Is There No 'I' in Team? Rational Players in Dynamic Team Competition*

Lingbo Huang

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Abstract

Empirical literature consistently challenges the rationality assumption of individuals' behaviour in dynamic situations and in teamwork environments. Here I examine rational forward-looking behaviour in a dynamic team competition with multi-period "battles". Using field data from professional squash team tournaments (820 matches), I provide evidence consistent with the game-theoretical prediction of "strategic neutrality" in team matches: the outcomes of previous battles do not affect the outcome of the current battle. Further, by exploiting a unique feature that each battle is in itself a multi-period contest between two contestants, I exclude another psychological mechanism that might explain the neutrality result, thus establishing the empirical relevance of its game-theoretical foundation.

Keywords: forward-looking behaviour, strategic neutrality, dynamic team competition, multi-period contest, squash tournament

JEL Classification: C31, C36, C72, D79, L83

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*Department of Political Science, Stony Brook University, NY, 11794 (e-mail: lingbo.huang@outlook.com). I am grateful for comments from Abigail Barr, Kai Barron, Subhasish Chowdhury, Robin Cubitt, Peter DeScioli, Qiang Fu, Simon Gächter, David Gill, Jingfeng Lu, Zahra Murad, Alex Possajennikov, Martin Sefton, Fangfang Tan and participants at several conferences and seminars. Financial support from the Centre for Decision Research and Experimental Economics (CeDEx) at the University of Nottingham and ESRC grant ES/J500100/1 is gratefully acknowledged.

1 Introduction

Economic theory is built on the tenets of unbounded rationality and unrelenting selfishness. One implication is that an "Econ" figure acts in a forward-looking manner, accurately evaluating the benefits and the costs of future actions and fully anticipating their impacts on the current action. Another implication is that an Econ does not take into account the influence of their actions on the well-being of others even when they share the common objective in a teamwork environment. These two key tenets have proven very powerful in analysing economic behaviour in many dynamic and social situations.

Over the past few decades, however, empirical literature has been consistently challenging both of the two presumptions. Built primarily on experimental dynamic games, most notably, alternating-offer bargaining (e.g., Johnson, Camerer, Sen, and Rymon, 2002; Binmore, McCarthy, Ponti, Samuelson, and Shaked, 2002) and centipede games (e.g., McKelvey and Palfrey, 1992; Levitt, List, and Sadoff, 2011), researchers found that equilibrium behaviour based on unbounded rational backward induction in dynamic situations often fits uneasily with intuition and experimental data.[1] Similarly, in social situations, seemingly irrelevant factors such as group norms that arise from a mere "minimal group" can promote cooperation, altruism towards in-group members, and discrimination against out-group members (e.g., Charness, Rigotti, and Rustichini, 2007; Chen and Li, 2009; Goette, Huffman, Meier, and Sutter, 2012). Furthermore, social incentives in the form of pure peer effects also have considerable impacts on workers' productivity (e.g., Mas and Moretti, 2009; Bandiera, Barankay, and Rasul, 2010).

In this article, I consider a dynamic team competition with multi-period battles—in its simplest version known as the best-of-three team contest—wherein behaviour is susceptible to non-Econ beliefs and preferences in an environment that is both dynamic and team-based. Six players from two competing teams are paired in three pairwise battles and each pair competes head-to-head on each of these battles, which are played out sequentially. The winning team is the one that prevails in at least two battles.[2] Based on a standard model with Econ agents, Fu, Lu, and Pan (2015b) showed an intriguing theoretical property—*strategic neutrality*: given the players' characteristics, the outcomes of previous battles do

[1]It remains as a heatedly debate issue whether there is indeed a uncompromising conflict between rationality and failures of backward induction in practice. For example, Aumann (1995) argued that backward induction not only requires rationality, but common knowledge of rationality. Players could also reason using forward induction, which might lead to different equilibrium predictions than backward induction (Kohlberg and Mertens, 1986; van Damme, 1989). Some studies also suggested that backward induction can be learned (Johnson et al., 2002) or is commonly practised by professionals (Palacios-Huerta and Volij, 2009).

[2]Team contests with such a structure have many real world examples. These include global competitions where multi-national corporations compete for market shares in each region, electoral competitions where rival political parties campaign over legislative seats, and team sports tournaments such as tennis and squash.

not affect the outcome of the current battle. As will be discussed in the section 2, while this prediction holds under a wide array of theoretical environments, it relies crucially on the assumption of (one-step) backward induction and implicitly on disregard towards the well-being of other team members.[3]

The strategic neutrality prediction, however, does not fit easily with the intuitive assessment that the final outcome of a team match should at least be partially path-dependent such that earlier successes or failures may have accumulative and amplified influences on later battles. The path-contingency in dynamic team contests can be driven by several psychological mechanisms. For instance, other-regarding players may internalise in their utility evaluations part of the effort costs borne by their teammates, and consequently fight harder than selfish players. Another possibility is that players at the pivotal battle of a team match may have differential private valuations of winning: because losing the second battle is an end for lagging teams, second battle players on lagging teams may entertain higher valuations of winning the battle and therefore fight harder than those on leading teams. Taking into account these psychological mechanisms in an otherwise standard model can alter the neutrality prediction in one direction or another.

Importantly, even if these psychological mechanisms do not figure prominently in practice and the neutrality prediction is indeed borne out in data, the underlying game-theoretical reasoning that players trade off effort costs and probability of winning remains observationally indistinguishable from the psychological intuition that players "do their best" under any circumstances. This expectation culminates in the so-called "There Is No 'I' in Team" slogan in team sports. Such an expectation can evolve to be a "norm", which might be enforced by high levels of scrutiny from team coaches and audiences, as Levitt and List (2007, p. 157) put it, "the moral cost of violating a social norm increases as scrutiny ... rises". Empirically identifying the strategic neutrality from the "do your best" norm thus presents the most challenging task that this article aims to solve.

To test for the strategic neutrality in best-of-three team contests, I assembled a unique field dataset from professional squash team tournaments (820 team matches). As detailed in the section 3, the structure of a squash team match corresponds almost exactly to the theoretical model of best-of-three team contest. In a squash tournament, after the first battle ends, individual players learn about whether their team is leading or lagging behind. By examining the effect on the second battle outcomes of their teams being in the leading or lagging position, I show in the section 4 that the strategic neutrality cannot be rejected.

