996	\$433,000/year 266.9 yards	0.05***ln\$/year	13.34
Fried et al. (2004)	PGA TOUR 1998	\$18,806/event 270yards	\$1,583/event	22.73
	SPGA 1998	\$17,749/event 262 yards	\$257/event	3.79
	LPGA 1998	\$5,598/event 237 yards	\$434/event	18.37
Alexander and Kern (2005)	PGA TOUR 1992–2001	\$306,600/year ^c 268.19 yards	\$11,728***/year 0.04*** ln\$/year	10.26 10.73
Pfiftzner and Rishel (2005)	LPGA 2004	\$10,370/event 249.8 yards	Reports elasticities	4.95***

Callan and Thomas (2007)	PGA TOUR 2002	\$953,000/year 280 yards	Reduced form: \$12,257/year Multi-equation: \$5,892/year	3.60 1.73
Shmanske (2008)	PGA TOUR 2006	\$71,258/event 289.1 yards	Reduced form: 0.0326***ln\$/event Structural model: 0.016 ln\$/event	9.42 4.63
Kahane (2010)	PGA TOUR 2004–07	\$52,020/event ^f 288.6 yards	OLS: \$926**/event Median: \$407*/event 90th% \$1,602*/event	5.14 2.26 8.89
Shmanske (2012)	PGA TOUR 2008	\$71,323/event 288.0 yards	0.017ln\$/event	4.90
	LPGA 2008	\$19,299/event 248.1 yards	0.018ln\$/event	4.47

Notes:

- *, **, *** denote statistical significance of estimate at 0.10, 0.05, and 0.01 levels where reported in original paper.
- Sample averages for earnings are measured in current dollars per golfer per year (or per event) unless otherwise noted. Sample averages for driving distance are those reported in the cited paper.
 - Implied elasticity of earnings (per year or per event) with respect to driving distance unless otherwise noted.
 - Elasticity of strokes per round with respect to driving distance.
 - SENIOR PGA TOUR or Champions Tour.
 - Constant dollars 1982–84.
 - Constant dollars 2007.

Shmanske (2000) applies the parameter estimates to compare the PGA TOUR to the LPGA for the 1998 season using the decomposition method of Oaxaca (1973). In a result of particular importance to this volume, the decomposition of the 1998 earnings gap between men and women in professional golf indicates that 32 percent of the gap is due to the higher return to the skill of driving distance on the PGA TOUR² and that 68 percent of the gap is due to the higher level of this skill exhibited on the PGA TOUR. In variations on this approach, Rishe (2001) decomposes the age-based earnings gap between the Champions Tour and the regular PGA TOUR using data from 1999, and Shmanske (2012) uses 2008 data to re-examine the gender-based earnings decomposition of his earlier study. By 2008, the higher return to driving distance on the PGA TOUR disappeared, and the portion of the gender gap in earnings due to the higher performance of men with respect to driving distance decreased to 45 percent.

Others have followed Shmanske (1992) in estimating a production function for women's golf. Pfitzner and Rishel (2005) use 2004 data from the LPGA and find a relatively low elasticity of earnings with respect to driving distance. Fried et al. (2004) use data envelopment analysis with 1998 data to define a frontier production function. They obtain very high elasticities of earnings with respect to driving distance for both the PGA TOUR and the LPGA.

Others presage or follow Scully's (2002) suggestion to estimate a structural model because golf skills do not directly produce earnings. Rather, skills produce scores in competitions that generate earnings according to a rank-based distribution of prizes. Wiseman et al. (1994) estimate the first half of the structure with 1992 data. They find that driving distance has a significant impact only on the PGA TOUR. One yard of distance decreases scores by 0.18 strokes per round. This translates to an elasticity of strokes per round with respect to driving distance of -0.66 .

Using 2002 data, Callan and Thomas (2007) extend Scully's insight by estimating a three-step structural model in which skills produce scores, scores produce ranks in tournaments, and ranks in tournaments generate earnings. Combining the results of three equations, they estimate that increasing driving distance by one yard increases yearly earnings by \$5,892. This is less than half of their reduced form estimate of the same VMP, \$12,257 per year, which they calculate for comparison.

