# Psychological Pressure in Competitive Environments: Evidence from a Randomized Natural Experiment

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## Abstract

Emotions can have major effects on performance and socioeconomic outcomes. We study a natural experiment where two teams of professionals compete in a tournament taking turns in a sequence. As the sequential order is determined by the random outcome of a coin flip, the treatment and control groups are determined via explicit randomization. Hence, absent any psychological effects, both teams should have the same probability of winning. Yet, we find a systematic first-mover advantage. Further, professionals are self-aware of their own psychological effects and, when given the chance, they rationally react by systematically taking advantage of these effects. (*JEL* C93, D01, D03)

Much as the rationality principle has successfully accommodated social attitudes, altruism, values and other elements (see, e.g., Gary S. Becker 1976, 1996; Becker and Kevin M. Murphy 2000), behavioral economics attempts to parsimoniously incorporate psychological motives not traditionally included in economic models. Theoretical models in this area firmly rely for empirical support on the observation of human decision making in laboratory environments. Laboratory experiments have the important advantage of providing a great deal of control over relevant margins. In these settings, observed behavior often deviates from the predictions of standard economic models. In fact, at least since the 1970s, a great deal of experimental evidence has been accumulated demonstrating circumstances under which strict rationality considerations break down and other patterns of behavior, including psychological considerations, emerge. Thus, an important issue is how applicable are the insights gained in laboratory settings for understanding behavior in natural environments. This challenge, often referred to as the problem of "generalizability" or "external validity," has assumed a central role in recent research in the area.

The best and perhaps only way to address this concern is by studying human behavior in real life settings. Unfortunately, however, Nature seldom creates the circumstances that allow a clear view of the psychological principles at work. Furthermore, naturally occurring phenomena are typically too complex to be empirically tractable in a way that allow us to discern psychological elements from within the characteristically complex behavior exhibited by humans.

In this paper we take advantage of an unusually clean opportunity to discern these elements by studying a randomized natural experiment, that is, a real life situation in which the treatment and control groups are determined via explicit randomization. As is well known, this situation guarantees internal validity since it satisfies the conditions for causal inference (Charles F. Manski 1995). The subjects in the experiment are professionals who have to perform a simple task in a tournament competition. In soccer, one of the methods of determining the winning team if a match is drawn but a winner is needed is by the two teams taking kicks from the penalty mark. This method is used worldwide in all major elimination tournaments involving both national and club teams (e.g., World Cups, European Cups, Champions League, etc). From the time it was first introduced in 1970 and until 2003, the basic procedure established that both teams alternately take five penalty kicks each, and that the order of the

kicks be decided by a referee who *tosses a coin* and the team whose captain *wins* the toss takes the *first* kick.

This randomized experiment gives us the chance to study a situation that is familiar to the subjects and takes place in the natural setting in which they operate. The subjects are professionals; in fact, they are among the highest paid professionals in the world, and the task they have to perform (kick a ball once) is one of the simplest they could possibly be asked to perform. Further, the competitive setting relates to an important framework of analysis in labor economics and in the economics of organizations (the tournament model). Moreover, from an empirical perspective all the relevant variables are perfectly observable, the task is effortless, outcomes are decided immediately, and with only two possible outcomes (score, no score) risk plays no role in the analysis. Finally, individuals are subject to high incentives, and so are interested in performing as well as they can. In fact, their actions often have enormous consequences not only for their individual careers, but also for their team, their city and even their country as in a World Cup final, for instance.

The explicit randomization mechanism used to determine which team goes first in the sequence in a situation where both teams have exactly the *same* opportunities to perform a task suggests that we should expect the first and second teams to have exactly the *same* probability of winning the tournament. Yet, we find a strongly significant and quantitatively important difference. Using data on 1,343 penalty kicks from 129 penalty shoot-outs over the period 1976-2003, we find that teams that take the first kick in the sequence win the penalty shoot-out 60.5 percent of the time. Given the characteristics of the setting we can attribute this difference in performance to psychological effects resulting from the consequences of the kicking order.

The paper is structured as follows. Section I briefly reviews relevant literature. Section II presents the natural experiment. Section III describes the data and reports the main empirical result. In section IV we study whether subjects are aware of the advantage of going first, whether they rationally respond to it by systematically choosing to kick first when given the chance to choose the order, and whether, when surveyed, they identify a specific psychological mechanism for their behavior. We find that the answer to these three questions is affirmative. We also study the mechanism whereby teams kicking first are more likely to win using a random effects dynamic panel data model and discuss some policy implications. Section V concludes.