[3] This theoretical property is robust to the length of contests (any best-of-$(2n+1)$ team contest), various contest rules (e.g., all-pay auction, generalized Tullock contest), information structures (e.g., complete information, two-sided incomplete information), the degree of heterogeneity among players, and formulations of payoffs.

Similarly, consistent with the neutrality prediction, the third battle outcomes, if decisive for final team match outcomes, do not depend on whether the second battles are won or lost.

While the aggregated outcomes of battles and team matches preclude the psychological mechanisms that alter the neutrality prediction, they do not explain away the psychological mechanism that also predicts neutrality. To distinguish it from the strategic neutrality, I exploit the nature of squash team matches that each battle is in itself a best-of-five contest between two paired contestants. Such a structure does not change the strategic neutrality prediction for battle outcomes. More importantly, in contrast to strategic neutrality in team contests, we know from the literature (Klumpp and Polborn, 2006; Konrad and Kovenock, 2009) that behaviour in an individual contest with a "best of" structure exhibits *strategic momentum*, or *discouragement effect*: because players have to entail any necessary effort costs incurred in subsequent periods, a score leader in a multi-period contest has more to lose than a laggard and therefore fights harder in the following periods (see the section 2 for more detail).

The significance of these nested contests is that if the *strategic mechanism* behind the neutrality prediction is not the underlying behavioural principle for battle outcomes, it is unlikely to be the behavioural principle for the best-of-five contest within each battle. Put differently, if the "do your best" norm dominates any strategic considerations for battle outcomes, it would also dominate them within each battle. Because the norm as such predicts neutrality even within a battle whereas the strategic mechanism predicts momentum effect, we can determine whether players act strategically. Hence, the results within a battle imply different interpretations of the neutral dynamics between battles. Importantly, it is the multi-period individual contest embedded within a battle in a team match that helps identify the strategic neutrality. If, instead, I were to use individual contests with the same "best of" structure from individual squash tournaments, the comparison between individual and team contests would be contaminated by other factors such as different financial incentives, game strategies, and norms.

By examining players' responses to outcomes of previous periods in best-of-five individual contests, I find strong evidence for the strategic momentum at every period within a battle. Importantly, the momentum effect is independent of the precise realisation of outcomes in previous periods. For example, the fifth period outcomes do not depend on which player has won the first, second, third and fourth periods so long as the score thereafter is equalised. This result rules out the psychological momentum—the most recent winning may encourage the player to win the next period—which is otherwise indistinguishable from the strategic momentum in individual contests.[4] Hence, the evidence of the strategic momentum effect

[4]Similar psychological momentum effects have been investigated using individual tennis matches data

within a battle, combined with the evidence of the strategic neutrality between battles, strongly suggests that players are not simply playing to their best but indeed behaving strategically in a way that is captured by the economic theory.

My study contributes to the newly emerging literature on dynamic team contests (Fu et al., 2015b; Feng and Lu, 2015). In addition to team contests with a "best of" structure, Häfner (2015) showed that the strategic intuition behind the neutrality result also applies to a tug-of-war team contest. Compared to the vast theoretical analysis and empirical evidence of non-neutral dynamic effects in multi-period individual contests,[5] the neutral dynamic effects in team contests highlight the importance of team structure, which can make a significant impact on individual contestants' strategic behaviour. Complementary to my field evidence, Fu et al. (2015a), in a real-effort laboratory experiment, compared players' behaviour in the second battles of best-of-three team contests to that of best-of-three individual contests. While they confirmed the prediction of strategic neutrality in team contests, they rejected the prediction of strategic momentum in individual contests and instead found that leaders slacked off, whereas laggards worked harder.

The current study also adds to the economics literature that customarily uses sports data or other naturally occurring field data to test specific game-theoretical properties.[6] An advantage of sports data is that rules for strategies and compensations in sports are usually very specific and can correspond closely to the underlying game under investigation. The sports data therefore are particularly conducive to testing game-theoretical predictions that are sensitive to strategies, information, and payoffs. In relation to investigating forward looking behaviour in dynamic competitions, for example, Lackner, Stracke, Sunde, and Winter-Ember (2015) examined basketball elimination tournament data and found that

(Malueg and Yates, 2010) and soccer penalty kicks data (Apesteguia and Palacios-Huerta, 2010; Kocher, Lenz, and Sutter, 2012).

[5]See surveys in Konrad (2009, Chapter 8), Konrad (2012), Kovenock and Roberson (2012), and Dechenaux, Kovenock, and Sheremeta (2015, Section 4). For example, in best-of-$(2n+1)$ individual contests, strategic momentum has been shown both theoretically (Klumpp and Polborn, 2006; Konrad and Kovenock, 2009; Sela, 2011; Gelder, 2014) and empirically (McFall, Knoeber, and Thurman, 2009; Malueg and Yates, 2010; Mago, Sheremeta, and Yates, 2013); see however countervailing evidence in the field (Ferrall and Smith, 1999) and in the lab (Fu, Ke, and Tan, 2015a; Irfanoglu, Mago, and Sheremeta, 2015). More generally, research on interim performance feedback in multi-stage tournaments between individuals often find non-neutral behavioural effects on efforts and outcomes in future stages, in theories (e.g., Harris and Vickers, 1985, 1987; Strumpf, 2002; Ederer, 2010; Goltsman and Mukherjee, 2011; Konrad and Kovenock, 2005), in field studies (e.g., Magnus and Klaassen, 1999; Apesteguia and Palacios-Huerta, 2010; Berger and Pope, 2011; Pope and Schweitzer, 2011; Kocher et al., 2012; Neugart and Richiardi, 2013; Gauriot and Page, 2014) and in (field and lab) experiments (e.g., Berger and Pope, 2011; Deck and Sheremeta, 2015; Eriksson, Poulsen, and Villeval, 2009; Fershtman and Gneezy, 2011; Gill and Prowse, 2012; Kuhnen and Tymula, 2012; Ludwig and Lünser, 2012; Girard and Hett, 2013).