Each of the above papers has used the yearly averages of earnings and skills as the basic units of analysis. Other work has attempted to improve upon the measurement of the skills or the calculation of the coefficients. Berry (1999) recognizes that the skills may be interdependent in his study of PGA TOUR data from the first 28 tournaments of 1999. For example,

the measure of sand saves depends upon how good a putter one is, the measure of greens in regulation depends on how long and accurate one's drives are, and, because of interaction, the value of driving distance depends on driving accuracy. Berry constructs new measures of each skill and includes the interaction term between driving distance and driving accuracy in his regression. Thus, one additional yard of driving distance reduces strokes per round by 0.067 directly and by another 0.108 indirectly when evaluated at the mean level of driving accuracy.

Shmanske (2008) follows the top 100 PGA TOUR earners from 2005 during the 2006 season to gather data on a tournament-by-tournament basis and offers two refinements. First, the measurements of the skills are adjusted for course characteristics. Second, instead of having only the year-end average skill level, a distribution of skills (from which mean, variance and skewness are calculated) is captured for each golfer. Then, following Scully's two-step suggestion, the distribution of skills produces a distribution of scores which, in turn, produces earnings per tournament. In the reduced-form estimation, one yard of driving distance increases earnings per tournament by 3.26 percent, whereas in the complex structural model one yard of driving distance affects mean, variance, and skewness of the scoring distribution for a combined effect on earnings of 1.6 percent, less than half of the reduced-form estimate.

Kahane (2010) further improves our understanding of the golf production function and the value of driving distance by estimating a quantile regression and contrasting these results with OLS estimates. He uses data from the PGA TOUR from 2004 to 2007 and controls for all the usual skills. His OLS estimates indicate that one additional yard increases earnings by \$926 per tournament. In the quantile regression, controlling for the other skills, at the median of the conditional earnings distribution, one additional yard leads to only an additional \$407 per tournament. At the 90th percentile, one extra yard leads to \$1,602 per tournament of extra winnings distribution. The return to driving distance is quantitatively higher as one moves up in the distribution of earnings, conditional on the explanatory variables. As expected, the typical, nonlinear prize distribution favors those at and near the top.

The most recent innovation in the estimation of a golf production function comes from using microdata collected by an army of PGA TOUR volunteers who track every shot by every golfer in every tournament. Thus, over time, the unit of observation has gone from yearly averages, to per tournament averages, and finally to individual shots. Results from studies using these new data are starting to arrive. Fearing et al. (2011) focus on putting performance based on the absolute distance of each putt. Recognizing that the contour of the green is also important, Stockl et al. (2011) measure the

putting skill from each location on a single green. Work along these lines on distance and accuracy from every spot on the golf course will be a focus of continued future research on the golf production function.

4.3 RECENT TRENDS IN DRIVING DISTANCE

Table 4.1 confirms that the average driving distance of professional golfers has increased over the period in which economists have been studying the golf production function. A deeper look at the papers indicates that there has not been a marked increase in the other skills over the same period. This is true for both genders, although the LPGA has been studied less, and the evidence is spottier. This section examines the trends in driving distance for men and women over the last two decades to ascertain whether women are catching up or falling farther behind in this skill.

I have collected data on the age and yearly average driving distance of 694 male and 630 female professional golfers on the PGA TOUR, the LPGA, and the Champions Tour from 1992 to 2010. I use the data for women to estimate the following equation:

$$DRIVDIST = \beta_0 + \beta_1 AGE + \beta_2 AGE^2 + \beta_3 1993 + \dots + \beta_{20} 2010 + \epsilon. \quad (4.1)$$

I have suppressed i and t subscripts indicating the golfer and year of the individual observation. The dependent variable, *DRIVDIST*, is the yearly average distance in yards of the golfer's tee shots. *AGE* and *AGE*² capture an expected inverted-U shape age profile of the skill. The years are dummy variables that control for recent improvements in the skill, whether due to increased practice or improvements in technology, without imposing a specific functional form. The dummy variable for 1992 is omitted so that the β_3 through β_{20} coefficients measure the improvement over the base year of 1992.