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# I. Related Literature

This paper relates to several strands of literature in economics and psychology. First, the natural setting is that of a tournament. Tournaments are pervasive in real life and often characterize competitive situations such as competitions for promotion in internal labor markets in firms and organizations, patent races, political elections, student competitions in schools and many others. The tournament model was first formalized by Edward P. Lazear and Sherwin H. Rosen (1981), and over the last couple of decades a large literature has studied both theoretically and empirically a number of important aspects of this incentive scheme.[1] Despite the large body of work, however, we are aware of no evidence documenting how psychological or emotional effects may be relevant in explaining the performance of subjects competing in a tournament setting. One possible reason for this is that the difficulties in clearly observing actions, outcomes, choices of risky strategies, and other relevant variables in naturally occurring settings are exceedingly high, and as a result it is not possible to discern with sufficient precision whether there are, in addition to these variables, any psychological elements at work.

The characteristics of the setting we study, however, are ideal for overcoming these obstacles. Variables such as the choice of effort levels and risky strategies that are typically hard to measure in tournaments and other competitive situations play no role in our setting: the task (kicking a ball once) involves no physical effort and, with only two possible outcomes (score or no score), risk plays no role either.[2] Outcomes can be perfectly observed and are immediately determined after players make their choices; that is, there is no subsequent play. This is important, indeed critical, to establish the empirical results.[3] Furthermore, the rules of the competition

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[1] See Canice Prendergast (1999) for a review.

[2] The role of risk in tournament competitions has been examined in Hans K. Hvide (2002) and Hvide and Eirik G. Kristiansen (2003). In dynamic competition games, there is a literature on the "increasing dominance" effect of a leader over a rival (e.g., Luis Cabral 2002, 2003), which studies the strategic choice of variance and covariance throughout a competition.

[3] The reason is that if there were subsequent actions that contribute to determine the outcome, we would need to have detailed information on the subjects' choice of effort levels and choice of risky strategies in those actions. Further, subjects may also have asymmetric information concerning their effort levels and be heterogeneous in their risk attitudes. These aspects mean that situations in which a coin toss is used to decide, for instance, initial sides or which team begins play (see, e.g., V. Bhaskar (2009) and Jan R. Magnus and Franc J. G. M. Klaassen (1999) for studies on cricket and tennis) are an order of magnitude more complex than a penalty kick for discerning the presence

are precisely established and require that subjects are always in the same physical situation (same position and location).

Second, an important literature in social psychology has studied expert performance and performance under pressure such as that induced by high stakes, the presence of an audience and others.[4] Dan Ariely, Uri Gneezy, George Loewenstein, and Nina Mazar (2009) review and discuss this literature in the context of a study of whether or not increases in motivation and effort result in improved performance. In our setting, however, *both* teams have the *same* stakes in the shoot-out and both perform in front of the *same* audience, an audience which in many shoot-outs roughly equally supports both teams. More importantly, although different forms of pressure (e.g., stakes, audience) may be complements with each other, the explicit randomization procedure that is used means that there is no reason why one team should be systematically more affected than the other. The novel result we obtain from the perspective of this literature is that differences in the *interim state* of the competition caused by the kicking order may generate differences in the psychological pressure that drives the effects on performance that we observe.[5]

Third, there is a literature showing the importance of psychology to economics. Stefano DellaVigna (2009) surveys the empirical evidence from natural settings documenting deviations from the standard rational model with respect to non-standard preferences, incorrect beliefs, and systematic biases in decision-making. It has been shown, for instance, that behavior often depends on reference points. In our setting, as will be documented later, the score at the time a player has to perform his task (the state of the competition) appears to act as a reference point, and the "ahead-behind" asymmetry associated with this partial score (that is, to be leading or lagging in the score) to have an impact on performance.[6] To the best of our knowledge there is no empirical evidence from real life strictly *competitive* environments on reference-

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of psychological elements. Further, winners of the coin toss in these settings typically *choose* sides and whether or not to begin batting or serving. This means that these situations do not represent a perfect randomized experiment.

[4]See, for instance, K. Anders Ericsson et al. 2006, Sian Beilock 2007, and other references therein.

[5]We will not speculate as to the actual form that these psychological effects may take beyond indicating that they may be associated with increased arousal, greater shifting of mental process from "automatic" to "controlled," or differences in the narrowing of attention (see Daniel Kahneman 1973). Also, they may represent differences in mental fatigue or mental strain.

