Reference Points, Prospect Theory and Momentum on the PGA Tour

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University of Virginia
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Background

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- Pope and Schweitzer (AER, 2011):

  PGA birdie putts 3% worse than par putts, ceteris paribus

  Greater ‘effort’ and/or risk-seeking for putts for par

  Par to bogey: feels bad. Birdie to par: not so bad

  But score vs par shouldn’t matter. A stroke is a stroke (usually)

  Arbitrary reference pt (par) matters. Key part of prospect theory
  (Kahneman and Tversky, Ecta, 1979)

  Field evidence of PT w high stakes, experienced agents

  "It’s nice to make birdie putts but I think those par putts are
  probably – I feel more energetic when I make those putts than I do a
  birdie"

  - Tiger Woods, last week

  See also DellaVigna et al, 2014 (job search), Camerer et al, AEA,
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Tversky et al (1985): no evidence of hot hand in basketball

Several follow up studies... Kahneman (2011): "hot hand is massive and widespread cognitive illusion"

So what? (who cares?)

2 significant issues

1) Just how biased can people really be?

2) Momentum matters (does confidence enhance performance? how much? when? implications for education, etc)
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Arkes, 2010; Miller and Sanjurjo, 2014, 2015

(New consensus: hot hand is real. But "hot hand bias" is real too)

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Arkes result suggests reference pt of par for 'recent holes'

 Seems plausible, worth looking into

But what about score vs par for the day (round)?

"You get to like the 12th hole and I'm three under par and I don't want to have one hole hurt a round so I end up laying up" - Phil Mickelson, earlier this summer

And even across rounds, for tournament?
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Extension of PS with much broader scope

And with hot/cold hand as competing force

Most of paper: tests of which factor dominates

Some auxiliary analysis where we more cleanly separate forces

Hope to better understand mechanisms, magnitudes of PT and momentum effects

Turns out PT and momentum may complement one another (not just compete.. yin and yang-ish)

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Context: PGA (golf) tournaments

- 40 per year
- 100-150 players at start
- 18 holes per round
- Each hole has par value 3, 4 (60-65%), or 5
- By coincidence, pr(score = par) = 60-65%
- 4 rounds, 1 per day
- Top half 'make the cut' after round 2

(We *just* analyze rounds 1, 3. Still end up with 1.5 million hole-level obs (non-major events, 2003-14).

Balsdon, 2013 and Ozbeklik and Smith, 2014 analyze late holes in rounds 2, 4 to focus on rational adjustment to risk strategies)
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Prospect theory (see Barberis, JEP, 2013)

1. People evaluate differences or changes (versus reference point), not levels

2. Loss aversion: losses hurt 2-3x as much as gains help

3. Diminishing marginal sensitivity to gains and losses

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$x = \text{score relative to reference point (score on current hole + score on relevant previous holes)}$

- Start hole in domain of losses:
  - Convex value function.
  - Highest returns to effort.

- Start hole in domain of gains:
  - Concave value function.
  - Lowest returns to effort.

- Start hole at reference pt:
  - Concave value function.
  - Moderate returns to effort.
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\[ v(x) \]
Crude summary of (best guess at) implications

- Concave in "domain of gains": more risk averse.
- 'Extreme' outcomes (birdie/bogey) less likely.
- Flatter: less effort.
- Worse overall performance (higher mean score).
- Convex and steeper in domain of losses: more risk seeking, effort.

(Just a sketch; all ambiguous really. Point is distribution, not just mean, of outcome important. Keep empirics flexible.)
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Predictions when starting hole in domain of gains

Pr(below par) + Pr(above par) - E(score) - Outcome for current hole

PT: effort
Pr(below par) - Pr(above par) + E(score) + Outcome for current hole

PT: risk
Pr(below par) - Pr(above par) - E(score)

0 or +

Predictions for domain of losses analogous
Predictions when starting hole in domain of gains

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- Probably ideal to jointly estimate distribution of outcomes
  - (maybe MNL)
  - But computationally infeasible - large sample, lots of FEs
- Use linear models for 3 LHS vars:
  - below par (bp = 0/1), above par (ap = 0/1), score (s = 1, 2, ...)
- RHS vars?
  - Theory says effects depend on position vs ref point
  - And depend on domain of gains/losses
  - tournament = strokes below par for tournament;
  - round = strokes above for rd

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\[ \text{RHS vars?} \]

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- And depend on domain of gains/losses
  - \(tournb\) = strokes below par for tournament;
  - \(tourna\) = strokes above for tourney
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- And depend on domain of gains/losses
- \(tournb\) = strokes below par for tournament;
- \(tourney\) = strokes above for tourney
- \(roundb\) = strokes below par for round; \(rounda\) = strokes above for rd
RHS vars ctd

lastb = strokes below last hole;  
lasta = strokes above

Checked out further lags and last2/last3 specifications; just makes things messier

Include last/round/tourn vars in all models as controls for each other

Note all have support: 0, 1, 2, ...