[6]Other examples of field data that have been used to test game-theoretical predictions are game shows (Post, van den Assen, Baltussen, and Thaler, 2008; van den Assen, van Dolder, and Thaler, 2012) and national lotteries (Östling, Wang, Chou, and Camerer, 2011).

the expected relative strength in future interactions affected team effort—as measured by the number of fouls—in earlier stages. Using tennis elimination tournament data, Brown and Minor (2014) found a similar dynamic effect of the shadow of future on current stage outcomes. Also using the tennis data, Malueg and Yates (2010) tested the strategic momentum in best-of-three matches between two equally strong competitors and found evidence consistent with forward looking behaviour. My current study complements and extends the previous works by showing that individual players in dynamic team competitions not only exhibit forward looking behaviour, but act as if they are purely self-interested with no apparent other-regarding considerations for their team members as prescribed by the economic theory.

2 Theoretical Background

This section is adapted from Fu et al. (2015b) and Fu et al. (2015a). Two teams compete in a contest for a final trophy W, which is awarded to each member of the winning team. Six risk neutral players from two competing teams are paired in three pairwise battles, which are played out sequentially. I refer to the paired players in the first battle as "first movers", pairs in the second battle "second movers", and pairs in the third battle "third movers". The team that prevails in at least two battles is awarded the trophy.

In each battle, two paired players simultaneously exert efforts, $x_{i(t)}, i = A, B; t = 1, 2, 3$, where i denotes the team that a player belongs to and t the participating order. Players' innate abilities, modelled as their constant marginal costs of effort functions—$c_{i(t)}$ for effort $x \geq 0$, are allowed to be heterogeneous. All effort cost functions $C_{i(t)}(x) = c_{i(t)} \cdot x$ are common knowledge.

Let $p_i(x_i, x_j), i, j = A, B; i \neq j$ denote the probability that player i wins in a battle; $p_A(x_A, x_B) + p_B(x_A, x_B) = 1$. I do not impose a specific functional form for the winning rule in a battle. Similar to Fu et al. (2015a), I assume that the winning rule only has to follow four regularity conditions, which are satisfied by the most popular contest rules in the literature—lottery rent-seeking contests and all-pay auctions. First, $p_i(x_i, x_j)$ *increases* in one's own effort, x_i, and *decreases* in the opponent's effort, x_j. Second, *independence*: if a pair equally values winning the battle, there is a unique equilibrium battle outcome, which depends only on the characteristics of effort cost functions of both contenders, and is independent of the common valuation of winning. Third, *monotonicity*: conditional on the effort cost function, higher valuations of winning encourage players to exert greater effort. Fourth, *fairness*: if one player exerts zero effort, the other player wins the battle with any positive effort level; if both players exert zero effort, they win with equal probabilities.

It can be readily inferred from the structure of the game that in each battle, a pair always has the same valuation of winning, irrespective of the outcomes of previous battles. To see this, let's focus on the second movers. First consider the second mover on the leading team (let the leading team be team A). The second mover's "continuation value" from winning her battle is the final trophy—W; her continuation value from losing, causing her team to fight in the third battle, is $W \cdot P_{A(3)}$, where $P_{A(3)}$ represents her third mover teammate's probability of winning the third battle. The net valuation of winning, or "effective prize spread", for the second mover on the leading team is, therefore, $W \cdot (1 - P_{A(3)})$. Now consider the opposing second mover on the lagging team B. The second mover's continuation value from winning is $W \cdot P_{B(3)} = W \cdot (1 - P_{A(3)})$, where $1 - P_{A(3)}$ is the complementary probability of winning the third battle by her third mover teammate; her continuation value from losing causes her team to lose the match, and therefore, is 0. Thus, the net valuation of winning for the second mover on the lagging team is also $W \cdot (1 - P_{A(3)})$.

With this observation, player i chooses effort $x_{i(t)}$ to maximise her expected payoff:

$$\pi_{i(t)}(x_{i(t)}, x_{j(t)}) = V \cdot Pr(x_{i(t)}, x_{j(t)}) - c_{i(t)} \cdot x_{i(t)},$$

where V is the common valuation of winning for both players. Similarly, player j chooses effort $x_{j(t)}$ to maximise her expected payoff:

$$\pi_{j(t)}(x_{j(t)}, x_{i(t)}) = V \cdot Pr(x_{j(t)}, x_{i(t)}) - c_{j(t)} \cdot x_{j(t)}.$$

In equilibrium, player i chooses effort $x_{i(t)} \in [0, V/c_{i(t)}]$, and player j chooses effort $x_{j(t)} \in [0, V/c_{j(t)}]$. Thanks to the independence condition, in the (stochastic) equilibrium battle outcome, each player's probability of winning the battle is independent of the common valuation of winning, and thus the size of the trophy. Hence, the key prediction—*strategic neutrality*—follows.

Proposition 1. *In a non-trivial battle of a best-of-three team contest, the equilibrium battle outcome depends only on the characteristics of effort cost functions of individual competitors, independent of the outcomes of previous battles and the size of the trophy.*

However, psychological factors such as altruism, differential private valuations of winning, and some subjective belief updating, may alter the neutrality prediction.

Altruism: altruism implies that players internalise part of the effort costs borne by their team members in the utility evaluations. Conditional on the effort cost functions, this consideration encourages second movers on leading teams to exert greater effort, and discourages second movers on lagging teams. To see this, again let's focus on the second movers. For the second mover on the leading team A, her continuation value from winning is W. However, her continuation value from losing is $W \cdot P_{A(3)} - \alpha c_{A(3)} \cdot x^*_{A(3)}$, where the second term represents the utility loss from the fact that her third mover teammate would have to fight in the third battle and incur an effort cost of $c_{A(3)} \cdot x^*_{A(3)}$; $x^*_{A(3)}$ is the third mover's equilibrium effort and α measures the strength of altruistic preferences of the second mover over the third mover's well-being. The net valuation of winning for the second mover on the leading team is, therefore, $W \cdot (1 - P_{A(3)}) + \alpha c_{A(3)} \cdot x^*_{A(3)}$. Now for the opposing second mover on the lagging team B. Her continuation value from winning is $W \cdot (1 - P_{A(3)}) - \alpha c_{B(3)} \cdot x^*_{B(3)}$; her continuation value from losing is 0. Thus, the net valuation of winning for the second mover on the lagging team is $W \cdot (1 - P_{A(3)}) - \alpha c_{B(3)} \cdot x^*_{B(3)}$.