[6]See Botond Köszegi and Matthew Rabin (2006) for a model of reference-dependent preferences where "gain-loss" (or "ahead-behind") evaluations around a reference point influence behavior.

dependent preferences and their impact on performance. Similarly, we are aware of no empirical evidence documenting how changes in mood and arousal associated with the state of the competition can generate deviations from the rational model in terms of performance.[7]

Lastly, there is some economic literature on the ex-post fairness of certain regulations in sports where a coin flip that determines the order of play may have a significant impact on the outcome of a game by giving the winner of the coin flip *more* chances to perform a task (e.g., Yeon-Koo Che and Terry Hendershott 2008, Wall Street Journal 2003, for the case of extra-time sudden-death regulations in the National Football League). Our results show that even under ideal circumstances where a coin flip determines only the order of competition and both teams have exactly the *same* chances human nature is such that the outcome of a perfect randomized trial may be considered ex-post unfair.

## II. The Randomized Natural Experiment

A penalty shoot-out is simply a sequence of penalty kicks. The rules that govern a penalty kick are described in the Official Laws of the Game (FIFA 2007) issued by the world governing body of soccer, the Fédération Internationale de Football Association (FIFA). Each penalty kick involves two players: a kicker and a goalkeeper. In the typical kick the ball takes about 0.3-0.4 seconds to travel the distance between the penalty mark and the goal line, which is less than the reaction time plus the goalkeeper's movement time to possible paths of the ball. Hence, both kicker and goalkeeper must move simultaneously and the outcome is determined immediately. The penalty kick has only two possible outcomes: score or no score. There are no second penalties or any form of subsequent play in the event of a goal not being scored. By any reasonable metric the task can be considered effortless, and with only two possible outcomes risk plays no role.[8] Further, players' actions and outcomes

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[7]For evidence on the impact of changes associated with exposure to media violence, the wheather and others, see DellaVigna (2009). With regard to formal models, Larry G. Epstein and Igor Kopylov (2007) develop a model of pessimism where individuals lose confidence in their outlook as they approach the moment of truth. Theoretical contributions on anxiety include Loewenstein (1987), Andrew Caplin and John Leahy (2001) and Michael T. Rauh and Giulio Seccia (2006). In cognitive psychology, Larry W. Morris, Mark A. Davis, and Calvin H. Hutchings (1981) provides a review.

[8]We refer here to physical effort, which is typically conceived as a choice variable. With regard to mental effort, arousal is the brain's way of increasing its level of effort, and it is not ordinarily under volitional control (see Kahneman 1973).

can be perfectly observed. The initial location of both the ball and the goalkeeper is always the same: the ball is placed on the penalty mark and the goalkeeper positions himself on the goal line.

The purpose of a penalty shoot-out is to decide the winning team where competition rules require one team to be declared the winner after a drawn match.[9] The penalty shoot-out was first introduced in 1970 and until July 2003 its main characteristics were as follows (FIFA 2002, 36):

• "The referee tosses a coin and the team whose captain wins the toss takes the first kick.

• Subject to the conditions explained below, both teams take five kicks.

• The kicks are taken alternately by the teams.

• If, before both teams have taken five kicks, one has scored more goals than the other could score, even if it were to complete its five kicks, no more kicks are taken.

• If, after both teams have taken five kicks, both have scored the same number of goals, or have not scored any goals, kicks continue to be taken in the same order until one team has scored a goal more than the other from the same number of kicks."

In July 2003, FIFA (2003, 36) decided to slightly change the first regulation in the procedure by replacing it with (italics added):

• "The referee tosses a coin and the team whose captain wins the toss *decides* whether to take the first or the second kick."

The focus of our analysis is the period 1970-2003 where we have a perfect randomized experiment, and post-2003 data will be used to assess other relevant aspects.

### III. Data and Empirical Evidence

The data come from the Union of European Football Associations (UEFA), the Rec.Sport.Soccer Statistics Foundation, the Association of Football Statisticians, and the Spanish newspaper MARCA. The dataset comprises 269 penalty shoot-outs with 2,820 penalty kicks over the period 1970-2008. It is fully comprehensive in that it includes *all* the penalty shoot-outs in the history of the main international competitions for national teams and for club teams, as well as data on various national club competitions. Table 1 provides a summary of the dataset.