I also estimate a variation of this equation for men with the addition of a dummy variable, *CHAMP*, for golfers on the Champions Tour. Finally, I pool both genders and add the dummy variables, *CHAMP* and *PGATOUR*, to separate the men's distance on the regular and senior tours from the women's distance on the LPGA. The results appear in Table 4.2.

The constant terms in the first two columns show that men out-drive women over this period by about 40 yards. This result is corroborated by the coefficients on *CHAMP* and *PGATOUR* in the pooled regression, which indicate that drives are 37 yards longer on the Senior Men's Tour and 38 yards longer on the PGA TOUR than they are on the LPGA

Table 4.2 Coefficient estimates (and t-statistics) of the determinants of driving distance

Dependent variable: DRIVDIST			
Variable \ Sample	Women	Men	Pooled
Constant	229.647 (84.06)***	269.803 (105.05)***	227.118 (120.35)***
AGE	0.021 (0.14)	-0.102 (-0.73)	0.129 (1.25)
AGE ²	-0.006 (-2.86)***	0.005 (-2.63)**	-0.007 (-5.12)***
CHAMP		-1.635 (-2.07)**	37.258 (54.38)***
PGATOUR			38.138 (173.14)***
1993	1.706 (1.66)*	-0.002 (-0.00)	0.932 (1.39)
1994	2.677 (2.60)***	1.868 (2.25)**	2.339 (3.47)***
1995	7.842 (7.71)***	3.524 (4.30)***	5.902 (8.87)***
1996	9.354 (9.22)***	6.649 (8.16)***	8.120 (12.24)***
1997	12.992 (12.03)***	8.183 (10.13)***	10.318 (15.14)***
1998	13.502 (12.54)***	11.215 (13.81)***	12.171 (17.83)***
1999	12.679 (11.00)***	12.929 (16.08)***	12.612 (18.07)***
2000	14.800 (13.76)***	14.029 (17.58)***	14.225 (21.05)***
2001	18.060 (16.77)***	20.003 (25.11)***	18.946 (28.05)***
2002	23.476 (21.83)***	20.232 (25.79)***	21.434 (32.05)***
2003	24.689 (24.39)***	26.621 (33.66)***	25.525 (39.07)***
2004	23.766 (23.48)***	27.189 (34.53)***	25.334 (38.88)***
2005	21.643 (21.20)***	29.068 (37.31)***	25.321 (38.91)***
2006	23.016 (22.55)***	29.333 (37.46)***	26.092 (40.02)***
2007	23.151 (22.44)***	28.930 (37.18)***	26.038 (39.86)***
2008	21.692 (21.03)***	27.497 (35.47)***	24.585 (37.73)***
2009	24.352 (22.94)***	28.053 (36.09)***	26.176 (39.61)***
2010	21.660 (20.32)***	28.127 (36.55)***	25.095 (38.15)***
adj. R ²	0.428	0.641	0.835
n	3823	4115	7938

Tour. These coefficients also show that, after controlling for age, there is only a one- or two-yard difference between the regular PGA TOUR and the Champions Tour. This result is confirmed by the small size of the *CHAMP* variable in the men's regression.

Comparing the *AGE* and *AGE*² coefficients shows an increasing falloff of driving distance as age increases, essentially forming the latter half of an inverted-U shape age profile; there is no evidence of the upward-sloped part of an inverted-U. The result is consistent across gender.

Both men and women have gained distance over the period. Women have gained over 20 yards, and men have gained close to 30 yards, but

the pattern and timing of the gains differ by gender. Early in the period, women gained more than men, closing the distance gap by almost five yards by 1997. However, from 1997 until 1999, women's distances leveled off while men continued to gain, both ending up about 12 yards longer than in 1992. Both genders made large gains in the three years following 1999, with women adding another 11 yards for a total gain of over 23 yards compared to 1992, while men added eight yards for a total gain of 20 yards. So from 1992 to 2002, women gained three more yards on their drives than men did, making a small inroad on closing the gender gap in driving distance. Men started from a higher base in 1992, so the diminishing gap in driving distance is consistent with the convergence of skill levels.

Skill convergence disappeared after 2002, as women's driving distance leveled off while men's driving distance rose by more than six yards from 2002 to 2003 before leveling off. By 2010, men's drives were 28 yards longer than in 1992 while women's drives added less than 22 yards. The comparative pattern of gains to driving distance over the period is shown graphically in Figure 4.1. The first half of the top panel (a) can be

Sources: PGA, LPGA, and Champions Tour websites.