All else being equal, an altruistic second mover on a leading team has a higher valuation of winning than a selfish one, whereas an altruistic second mover on a lagging team has a lower valuation of winning than a selfish one. Thus, given the monotonicity condition, the altruistic second mover on the leading team exerts greater effort, and the altruistic second mover on the lagging team exerts less effort than the selfish one.

Note that if all players are homogeneous and $\alpha = 1$, the team situation with altruistic second movers are formally equivalent to a best-of-three contest with two individual players. Thus, I have shown a (weaker) form of *strategic momentum effect* in best-of-three team contests with altruistic players, consistent with the similar momentum effect in best-of-three individual contests with Econ players (Klumpp and Polborn, 2006; Konrad and Kovenock, 2009). The intuitions behind these two momentum effects are also similar: players/teams in the leading position have stronger incentives to win the second battle in order to save on effort costs incurred by themselves/teammates in the otherwise occurring third battle; players/teams in the lagging position have the opposite incentives.

Differential private valuations of winning: a second mover on a lagging team may have a higher valuation of winning than a second mover on a leading team, because the pivotal status of this battle for the former induces additional psychic values from winning, such as self-image (i.e. self-derived utility of being the "saviour" of her team) or aversion to being "responsible" for the defeat of her team. Given the monotonicity condition, the second mover on the lagging team would exert greater effort and enjoy a higher probability of winning than an Econ counterpart. Alternatively, a second mover on a leading team may have a higher valuation of winning than a second mover on a lagging team when she derives additional psychic utility from helping her team achieve the final victory. Consequently, she would exert greater effort and be more likely to win than an Econ player.

Subjective (asymmetric) belief updating: upon knowing the outcome of the first battle, the second mover on the lagging team may perceive her third mover teammate as less competitive or skilled than the opposing third mover, and thus she will entertain a lower valuation of winning. Alternatively, the second mover on the leading team might perceive her third mover teammate as more competitive than the opposing third mover. Such a belief updating leads to a discouragement effect on the lagging team and an encouragement effect on the leading team.

In sum, the standard economic theory predicts that the outcomes of second battles and third battles in best-of-three team contests will not depend on whether the teams are in the leading or in the lagging position after the first battles. However, there are several psychological mechanisms that may alter the neutrality prediction. In particular, altruism predicts that if a second mover values the well-being of her third mover teammate as much as her own well-being, conditional on all other characteristics of both players in a battle, the second mover on the leading team will be more likely to win than the second mover on the lagging team. The rationale behind the momentum effect is similar to that in a best-of-three individual contest, where a leader is more likely to win the second battle than a laggard. However, it is also possible to observe the reversed momentum effect if, for example, the second mover on the lagging team derives additional psychic values from evening the score more than the second mover on the leading team from achieving a final victory for her team.

3 Data: Professional Squash Match

To test the theoretical prediction of strategic neutrality, I examine the behaviour of professional squash players in 31 high-stakes professional squash team championship tournaments during 1998–2014, including Men's World Team Championship, Women's World Team Championship, and Women's European Team Championship.[7] The data include 820 national team matches with game-level scores and monthly updated world rankings for all second movers.[8] All tournaments begin with a qualification stage using a Round-Robin type tournament followed by an elimination stage adopting the Monrad system.[9] This tournament format requires teams to have lots of matches and maintain players' involvement right through to the end of the tournament until a final position is produced for each team. The

[7] Both World championships are biannual events and the European championship is an annual event. We do not include Men's European Team Championship because this tournament adopts a peculiar "best-of-four" game form with ties broken by points count back.

[8] The data is collected from `http://www.squashinfo.com`. Last time accessed was April 25, 2015.

[9] The details of the Monrad system are complicated. See its adoption in squash tournaments on the website of English Squash and Racketball (`http://www.englandsquashandracketball.com/system/files/2099/original/The_Court_Challenge_Series_-_Competition_Organisers_Guide.pdf`). Since I only focus on the dynamics within each team match, the specific format of the tournament is inessential for my analysis.

data include matches from both qualification and elimination stages.

I measure players' abilities using the world rankings statistics, which are based on ranking points earned by players competing in Professional Squash Association (PSA) *individual* tournaments according to how far they advance as well as the prize money. The total number of points a player earns over the previous 12 months is divided by a divisor that increases in the number of tournaments played. The PSA world rankings are then a rank order of average earned points by all players, and are updated monthly.[10] Importantly, the rankings are *only* based on players' performance in individual tournaments and therefore are uncorrelated with their performance in past team tournaments.

Professional team squash data is particularly suited to test the theoretical predictions. A team match follows almost exactly the same best-of-three rule as in the theory. Each national team normally comprises 3–5 players. Before a match, the identity of players and the order in which they will play in each battle are predetermined and each player can play at most once in a match. Moreover, the three players of each team are nominated by team coaches in order of strength and they are typically paired with the three other players in the same order of strength. Thus, the structure of a team squash match corresponds to the theoretic best-of-three team contest with complete information.[11] What makes the squash team contest slightly richer in structure than the stylised theoretical model is the fact that each battle is in itself a best-of-five contest between two paired players, instead of a single-period contest. Importantly, the nested contest structure does not alter the neutrality prediction of battle outcomes.[12] I shall exploit this feature to distinguish the strategic neutrality from the "do your best" norm, which is otherwise unidentifiable from only examining the aggregated battle outcomes.

Table 1 shows some summary statistics reported separately for each of the three championships. The match ends with a final score of 2:0 in approximately 67.3% of all matches. More 2:0 than 2:1, at first glance, appears to suggest a non-neutral effect, but it might merely reflect that stronger players have better teammates. Therefore, I explore the influence of the

[10] My dataset only contains the world rankings statistics, not the ranking points behind those statistics.

[11] It is conceivable that teammates who often attend training camps together before a major tournament may know about the competence of each other more accurately than players from rival teams. If this superior knowledge implies deviations from players' skill levels as reflected at current world rankings, this fact will alter strategic neutrality. However, since in the professional squash world there are much more individual tournaments on which rankings are based, the concern about "hidden" information of players' competence does not appear to be warranted in reality.