Yes, highly correlated, hard to see marginal effects, magnitudes. Address this later

Also look at simple non-linear variants

And consider heterogeneity (in ref pts used and effects)
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Empirics ctd

Controls?

Course/weather difficulty: hole-day FEs

Tournament standing: restrict analysis to rounds 1 and 3

Player ability: definitely. But this varies..

Allow ability to vary by year? By hole type? By course?

Issue: last/rd/tourn vars correlated w/ lagged dep var. Endogenous

Intuition: suppose we used player-yr FEs and there were just 3 holes in yr, and mean score = 0

Then last_b = 2 = 1 would have 50% chance of predicting ap_h = 2 = 1

(But last_b = 2 = 1 isn't causing ap_h = 2 = 1. Just correlated)

Arellano-Bond doesn't work b/c all lags/leads possibly correlated
Empirics ctd

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Then lastb h = 2 would have 50% chance of predicting ap h = 2 (but lastb h = 2 isn’t causing ap h = 2. Just correlated)

Arellano-Bond doesn’t work b/c all lags/leads possibly correlated
Empirics ctd

- Controls?
- Course/weather difficulty: hole-day FE
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- Then lastb = 2 = 1 would have 50% chance of predicting ap = 2 = 1
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Empirics ctd

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Good news: dynamic panel problem disappears as $T \to \infty$ ($T$ = # obs per FE group).

How high does $T$ need to be for minimal bias? Check empirically (results for rd 3, bp).

Idea: if FE groups w/low $T$ cause bias, dropping them should change estimates.

<table>
<thead>
<tr>
<th>Panel A: Player-course FEs</th>
<th>#Obs per FE group:</th>
<th>lastb</th>
<th>lasta</th>
<th>N</th>
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</thead>
<tbody>
<tr>
<td>&gt; 0</td>
<td>&gt; 50</td>
<td>-0.0165***</td>
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<td>1072649</td>
</tr>
<tr>
<td>&gt; 100</td>
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<table>
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<tr>
<th>Panel B: Player-year-par FEs</th>
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<th>lasta</th>
<th>N</th>
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Use player-yr-par FEs (reghdfe!)
Cluster SEs by player-tournament-year.
Empirics

- Good news: dynamic panel problem disappears as $T \to \infty$ ($T = \#$ obs per FE group)
Empirics

- Good news: dynamic panel problem disappears as $T \rightarrow \infty$ ($T = \# \text{obs per FE group}$)
- How high does $T$ need to be for minimal bias? Check empirically (results for rd 3, $bp_h$)

Panel A: Player-course FEs
#Obs per FE group: >0 >50 >100

<table>
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N 1072649 654653 276012

Panel B: Player-year-par FEs
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<table>
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<tr>
<th>FE Groups</th>
<th>#Obs per FE group:</th>
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<tr>
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Panel A: Player-course FEs

Panel B: Player-year-par FEs

- Use player-yr-par FEs (reghdfe!)

- Cluster SEs by player-tournament-year
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| ...                |          |          |          |
| N                  | 1072649  | 654653   | 276012   |
| Panel B: Player-year-par FE
| \(lastb\)          | -0.0039*** | -0.0038*** | -0.0029**  |
| \(lasta\)          | -0.0004   | 0.0004    | 0.0003    |
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- Cluster SEs by player-tournament-year
(Selected) main results: domain of gains

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<thead>
<tr>
<th></th>
<th>Round 1</th>
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PT effort effects, some PT risk, no HH
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- PT effort effects, some PT risk, no HH
Main results: domain of losses

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Risk-seeking/cold in round 1; cold in round 3
Main results: domain of losses

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Main results: domain of losses

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Main results: domain of losses

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\[\text{Risk-seeking/cold in round 1; cold in round 3}\]
Quadratics
## Quadratics

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N | 943575  | 943575  | 943575  |

PT effort effects for low values of `rounda`; becomes risk/cold for higher values

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...  

N | 943575  | 943575  | 943575  |

PT risk effects for low `roundb`; effort for higher `roundb`
Quadratics

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... 

|  N    | 943575 | 943575 | 943575 |

- PT effort effects for low values of \textit{rounda}; becomes risk/cold for higher values
## Quadratics

### Round 1

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- PT effort effects for low values of *rounda*; becomes risk/cold for higher values

### Round 3

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<tr>
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...  