Figure 4.1 *Driving distance*

construed to indicate that women's driving distance was converging to the men's driving distance, but the second half of the top panel shows that the gains were lost. The bottom panel (b) puts into perspective the relatively unchanged gender gap into perspective.

4.4 PURSES, DISTANCE, AND GRANGER CAUSALITY

Both driving distance and prize funds have increased dramatically over the past two decades. Causality could run in both directions between these two time series, or both series could move together in response to an exogenous influence. For example, the growth in prize funds means that there is a greater incentive to practice all golf skills, thus supporting the argument that increases in prize funds cause increases in driving distance. At the same time, increases in driving distance may attract more fans, thus allowing tournament promoters to offer higher purses. Additionally, an outside factor may be causing both trends. For example, the arrival of popular and charismatic golfers, such as Tiger Woods and John Daly, who also happen to be long drivers, may simultaneously lead to increases in purses and average driving distances in professional golf.

It is beyond the scope of this chapter, and possibly beyond the limitations of the available data, to sort out all the possible directions of causality in a fully specified simultaneous equation model. It is possible, however, to get a sense of the timing of the growth in the related time series by applying a Granger causality test. The simple intuition is that if long drives, perhaps from technological innovations, stimulate fan interest and lead to higher prize funds, then the long drives should appear before the increases in the prize funds. Alternatively, if the increased prize funds create the incentive to practice more to develop higher skills, then the prize funds should increase first.³ In reality, causation might run in both directions so that there is no clear cause and effect. Furthermore, recognizing the *post hoc ergo propter hoc* fallacy, causality cannot be determined from a simple comparison of the timing of effects in the time-series data. What is discoverable from this type of analysis is Granger causality, which I explain more fully below. Granger causality can never prove causality for the same reasons that statistical correlation can never prove actual causation. A Granger causality test can show whether the data are consistent with causality.

Despite the above concerns, it is interesting to compare the results obtained for the LPGA to those for the PGA TOUR. Thus, I run separate

causation tests for the PGA TOUR and the LPGA. On the one hand, it is possible that the ‘wow factor’ of long drives leads to higher purses on the PGA TOUR, where the drives are longer, but not in LPGA tournaments. Women professionals still impressively outdrive casual amateur golfers, creating considerable entertainment value for the fans of the sport, which may lead to increases in prize funds for the LPGA. However, the effect of women’s driving distances on purse size may pale in comparison to those of men.

I also run separate Granger causality tests in the other direction because there may be a gender-based difference in the impact of prize money on driving distance. One could argue that the higher prize funds on the open-to-all-genders PGA TOUR supplies the same incentive to both men and women to develop longer tee shots. However, the *marginal* impact of purse size on driving distance could be higher in LPGA events. In theory, any pattern of causality could be uncovered, making it important to analyze the data.

The Granger test has two parts. First, each data series is differenced, and these first differences are regressed on their own lagged values to determine the statistical lag structure. Second, keeping the significant own lags (time-series ‘A’) on the right-hand side, the lags of the other time series (time-series ‘B’) are added to see if they add significant explanatory power. If they do, then series A is Granger-caused by series B. If none of the lagged differences of B is significant, then there is no evidence that B Granger-causes A. The Granger test is thus a negative test – of non-causality. Because series B cannot cause series A if B does not occur first, we can only rule out the possibility that B causes A; we cannot definitively conclude that A causes B because other factors might have caused both B and A. The Granger causality tests were performed separately for men and women on the time series of average driving distances and yearly total purses. The results are in Table 4.3.

The columns in the bottom panel of Table 4.3 report the results of four regressions. The first column reports whether purses can Granger-cause distance for men. First, regressions not reported indicate that for the change in driving distance for men, the second own lag was significant but not the first. Using this lag structure, the lagged change in purses is not statistically significant. Thus, changes in purses do not Granger-cause changes in driving distance for men.

The second column shows whether changes in driving distance Granger-cause changes in purse size for men. In regressions not shown here, only the first-lagged change in purses was significant. With this lag structure, the lagged change in driving distance is statistically significant. Thus, driving distance Granger-causes purse size for men.