[12] It can be shown that, given that the winning rule in each period within a battle satisfies the four regularity conditions discussed in the previous section and that strategic momentum holds between periods, the aggregated battle outcome still satisfies those four regularity conditions. In particular, the independence condition holds *in expectations* over all possible realisations of period outcomes such that the *expected* equilibrium battle outcome is still only dependent on the characteristics of effort cost functions of both contestants, and is independent of the common valuation of winning the battle.

Table 1: Actual and Simulated Match Outcomes

	Men's World	Women's World	Women's European
No. of matches	362	228	230
Actual *% of matches with a final score of 2:0*	69.3	67.5	64.3
Simulated *% of matches with a final score of 2:0*	72.0	76.0	69.2

Note: Simulated final scores are calculated based on a simple criterion: the player with higher ranking wins in each battle. The final score is then produced by adding up the wins and loses from those battles.

within-team ability matching by simulating the match outcomes using the PSA rankings. Based on a simple criterion that the higher-ranked player wins the battle against her paired lower-ranked opponent, I find that the simulated final score is 2:0 in about 72.3% of all matches. Hence, the positively assortative ability matching within a team could confound the evidence of strategic effects, and therefore must be taken into account when performing empirical analysis.

4 Results

In this section, I present empirical tests of the theoretical prediction of strategic neutrality. I first examine the dynamics between battles within a best-of-three team match, and I particularly focus on the (in)dependence of the second battle outcomes on the first battle outcomes. Next, I explore the dynamics within a battle, which help identify the strategic neutrality from the "do your best" norm.

4.1 Dynamics Between Battles: Single Equation Models

I test the theoretical prediction on the second battle outcomes using the following specification:

$$Win_{2(is)} = \beta_0 + \beta_1 Leading_{(is)} + \beta_2 RatioRank_{2(is)} + \beta_3 RatioRank_{3(is)} + \delta + \omega_{(s)} + \epsilon_{(is)}, \quad (1)$$

where the dependent variable is an indicator variable: $Win_{2(is)} = 1$ if the higher-ranked second mover won the second battle in match i of tournament s, and zero otherwise. Similarly, the indicator variable $Leading_{(is)} = 1$ if the first mover teammate won the first battle in match i of tournament s, and zero otherwise. $RatioRank_{2(is)}$ represents the second movers' ability differential, measured by the ratio of the rankings of the higher-ranked second mover and that of his/her paired lower-ranked second mover (e.g., if a seventh ranked player competed against a tenth ranked player, the variable takes a value of 7/10). $RatioRank_{3(is)}$ represents the third movers' ability differential, measured by the ratio of the ranking of the third mover teammate and that of his/her paired third mover. δ captures the home advantage of whether the higher-ranked second mover's team played on the home field, the neutral field or the opponent field (with the opponent field providing the omitted category). $\omega_{(s)}$ is a matrix of tournament event fixed effects and $\epsilon_{(is)}$ is the error term. All equations are estimated using a probit model with a robust variance estimator that is clustered at the tournament event level (totalling 31 events).

Table 2: Determinants of Second Battle Outcomes

	Average Marginal Effects (S.E.)				
	(1)	(2)	(3)	(4)	(5)
Leading	0.139***	0.045	0.007	0.044	0.002
	(0.030)	(0.033)	(0.039)	(0.033)	(0.039)
$RatioRank_2$		−0.536***	−0.534***	−1.048*	−1.844*
		(0.037)	(0.060)	(0.591)	(1.012)
$RatioRank_3$			−0.022		−0.024
			(0.016)		(0.017)
Home			0.036		0.039
			(0.118)		(0.117)
Neutral			0.017		0.019
			(0.082)		(0.078)
2nd-order polynomial of $RatioRank_2$				Yes	Yes
3nd-order polynomial of $RatioRank_2$				Yes	Yes
Fixed effects for each tournament	Yes	Yes	Yes	Yes	Yes
$N(matches)$	815	815	448	815	448

Note: Robust standard errors are in parentheses. * p < 0.10, *** p < 0.01

The theory predicts that higher-ranked second movers are equally likely to win the second battles whether they are on a leading team or on a lagging team. Therefore, the estimate of coefficient of *Leading* is predicted to be zero. $RatioRank_{2(is)}$ imposes a restriction on the second movers' ability differential to adjust for potential biases induced by a positive correlation in rankings between team members. $RatioRank_{3(is)}$ controls, to some degree, the potential influence of underlying non-constant marginal costs of effort and non-neutral risk attitudes.[13]

Table 2 reports estimates of the average marginal effects of Equation 1. Column (1) shows that the coefficient estimate of *Leading* is highly significant ($p < 0.001$) in the full sample when second movers' ability differentials are not controlled, reminiscent of assortative ability matching within a team as presented in Table 1. However, when second movers' ability differentials are controlled in column (2), consistent with strategic neutrality, the coefficient estimate of *Leading* becomes much smaller and statistically insignificant. When the controls for third movers' ability differentials and home advantage are added, the estimate is 0.007 and remains statistically insignificant ($p = 0.859$). Note that there is a loss of some observations because of some missing information in $RatioRank_3$.[14] However, re-estimating the model specification used in columns (1) and (2) of Table 2 by focusing on this sub-sample ($N = 448$) leads to the same conclusion: the coefficient estimates of *Leading* is 0.122 ($p = 0.001$) when second movers' ability differentials are not controlled, and is 0.022 ($p = 0.576$) when they are controlled.

In the main regressions, I use the ratio of the ordinal rankings as a measure of the second movers' skill disparity and only account for it linearly. As a robustness check, I add the second-order and the third-order polynomials of this measure to regressions. I find that both polynomials have virtually no impact on the coefficient estimate of *Leading*—0.044 ($p = 0.182$) in column (4) and 0.002 ($p = 0.962$) in column (5)—and are not statistically significant in themselves.