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[9]The complete set of rules in a penalty shoot-out is available in `http://www.fifa.com`.

[Table 1 here]

For every shoot-out of every competition we have information on the date, the identity of the teams kicking first and second, the final outcome, the outcomes of each of the kicks in the sequence (with the exception of one shoot-out), and the geographical location of the game (that is, whether the game was played at a home ground, a visiting ground, or in a neutral field).

As is well known, and following the description in Manski (1995), let $y_z$ be the outcome that a subject (a team in our case) would realize if he were to receive treatment $z$, where $z = 0, 1$. Let $P(y_z | x)$ denote the distribution of outcomes that would be realized if all subjects with covariates $x$ were to receive treatment $z$. The objective is to compare the distributions $P(y_1 | x)$ and $P(y_0 | x)$. When the treatment $z$ received by each subject with covariates $x$ is statistically independent of the subject's outcomes, we have $P(y_z | x) = P(y_z | x, z = 1) = P(y_z | x, z = 0)$ for $z = 0, 1$. Now let $y \equiv y_1 z + y_0 (1 - z)$ denote the outcome actually realized by a member of the population, namely, $y_1$ when $z = 1$ and $y_0$ when $z = 0$. Note that $P(y | x, z = 1) = P(y_1 | x, z = 1)$ and $P(y | x, z = 0) = P(y_0 | x, z = 0)$. Hence, if we denote by $B$ the set of outcome values (that is, win or lose in our case), when the treatment is independent of the outcomes, the estimate of the average treatment effect $T(B | x)$ is:

$$T(B | x) = P(y \in B | x, z = 1) - P(y \in B | x, z = 0).$$

Next, we first confirm the statistical similarity of the pre-treatment characteristics of the two teams involved in a shoot-out. The main covariates we are interested in are variables that measure the quality of the teams, their previous experience in shoot-outs, and environmental factors such as the nature of the crowd in the stadium since these may represent differences in support or pressure experienced by the teams. With respect to the quality of the teams, FIFA and UEFA publish yearly rankings both for national teams and clubs based on their performance in certain competitions. For the national team competitions we use the "FIFA rankings," and for international club competitions the "UEFA team rankings."[10] For club competitions at the national level we consider the division or category to which the teams belong at the time of the shoot-out and, when they belong to the same division, their standings in the

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[10]The methodology used to construct these rankings is described in http://www.fifa.com and http://www.uefa.com.

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table. With respect to experience, we compute the number of previous shoot-outs observed in our dataset in which a given team has been involved. Lastly, we consider whether a team is playing at its own stadium in front of mostly a supporting home crowd, at the stadium of its opponent in front of a predominantly unfriendly crowd, or at a neutral venue. Table 2 reports the differences in these characteristics.

[Table 2 here]

Consistent with the randomization procedure used to determine the order of play, it is not possible to reject the null hypothesis of equality in any of these covariates at conventional significance levels.

We now turn to the main result of this paper. As indicated earlier, the estimate of the average treatment effect is $P(y \in B \mid x, z = 1) - P(y \in B \mid x, z = 0)$. We compute this effect and find that teams kicking first in the sequence win the penalty shoot-out 60.5% of the time. That is, kicking first conveys a strongly significant (at the 1.7 percent level) and sizeable advantage.

[Figure 1 here]

In Table 3 we use a regression framework to provide an estimate of the treatment effect using various probit and logit specifications.

[Table 3 here]

We find, not surprisingly, that the order of play is strongly significant in every specification. Furthermore, it is also interesting to note that none of the covariates included in the regressions are significant in any of the specifications. These results confirm the significant and sizeable advantage gained by the team that is first to kick.

## IV. Discussion

*A. Are Professionals Aware of Any Psychological Effects on Performance?*

As indicated earlier, in July 2003 FIFA introduced a slight change in the procedure used to determine the kicking order. Rather than requiring that the winner of the coin toss *must* take first kick, it required that he *chooses* whether to take the first

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kick or the second kick. This change allows us to study the response of professionals to the psychological phenomenon we have documented: (1) Professionals may or may not be aware of it; (2) If they are, they may or may not react optimally to it; (3) And if they do react optimally, they may or may not do so for the right reason.