Table 4.3 Granger tests of purses and driving distance

Variable	Descriptive statistics			
	Mean	Standard deviation	Minimum	Maximum
DRIVDIST: ^a men	275.6	10.01	260.2	286.9
DRIVDIST: ^a women	239.3	8.51	223.5	248.8
Purses: ^b PGA TOUR	167.9	88.5	49.4	279.4
Purses: ^b LPGA	38.2	12.0	20.4	63.2
Sample	Coefficient estimates (<i>t</i> -statistics)			
	Men		Women	
Dependent variable	Δ DRIVDIST	Δ Purse ^c	Δ DRIVDIST	Δ Purse ^c
Constant	0.27 (0.44)	6.86E+05 (0.39)	0.74 (1.04)	3.16E+05 (0.39)
Δ DRIVDIST ₋₁		1.15E+06* (1.76)	0.19 (0.68)	3.76E+04 (0.12)
Δ DRIVDIST ₋₂	0.47* (1.88)			
Δ Purse ₋₁	7.8E-08 (1.01)	0.52** (2.57)	4.8E-07* (1.90)	7.81E-04 (0.00)
Adj. R^2	0.29	0.41	0.09	0.00
<i>n</i>	16	17	17	17

Notes:

*, **, *** denote statistical significance at the 0.1, 0.05, and 0.01 levels.

a. In yards.

b. In undeinflated millions of dollars.

c. In deflated (1982–84) dollars.

These inferences are reversed for women. In the third column, the lagged change in purse size influences the change in driving distance, even after controlling for the (insignificant) first-lag effect in driving distance. So there is evidence consistent with the hypothesis that the increased prize funds for women have spurred efforts to increase the length of their tee shots, and that the efforts have paid off.

Column four shows that the increased length of women's tee shots does not seem to be a factor in the growth of prize money for women. There is virtually no explanatory power for the first difference in purses from either lagged changes in driving distance or lagged changes in the purses themselves.

Overall, these results are hampered by the small sample size.

Unfortunately, the comparable statistics on golfer skills do not go back far enough in time. Nevertheless, a coherent story emerges from the data. For men, the prodigiously increased length of tee shots, whether from technological innovation or practice, has been a factor in the fast-growing prize funds on the PGA TOUR. The 'drive for show' part of the old adage is in operation, as the popularity of long drivers, such as Tiger Woods, Phil Mickelson, and John Daly, has fueled the growth in purses. The same, however, is not true for women in LPGA events.

Meanwhile, on the incentives side, the purse growth does not seem to be a factor in bringing about longer drives for men. Perhaps men have already been maximizing their efforts in this dimension of the game. Most of the increased length of drives could then be attributable to technology.⁴ But for women, the increased purses may be bringing about extra practice and effort to increase driving distance in the desire to cash in on the higher prizes. Curiously, higher prizes have always been available to women on the men's Tour if they wanted to compete directly against men. However, this has not brought the women's driving distance up to the men's level. The fact that there is a higher dollars per-yard return on the PGA TOUR than in LPGA events is irrelevant to women because they almost never play in PGA TOUR sponsored events. As a result, the relevant marginal increase in prize money occurs in LPGA events. It is reassuring that auxiliary regressions (not shown here) testing for Granger causality from men's distance to women's purse growth or from men's purse growth to women's driving distance show no correlations. Nor is there evidence that men's purses Granger-cause women's purses or that any women's variables Granger-cause any men's variables. These regressions are statistically insignificant, which provides a robustness and consistency check on the regressions reported in this chapter.

4.5 CONCLUSION

Most of the skills in golf do not necessarily depend upon brute strength or physical size, but driving distance may be the exception.⁵ Therefore, if women's and men's skills converge in this dimension, golf may become gender neutral. An examination of driving distance indicates that both men's and women's driving distances increased from 1992 to 2010, probably due to innovations in club and ball designs and materials. Unfortunately, although women started to catch up to men in the 1990s, the gains were transitory. As a result, women are unlikely to compete against men in golf in the foreseeable future.