4.2 Testing for Selectivity Bias

In this subsection, I ask whether the results from the single equation models are robust. The primary concern is that there may exist some unobserved characteristics of a team that influence all of its players' performance such that being in a leading position is correlated with these unobserved variables. The unobserved characteristics may include team morale and training status at the time of the match. As a consequence, if I do not treat the variable *Leading* as endogenous, I may have overstated the effect of being on a leading team on the second mover's performance. Given the above single equation estimates, this implies

[13] I have assumed constant marginal costs of effort and risk neutrality in the theoretical model. If either of them does not hold, the equilibrium battle outcome would be partially dependent on the valuation of winning. This implies that in my empirical strategy, the valuation of winning needs to be controlled. Controlling third movers' ability differential achieves this goal by keeping the common valuation of winning constant for all second movers.

[14] The missing information is not because the third movers' identities and rankings are omitted when a team competition ended after the second battle. Therefore, it does not cause data selection biases.

that the coefficient of *Leading* may have a negative sign, which is to be interpreted as an encouragement effect on the lagging team.

To properly deal with the selection problem on the unobservables, I estimate an instrumental-variables model by using $RatioRank_1$ (the ranking ratio of the first mover teammate and the paired first mover) to instrument *Leading*. The IV results rest on the premise that $RatioRank_1$ is a valid instrument. To be so, the excluded instrument must satisfy that (i) it strongly influences the prospect of winning the first battle, and (ii) conditional on $RatioRank_2$ it is uncorrelated with the error term in Equation 1. It is easy to show the first qualification. In a probit model that explains the probability of winning the first battle, the coefficient estimate of $RatioRank_1$ is highly statistically significant ($p < 0.001$). The second qualification can also be confirmed by including $RatioRank_1$ in Equation 1. If the excluded instrument can only influence the probability of winning in the second battle through the channel of whether being on the leading team or not, then its estimated coefficient in the single equation model should be statistically insignificant. This is indeed the case ($p = 0.762$).[15]

Formally, following Equation 1, the endogenous variable *Leading* can be written as

$$Leading_{(is)} = \gamma_0 + \gamma_1 RatioRank_{1(is)} + \gamma_2 RatioRank_{2(is)} + \gamma_3 RatioRank_{3(is)} + \delta + \omega_{(s)} + \pi_{(is)}, \tag{2}$$

where all the covariates except $RatioRank_{1(is)}$ are the same as in Equation 1 and $\pi_{(is)}$ is an error term. To allow for the possibility that the unobserved determinants of a first battle outcome and the unobserved determinants of a second battle outcome are uncorrelated, I assume that $\pi_{(is)}$ and $\epsilon_{(is)}$ are distributed bivariate normal, with $E[\pi_{(is)}] = E[\epsilon_{(is)}] = 0$, $var[\pi_{(is)}] = var[\epsilon_{(is)}] = 1$ and $cov[\pi_{(is)}, \epsilon_{(is)}] = \rho$. $RatioRank_{1(is)}$ serves as an excluded instrument that provides an identification for the system consisting of Equation 1 and Equation 2. Because both dependent variables are dichotomous, the likelihood function corresponding to all four possible states of the world is therefore a bivariate probit.

Table 4 reports the maximum likelihood bivariate probit estimates. The results show that the estimate of the average marginal effect of *Leading* remains statistically insignificant in all specifications, indicating that the potential endogeneity problem does not systematically bias the single equation estimates.[16] The estimate of the correlation coefficient ρ is positive and statistically insignificant in all specifications.

[15]It should be noted, however, that this is not a formal test if the single equation model is misspecified. But it does give us a clear indication of the patterns in the data. Also, given the independent nature of battles, it is implausible that conditional on second movers' ability differential, the first movers' ability differential will directly affect the outcome of the second battle before the first battle ever begins.

[16]A more straightforward two-stage least squares (2SLS) model one could estimate by treating the two dependent variables as continuous gives very similar results.

Table 3: Determinants of Second Battle Outcomes: Bivariate Probit Estimates

	Average Marginal Effects (S.E.)			
	(1)	(2)	(3)	(4)
Leading	0.001	−0.116	0.003	−0.164
	(0.091)	(0.130)	(0.097)	(0.144)
$RatioRank_2$	−0.555***	−0.543***	−1.724***	−2.806***
	(0.071)	(0.089)	(0.755)	(1.044)
$RatioRank_3$		−0.043*		−0.050**
		(0.024)		(0.023)
Home		0.144		0.162
		(0.154)		(0.149)
Neutral		0.061		0.075
		(0.112)		(0.104)
2nd-order polynomial of $RatioRank_2$			Yes	Yes
3nd-order polynomial of $RatioRank_2$			Yes	Yes
Fixed effects for each tournament	Yes	Yes	Yes	Yes
ρ	0.056	0.317	0.049	0.462
	(0.225)	(0.349)	(0.246)	(0.421)
$N(matches)$	565	353	565	353

Note: Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.3 Dynamics Within a Battle: Strategic Neutrality or "Do Your Best"?

The evidence for the neutral dynamic effect between battles helps to preclude some of the psychological mechanisms that may alter the neutrality result such as altruistic preferences towards teammates, differential valuation of winning due to psychological (dis)utilities, and subjective belief updating about teammates' competence. It, however, provides *consistent but not conclusive* evidence for the strategic mechanism behind the neutrality result. For example, instead of carefully trading off effort costs and probability of winning, as stated in the theory, players may simply try as hard as possible to win their battles. Such a motivation or a norm seems natural and plausible if the effort exertion only involves physical, physiological or psychological costs. As a result, the "do your best" norm implies the neutrality result as well as the strategic neutrality does.

Fortunately, a unique feature of the squash data allows me to distinguish the strategic neutrality from the "do your best" norm. As noted in the Data section, each battle is a multi-period individual contest—a best-of-five contest between two paired players, and the nested multi-period contest structure does not alter the theoretical neutrality prediction for the battle outcome. Unlike the aggregated battle outcome, the strategic mechanism and the "do your best" norm have very different predictions of period outcomes within a battle. On the one hand, the strategic model predicts strategic momentum—a score leader always fight harder and is therefore more likely to win the next period than a laggard (Klumpp and Polborn, 2006; Konrad and Kovenock, 2009). On the other hand, the competing psychological motivation still predicts the neutrality for period outcomes. Therefore, if I were to find the evidence of non-neutral dynamic effects *within* a battle, it implies that it is indeed the strategic mechanism drives the observed neutrality *between* battles.