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**Quadratics**

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\[ \ldots \]  

\[ N \quad 943575 \quad 943575 \quad 943575 \]

- PT effort effects for low values of \( \text{rounda} \); becomes risk/cold for higher values

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\[ \ldots \]  

\[ N \quad 473451 \quad 473451 \quad 473451 \]

- PT risk effects for low \( \text{roundb} \); effort for higher \( \text{roundb} \)
## Dummy RHS vars

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...  
N     | 943575  | 943575  | 943575 |

Lower effort kicks in for larger gains. Supports round 3 interpretation above.
### Round 1

<table>
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...  

| N     | 943575  | 943575  | 943575  |

- Lower effort kicks in for larger gains. Supports round 3 interpretation above
Heterogeneity

▶ Better players may have more ambitious reference points (shoot for better than par)
▶ All players may be more ambitious when holes are easier
▶ Köszegi and Rabin reference points
▶ Also possible better players less influenced by reference points (more standard-rational)
▶ And importance of reference points may vary across holes, shots
Heterogeneity

- Better players may have more ambitious reference points (shoot for better than par)

'K˝ oszegi and Rabin reference points'

Also possible better players less influenced by reference points (more standard-rational)

And importance of reference points may vary across holes, shots
Heterogeneity

- Better players may have more ambitious reference points (shoot for better than par)
- All players may be more ambitious when holes are easier
Heterogeneity

- Better players may have more ambitious reference points (shoot for better than par)
- All players may be more ambitious when holes are easier
- ‘Kőszegi and Rabin reference points’
Heterogeneity

- Better players may have more ambitious reference points (shoot for better than par)
- All players may be more ambitious when holes are easier
- ‘Kőszegi and Rabin reference points’
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Heterogeneity

- Better players may have more ambitious reference points (shoot for better than par)
- All players may be more ambitious when holes are easier
- ‘Kőszegi and Rabin reference points’
- Also possible better players less influenced by reference points (more standard-rational)
- And importance of reference points may vary across holes, shots
## Hole-difficulty adjusted reference pts

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## Hole-difficulty adjusted reference pts

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- Strengthens effects
Front vs back 9

Roundb more important at start of round; lastb more important later
Front vs back 9

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...
### Front vs back 9

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<td>Back 9</td>
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... more important at start of round; lastb more important later...
Front vs back 9

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...  
Back 9

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- roundb more important at start of round; lastb more important later
Player ability
### Top players (Rank $\leq$ 200), rd 1

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### Player ability

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Player ability

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<tr>
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<th>Top players (Rank ≤ 200), rd 1</th>
<th>Rank &gt; 200, rd 1</th>
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<td>( lastb )</td>
<td>-0.0027*</td>
<td>-0.0011</td>
</tr>
<tr>
<td>( roundb )</td>
<td>-0.0011**,-0.0006</td>
<td>0.0002</td>
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</table>

- Better players have higher standards (or less PT affected) in round 1
Player ability

But better players are still behavioral
### Player ability

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<td>tourna</td>
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...
# Player ability

But better players are still behavioral

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<th>Top players (Rank ≤ 200), rd 3</th>
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Shot types

Data on within hole outcomes - start/end locations for all shots

Worth analyzing for 2 reasons:

1. Diff ref pts/momentum may affect diff shots in diff ways

2. Can control for lagged performance on particular shot type to separate momentum, ref pt effects
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Less than 1% (mean rd score around 70)

- PS estimate 0.25 strokes per rd and > $100k/yr for top players; Brown (JPE, 2011), 0.2 strokes per rd
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<td>0.057</td>
<td>0.104</td>
</tr>
<tr>
<td>Rd 3, ( tsa = 5 )</td>
<td>0.231</td>
<td>0.123</td>
<td>0.164</td>
</tr>
</tbody>
</table>

- Less than 1% (mean rd score around 70)
- PS estimate 0.25 strokes per rd and \( > $100k/yr \) for top players; Brown (JPE, 2011), 0.2 strokes per rd
- Some of our estimates much smaller due to negative feedback (prospect theory in domain of gains)
- Some of ours are in their ballpark (0.231 for round, 0.166 for half-round)
- And attenuated since don’t account for heterogeneous ref pts (here)
- Precise b/c of large samples and negative covariances of coefficients
Wrapping up

Prospect theory effects exist, dominate hot hand effects for 3 new reference pts

Evidence of greater conservatism in domain of gains, 'shirking' when further into domain of gains

Some PT effort and risk effects in domain of losses but stronger cold hand effects

Reference points adjust based on many factors (hole difficulty, player ability, part of round), hard to nail down, but matter
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(Or maybe hot hand bias causes reduced PT effort effect??)

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