Clearly, if subjects are aware of any psychological effects caused by the order of play and their detrimental impact on performance, they should always choose to go first in the tournament. Unfortunately, there are no public records of players' choices because FIFA regulations do not require referees to record this information.[11] In order to get to know what their choices after July 2003 are, we have done the following:

1. First, we watched about twenty videos of matches that ended in a penalty shoot-out. Although the interval between the end of a game and the beginning of a shoot-out is typically used by TV channels to air commercials, it is sometimes possible to catch the very instant when the referee flips the coin and talks to the winner of the toss. We found that in each and every case that we were able to observe with just one exception, the winner of the coin toss chose to kick first.[12]

2. Second, we conducted a survey of more than 240 players and coaches in the professional and amateur leagues in Spain, who were asked the following question: ``Assume you are playing a penalty shoot-out. You win the coin toss and have to choose whether to kick first or second. What would you choose: first; second; either one, I am indifferent; or, it depends?'' The results are collected in Table 4.

[Table 4 here]

We found that just about 100% of the subjects answered that they would prefer to go first. More importantly, when asked to explain their decision, they systematically argued that their choice was motivated by the desire to put pressure on the kicker of the opposing team. Coding their answers to a second question we asked in the survey: ``Please explain your decision: why would you do what you just said?,'' we find that in 96% of the cases they explicitly mention that they intend

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[11]See the complete regulations in http://www.fifa.com.

[12]The exception is the Italy-Spain match in the quarter finals of the European Championship, June 2008. Gianluigi Buffon, the Italian goalkeeper, won the toss and chose Spain to kick first. Spain won.

to put pressure on the kicker of the second-kicking team, and that in no case they refer to the possibility of enhancing the performance of their own goalkeeper.

We interpret this evidence as supporting the hypothesis that subjects are perfectly aware of the result and, more importantly, they respond optimally to it. This means, following the terminology used in behavioral economic theory, that they can be characterized as "sophisticates." Further, they attribute the result to a specific psychological mechanism that leads to pressure and underperformance. In the next subsections we study whether this is also substantiated in the data.

### B. Descriptive Evidence of Dynamic Performance

Table 5 reports round-by-round data of winning frequencies for each team. As indicated earlier, when the shoot-out remains tied after five rounds kicks continue to be taken in the same order in additional rounds until one team has scored a goal more than the other from the same number of kicks. We will call these "decisive rounds."

[Table 5 here]

We find that most of the shoot-outs (about three quarters) end in five or fewer rounds, and the rest move into decisive rounds. The team kicking first wins 65.9% of all the shoot-outs that end in five rounds or less, and 52.9% of the rest. The lower advantage in the decisive rounds may simply reflect a selection effect, namely that it involves first teams that have failed to capitalize on the advantage of kicking first during five rounds or more.

Figures 2A and 2B report the unconditional scoring rates per round for the first five rounds, and the unconditional frequencies with which a given team (first or second) is ahead of its opponent in the score at the end of each of these rounds.

[Figures 2A and 2B here]

The scoring rate in the aggregate data is 73.1 percent, 76.3 percent for the first team and 69.7 percent for the second.[13] Figure 2A shows that it is always greater

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[13]These rates are lower than the average scoring rate in penalty kicks in the normal course of a game (that is, not in shoot-outs), which is about 80 percent, but similar to the scoring rate in games with a close score (a tie or a one goal difference) when there is little time left to play in the game (see, e.g., Ignacio Palacios-Huerta 2003). These lower rates may reflect the increased pressure associated with the fact that scoring a goal or not is a critical determinant of the final outcome both in a penalty shoot-out and in close games.

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for the first team than for the second team, and appears to decline in the later rounds. Figure 2B shows that the differences in scoring rates tend to make the first team more likely to be leading in the score than the second team at the end of every round. The difference between the teams is 7 percentage points in each of the first two rounds, which is not significant at conventional levels, and increases in magnitude in subsequent rounds to 12, 13 and 19 percentage points respectively, becoming statistically significant (at the 1 percent level). Interestingly, the relative frequency with which the first team leads in the partial score when one of the two teams is leading is around 60%, increasing slightly in the later rounds. These findings suggest that the detrimental effects on performance become more pronounced as the potential final rounds are approached.

Table 6 provides a more detailed description of both scoring probabilities and winning frequencies by team, round and partial score.