I use the following specification to examine the determinants of period outcomes within a battle:

$$Win_{k(is)} = \alpha_0 + \alpha_1 WonPeriod_{k(is)} + \alpha_2 RatioRank_{k(is)} + \delta + \omega_{(s)} + \nu_{k(is)}, \tag{3}$$

where the dependent variable is an indicator variable: $Win_{k(is)} = 1$ if the higher-ranked player won the ith period of battle k in tournament s, and zero otherwise. $WonPeriod_{k(is)}$ calculates the number of periods the high-ranked player won so far before the ith period of battle k in tournament s. $RatioRank_{k(is)}$ represents the players' ability differential, measured by the ratio of the ranking of the higher-ranked player and that of the paired lower-ranked opponent. All equations are estimated using a probit model with a robust variance estimator that is clustered at the tournament event level.[17]

In a best-of-five individual contest, I examine dynamic effects at the second, the third, and the fourth periods. $WonPeriod$ can take on the value of 0 or 1 at the beginning of the second period, 0, 1 or 2 at the beginning of the third period, and 1 or 2 at the beginning of the fourth period.[18] Note that $WonPeriod$ captures the current state within a battle, which is all that matters from the theoretical viewpoint. Nonetheless, I also estimate an alternative specification in which I use indicator variables for whether the high-ranked player won in each of the previous periods, thereby allowing for a finer examination of dynamic effects between periods.

Table 4 reports estimates of the parameters in Equation 3. The results show a positive and significant impact of $WonPeriod$ on the probability of winning the current period, be it the second, third or fourth period. Furthermore, estimates from columns (3) and (5) show that, consistent with the theoretical predictions, the strategic momentum occurs at every period, meaning that each additional victory in the previous periods contributes to

[17] Adding the second-order and the third-order polynomials of $RatioRank_{k(is)}$ to all specifications has practically no influence on the estimates, and both polynomials themselves are not statistically significant. These results are therefore not reported.

[18] The fifth period is a case where $WonPeriod$ is always 2.

Table 4: Determinants of Individual Period Outcomes Within Battles

	Average Marginal Effects (S.E.)				
	(1) 2nd Per.	(2) 3rd Per.	(3) 3rd Per.	(4) 4th Per.	(5) 4th Per.
WonPeriod	0.199***	0.154***		0.194***	
	(0.025)	(0.012)		(0.030)	
Won the 1st Per.			0.151***		0.129***
			(0.016)		(0.038)
Won the 2nd Per.			0.158***		0.209***
			(0.020)		(0.034)
Won the 3rd Per.					0.247***
					(0.037)
RatioRank	−0.370***	−0.285***	−0.285***	−0.340***	−0.328***
	(0.036)	(0.026)	(0.026)	(0.069)	(0.071)
Home	0.060	−0.051	−0.050	−0.038	−0.013
	(0.060)	(0.055)	(0.055)	(0.101)	(0.099)
Neutral	0.021	−0.016	−0.016	0.043	0.051
	(0.043)	(0.041)	(0.041)	(0.086)	(0.083)
Fixed effects for each tournament	Yes	Yes	Yes	Yes	Yes
$N(matches)$	2260	2133	2133	811	811

Note: Robust standard errors are in parentheses. *** p < 0.01

a higher probability of winning the current period. To mitigate some potential bias that might arise from using the ratio of ordinal rankings as a measure of ability differential, I also re-estimate the same model by focusing only on the observations in which players' rankings are close—that is, $RatioRank > 0.8$.[19] The results, reported in Table A1 of the Appendix A, show that similar, if not stronger, momentum effects also prevail among relatively equally skilled players. Finally, I estimate the same model separately for each mover type and report estimates in Table A2. The results for each of the mover type show similar momentum effects to those for all players.

However, momentum effects as such can also be explained by a psychological momentum effect, wherein the winner of the first period has momentum in the second and the winner of the second period has momentum in the third, and so on. To distinguish such a psychological momentum from the strategic momentum, I follow the strategy of Malueg and Yates (2010, pp.691-692) by examining whether a player's probability of winning the (non-trivial) fifth period is *independent* of the outcome in the fourth period, or, to even a greater extent such that be incompatible with any types of psychological momentum effects, independent of the

[19]Using other cutoffs such as 0.9 or 0.7 gives very similar results.

outcomes in any of the previous periods. In a probit model similar to Equation 3 that explains the fifth period outcomes ($N = 276$), I do not reject either of these two null hypotheses of independence. Similarly, I could examine the third periods before which the players' scores are equalised ($N = 578$). Again, there is no evidence that a player's probability of winning these third periods is dependent on whom won the second period. Hence, these results provide strong evidence for players' behaving strategically within a battle.[20]

5 Discussion

In short, the squash data support the game-theoretical prediction of strategic neutrality in best-of-three team competitions. The prediction, which relies crucially on players' abilities of exercising backward induction and on their purely selfish preferences, does not appear to accord well with psychological intuitions as well as the recent empirical literature, which has been challenging both of these two presumptions. However, by comparing the dynamics between and within battles, the evidence strongly suggests that the psychological mechanisms, which either alter the neutrality prediction or lead to the same conclusion as the strategic neutrality, are not the underlying behavioural mechanisms. Professional squash players do seem to act rationally in the way prescribed by the economic theory.

The inherent difficulty in identifying null effects may raise concerns over the power of statistical tests. It seems possible that a clear inference may be clouded by some unobserved individual ability differences.[21] However, if these unobservables would have resulted in imprecisely estimated dynamic effects between battles, it would have also led to imprecisely estimated dynamic effects within a battle. As shown in column (3) of Table 2, the estimated dynamic effect between battles, even if is true, is practically close to zero: taken literally, conditional on all other characteristics, second movers on leading teams have an average 0.7% better chance of winning their battles than those on lagging teams. However, the dynamic effect within battles is much stronger and both statistically and economically meaningful: each additional victory in the previous periods increases the chance of winning the current period by at least 15%. I view these results as a strong indication that the neutrality result

[20] My results on "best of" individual contests are consistent with the field findings by Malueg and Yates (2010) and the experimental evidence by Mago et al. (2013), but contradicts the experimental findings by Fu et al. (2015a) and Irfanoglu et al. (2015). Ferrall and Smith (1999) also studies a best-of-($2n$+1) type tournament using field data from professional baseball, basketball, and hockey championships, but they found neutral dynamic effects. The mixed evidence on dynamic effects may reflect differences in experimental designs as well as in field environments.