Although women and men typically compete on distinct Tours, the

separation is not based on *de jure* segregation. Men are precluded from entering LPGA-sponsored events, but the PGA TOUR is explicitly non-discriminatory. Even though purses are lower in LPGA events, women self-segregate. When women compete with other women, they have higher expected returns, conditional on their skills, than on the PGA TOUR. Women might be motivated to improve their driving distance by prize levels in LPGA events, but they are not further motivated by the even higher purses on the PGA TOUR. Thus, women are motivated more by the attainable lower prizes in LPGA events than by the much higher prizes on the PGA TOUR.

In contrast, men are not motivated by increases in prize funds to increase their driving distances in terms of Granger causality. Given the already high prize funds in 1992, perhaps men were already practicing to the point of sharply diminishing returns so that the extra motivation supplied by the increases in prizes did not lead to a measurably significant increase in practice. There does, however, seem to be Granger causality from driving distance to prize funds. Spectators enjoy the long distances of professional golfers' drives, and purse increases have followed driving distance increases that result from technological innovations in golf-club and golf-ball design.

The impact of driving distance on overall performance and on purse size creates a vicious cycle for women's golf. Their shorter drives keep women from succeeding on the men's Tour. At the same time, shorter driving distances make women's golf less attractive to audiences and sponsors, increasing the difference in rewards on the two Tours. Separate and unequal golf Tours will thus persist.

NOTES

1. Historical information was gleaned from the following websites: www.uswomensopen.com/2002/history; www.usga.org/champnewsarchive.aspx; www.pgatour.com; www.lpga.com. Another good source is Crosset (1995).
2. There is a higher return to putting and reaching greens in regulation in LPGA-sponsored tournaments.
3. If the increased prize funds are anticipated, then the driving distance skill could be developed beforehand thus leading to contemporaneous increases, but there seems to be little reason to increase the skill *because of the money* even before the money arrives.
4. Technology growth may have been continuous over the period in question, but the application of the technology is also subject to the rules-making bodies in professional golf. Interestingly, driving distance appears to have leveled after 2002, at about the same time when rules were adopted limiting certain technical aspects of golf-ball and golf-club design. See Stachura (2002).
5. For a different perspective on the value of specific skills to performance in golf, see Chapter 18 in this volume.