[21] The PSA world rankings may not perfectly reflect players' competence at the moment of the match. For example, fatigue or unexpected injuries, which are unobservables in the field data, may impact players' actual odds of winning. Some peculiar past records from previous tournaments between some specific pairs of players may also render the current PSA ranking an imperfect skill measurement.

is unlikely to be an artefact simply due to the lack of statistical power.

Although I have mainly focused on second battles, the strategic neutrality can also be tested against whether the third battle outcomes are independent of the outcomes of the first battles. Note that a third battle is non-trivial only if the match score is thus far 1:1. I only focus on non-trivial third battles. Table A3 in the Appendix A reports estimates of a probit model that explains the third battle outcomes from the perspective of higher-ranked third movers. The coefficient estimates of *Leading* (=1 if the first battle was won), which are not statistically significantly different from zero, confirm that the strategic neutrality is also evident in the third battles. One might also worry that those matches from qualifying stages are presumably with lower stakes in expectations, which might have contributed to the observed neutrality result. All of my results, however, are robust if I focus on the subset which only comprises matches from elimination stages.

One limitation of the current study is that it does not yet give the most strenuous test of the theory because teams in best-of-three contests can at most be one battle ahead or behind. It would be interesting to test whether the strategic neutrality still holds in best-of-five or best-of-seven contests when teams can be two or three battles ahead or behind. Another advantage of using contests with longer length is that we can examine some other psychological motivations, which might seemingly be consistent with the neutrality result. For instance, in the second battle of a best-of-three, the player who is on the lagging team is both in a position where he can draw his team even with the opposing team with a win and in a position where he can cost his team an entire match win a loss. Similarly, the player is on the leading team is both in a position where he can bring a final victory for his team with a win and in a position where he may put his team in an uncertain situation with a loss. All these factors may lead to psychological (dis)utilities. Although only in rare combinations can these factors be consistent with the strategic neutrality, they could be more easily teased apart and might even in themselves loom larger in contests with longer length. The lack of data may preclude investigating such a question in the field. The closest dataset that I can think of is tennis team matches in Davis Cups which adopt a best-of-five format. However, there are other complications in these matches, such as repeated appearance of a single player in a match, that may preclude a clear inference of strategic effects. Alternatively, future research can implement longer "best-of" contests in controlled laboratory experiments.

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A Appendix: Additional Tables (intended for online publication)

Table A1: Determinants of Individual Period Outcomes Between Equally Competent Players

	Average Marginal Effects (S.E.)				
	(1) 2nd Per.	(2) 3rd Per.	(3) 3rd Per.	(4) 4th Per.	(5) 4th Per.
WonPeriod	0.353***	0.191***		0.240***	
	(0.045)	(0.029)		(0.092)	
Won the 1st Per.			0.120*		0.078
			(0.063)		(0.112)
Won the 2nd Per.			0.257***		0.323***
			(0.054)		(0.123)
Won the 3rd Per.					0.285**
					(0.141)
RatioRank	−0.334	−0.045	−0.070	0.036	0.038
	(0.436)	(0.557)	(0.563)	(0.993)	(0.940)
Home	0.032	0.027	0.034	0.075	0.092
	(0.204)	(0.167)	(0.163)	(0.269)	(0.276)
Neutral	0.060	0.003	−0.002	−0.032	−0.060
	(0.103)	(0.129)	(0.127)	(0.218)	(0.231)
Fixed effects for each tournament	Yes	Yes	Yes	Yes	Yes
$N(matches)$	311	289	289	136	136

Note: All equations are estimated using probit regressions with a robust variance estimator that is clustered at the event level. Robust standard errors are in parentheses. The subsample includes observations in which *RatioRank* > 0.8. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A2: Determinants of Individual Period Outcomes for Each Mover Type

	First Movers			Second Movers			Third Movers		
	(1) 2nd Per.	(2) 3rd Per.	(3) 4th Per.	(4) 2nd Per.	(5) 3rd Per.	(6) 4th Per.	(7) 2nd Per.	(8) 3rd Per.	(9) 4th Per.
$WonPeriod$	0.183***	0.168***	0.221***	0.240***	0.134***	0.129***	0.148***	0.164***	0.296***
	(0.021)	(0.020)	(0.036)	(0.039)	(0.020)	(0.050)	(0.038)	(0.019)	(0.065)
$RatioRank$	−0.397***	−0.271***	−0.385***	−0.369***	−0.363***	−0.369***	−0.362***	−0.248***	−0.243*
	(0.040)	(0.038)	(0.107)	(0.055)	(0.037)	(0.109)	(0.049)	(0.059)	(0.143)
$Home$	0.045	−0.126	−0.126	−0.032	0.041	0.060	0.228**	−0.018	0.046
	(0.097)	(0.091)	(0.185)	(0.080)	(0.084)	(0.123)	(0.104)	(0.102)	(0.231)
$Neutral$	0.024	−0.041	−0.019	−0.038	0.025	−0.012	0.085	−0.025	0.187
	(0.074)	(0.067)	(0.134)	(0.061)	(0.058)	(0.128)	(0.068)	(0.072)	(0.146)
Fixed effects for each tournament	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$N(matches)$	864	858	322	814	781	289	559	468	164

Note: All equations are estimated using probit regressions with a robust variance estimator that is clustered at the event level. Average marginal effects reported. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A3: Determinants of Third Battle Outcomes

Dep. Var.: Higher-ranked third mover won	Average Marginal Effects (S.E.)		
	(1)	(2)	(3)
Leading	0.061	0.116	0.089
	(0.258)	(0.277)	(0.267)
$RatioRank_3$		-1.344^{**}	-1.324^{**}
		(0.560)	(0.563)
Home			0.512
			(0.750)
Neutral			0.260
			(0.471)
Fixed effects for each tournament	Yes	Yes	Yes
$N(matches)$	165	165	165

Note: All equations are estimated using probit regressions with a robust variance estimator that is clustered at the event level. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$