REFERENCES

- Alexander, Donald and William Kern (2005), 'Drive for Show and Putt for Dough? An Analysis of the Earnings of PGA Tour Golfers', *Journal of Sports Economics*, **6**(1), February: 46–60.
- Berry, Scott M. (1999), 'Drive for Show and Putt for Dough', *Chance*, **12**(4): 50–55.
- Callan, Scott J. and Janet M. Thomas (2007), 'Modeling the Determinants of a Professional Golfer's Tournament Earnings: A Multiequation Approach', *Journal of Sports Economics*, **8**(4), August: 394–411.
- Crosset, Todd W. (1995), *Outsiders in the Clubhouse: The World of Women's Professional Golf*, Albany, NY: State University of New York Press.
- Davidson, James D. and Thomas J. Templin (1986), 'Determinants of Success Among Professional Golfers', *Research Quarterly for Exercise and Sport*, **57**(1), March: 60–67.
- Fearing, Douglas, Jason Acimovic and Stephen C. Graves (2011), 'How to Catch a Tiger: Understanding Putting Performance on the PGA TOUR', *Journal of Quantitative Analysis in Sports*, **7**(1), January.
- Fried, Harold O., James Lambrinos and James Tyner (2004), 'Evaluating the Performance of Professional Golfers on the PGA, LPGA, and SPGA Tours', *European Journal of Operational Research*, **154**(2), April: 548–61.
- Granger, Clive W.J. (1969), 'Investigating Causal Relations by Econometric Models and Cross-Spectral Methods', *Econometrica*, **37**(3), July: 424–38.
- Kahane, Leo H. (2010), 'Returns to Skills in Professional Golf: A Quantile Regression Approach', *International Journal of Sport Finance*, **5**(3), August: 167–80.
- Kalist, David E. (2008), 'Does Motherhood Affect Productivity, Relative Performance, and Earnings?', *Journal of Labor Research*, **29**(3), September: 219–35.
- Marple, David (1983), 'Tournament Earnings and Performance Differentials between the Sexes in Professional Golf and Tennis', *Journal of Sports and Social Issues*, **7**(1), March: 1–14.
- Matthews, Peter Hans, Paul M. Sommers and Francisco J. Peschiera (2007), 'Incentives and Superstars on the LPGA Tour', *Applied Economics*, **39**(1), October: 87–94.
- Moy, Ronald L. and Thomas Liaw (1998), 'Determinants of Professional Golf Tournament Earnings', *The American Economist*, **42**(1), Spring: 65–70.
- Nero, Peter (2001), 'Relative Salary Efficiency of PGA Tour Golfers', *The American Economist*, **45**(1), Fall: 51–6.
- Nix, Charles L. and Robert Koslow (1991), 'Physical Skill Factors Contributing to Success on the Professional Golf Tour', *Perceptual and Motor Skills*, **72**(3c), June: 1272–4.
- Oaxaca, Ronald (1973), 'Male–Female Wage Differentials in Urban Labor Markets', *International Economic Review*, **14**(3), October: 693–709.
- Pfützner, C. Barry and Tracy D. Rishel (2005), 'Performance and Compensation on the LPGA Tour: A Statistical Analysis', *International Journal of Performance Analysis in Sport*, **5**(3), December: 29–39.
- Rishe, Patrick James (2001), 'Differing Rates of Return to Performance: A Comparison of the PGA and Senior Golf Tours', *Journal of Sports Economics*, **2**(3), August: 285–96.
- Scully, Gerald W. (2002), 'The Distribution of Performance and Earnings in a Prize Economy', *Journal of Sports Economics*, **3**(3), August: 235–45.
- Shaffer, Thomas L., Daniel P. Connaughton, Ronald A. Siders and John F. Mahoney (2000), 'An Analysis of the Most Significant Variables for Predicting Scoring Average and Money Won per Event in Professional Golf', *Research Quarterly for Exercise and Sport*, **71**(1), March: 119A–20A.
- Shin, Eui Hang and Edward Adam Nam (2004), 'Culture, Gender Roles, and Sport: The Case of Korean Players on the LPGA Tour', *Journal of Sport and Social Issues*, **28**(3), August: 223–44.
- Shmanske, Stephen (1992), 'Human Capital Formation in Professional Sports: Evidence from the PGA Tour', *Atlantic Economic Journal*, **20**(3), September: 66–80.
- Shmanske, Stephen (2000), 'Gender, Skill, and Earnings in Professional Golf', *Journal of Sports Economics*, **1**(4), November: 400–415.

- Shmanske, Stephen (2004), *Golfonomics*, River Edge, NJ: World Scientific.
- Shmanske, Stephen (2008), 'Skills, Performance, and Earnings in the Tournament Compensation Model: Evidence from PGA Tour Microdata', *Journal of Sports Economics*, **9**(6), December: 644–62.
- Shmanske, Stephen (2012), 'Gender and Discrimination in Professional Golf', in Shmanske and L. Kahane (eds), *The Oxford Handbook of Sports Economics, Volume 2: Economics through Sports*, New York: Oxford University Press, pp. 33–54.
- Sommers, Paul M. (1994), 'A Bread and Putter Model', *Atlantic Economic Journal*, **22**(4), December: 77.
- Stachura, Mike (2002), 'About-Face: The USGA's Final Edict on COR Should End the Confusion Over Which Drivers Conform and Which Do Not', *Golf Digest*, **53**, October.
- Stockl, Michael, Peter F. Lamb and Martin Lames (2011), 'The ISOPAR Method: A New Approach to Performance Analysis in Golf', *Journal of Quantitative Analysis in Sports*, **7**(1).
- Tiruneh, Gizachew (2010), 'Age and Winning in Professional Golf Tours', *Journal of Quantitative Analysis in Sports*, **6**(1), January.
- Wiseman, Frederick, Sangit Chatterjee, David Wiseman and Neil S. Chatterjee (1994), 'An Analysis of 1992 Performance Statistics for Players on the U.S. PGA, Senior PGA, and LPGA Tours', in A.J. Cochran and M.R. Farrally (eds), *Science and Golf: II. Proceedings of the World Scientific Congress of Golf*, London: E & FN Spon, pp. 199–204.