[Table 6 here]

Not surprisingly, most of the observations for the first team occur when the partial score is tied, and for the second team when it is lagging in the score. The scoring rate along these two paths of observations (columns 2 and 4) is nearly always higher for the first team than for the second. It also appears to drop over the rounds quite significantly for the second team but not for the first: for the second team it falls from about 75-80 percent in the first two rounds to about 62-66 percent in rounds 3 to 5, whereas for the first team it remains fairly stable in a range of 72-78 percent. The percentage of times with which the teams observed at every round-score combination eventually win the shoot-out reveals that the impact of scoring versus not scoring increases over the rounds for both teams. In round 1, for instance, the first team begins with a 60.2 percent chance of winning. If it scores, this probability increases 7.1 percentage points (to 67.3 = 100 - 32.7) and if it misses the probability drops 26.9 percentage points (to 33.3 = 100 - 66.7). The corresponding figures for round 5 are +17.6 and -35.7 percentage points, respectively. Thus, the cumulative impact of any scoring rate differentials over five rounds can be substantial. One way to capture the "importance" of a penalty kick is to compute the difference in these conditional probabilities relative to the ex ante probability of winning the shoot-out at that state. For instance, for the first team in round 1, the "Penalty Kick Importance"

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is simply $(67.3\text{-}33.3)/60.2 = 56.5$. It turns out that there is a slightly negative but insignificant correlation $\rho$ between the importance of a penalty kick and the scoring rate ($\rho = -0.008$, $p$-value $= 0.96$). Interestingly, however, the data also show that along the two most frequent paths of observations (columns 2 and 4) in nearly all the cases the importance is substantially greater for the second team than for the first team. The correlation between importance and performance just within this subset of observations is $\rho = -0.557$, $p$-value $= 0.06$.

Taken together, while the descriptive evidence just presented is at most suggestive of the mechanism that may generate the phenomenon we study, it shows substantial differences between the two teams: the second team has a lower scoring rate, especially in the later rounds, and typically finds itself kicking penalty kicks which have greater importance in terms of changes in probabilistic outcomes. In the next subsection we provide a more rigorous analysis of the dynamics of the tournament.

## C. Dynamic Panel Data Analysis

The outcome of a penalty kick (score, no score) in a shoot-out may depend on certain observed and unobserved characteristics of the teams and the penalty shoot-out, the specific sequence of past outcomes and the state of the tournament shoot-out. Not having a random assignment of any of these variables, we estimate a binary choice panel data model with lagged endogenous variables and unobserved heterogeneity. In particular, in order to appropriately control for the effect of state dependence in our setting, we estimate the semi-parametric dynamic random effects panel data model of Manuel Arellano and Raquel Carrasco (2003). These authors develop a consistent random effects estimator where: (a) explanatory variables are predetermined but not strictly exogenous, and where (b) individual effects are allowed to be correlated with the explanatory variables. In online Appendix A we describe this method, discuss its advantages over the alternatives available in the literature, and show how our short panel fits its identification requirements.[14] The results are collected in Table 7.

[Table 7 here]

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[14]The econometric estimation of these models is typically subject to a number of difficulties. For example, parameter estimates from short panels jointly estimated with individual fixed effects can be seriously biased and inconsistent. See Arellano and Bo Honoré (2001) for a review.

We find that the main determinant of the scoring rate is whether the team is lagging in the score: the variable "partial score -1" has a negative effect that is strongly significant at conventional levels, regardless of whether other endogenous variables relating to the state of the shoot-out are included or not. This means that lagging in the score hinders the performance of the subjects. Consequently, the team more likely to find itself with a partial score of -1 (by construction, the second kicking team) will have significantly greater chances of losing the tournament. We also find that this effect is mitigated if the kicking team is the one kicking in second place. This latter result is consistent with the intuition that, while a negative partial score is bad news, it is especially bad news for a team that has had exactly the same opportunities to score as its opponent (the first team to kick). With respect to the magnitude of the effects, Table 8 reports the marginal effects associated with different partial scores and different rounds.

[Table 8 here]

The results in Panel A show that the transition of a team from a partial score of 0 to +1 has a positive impact. For the team kicking first, the increase in the probability of scoring is around 1.50% per round for rounds 2 to 4, reaching 3.74% in the 5th round. The impact is, as expected, greater for the second team, and ranges from 2.35% to 3.55% for rounds 2 to 4. Moving a team from a partial score of 0 to -1 has a negative impact, whose magnitude in absolute value is greater for the team kicking first and lower for the team kicking second at any given round than in the case when we move a team from 0 to +1. Finally, since we are dealing with a two-agent zero-sum game, these marginal effects must be compounded in a zero-sum fashion (when one team goes from 0 to +1, the other team *must* go from 0 to -1) to gain a sense of their impact on a team's chances of winning the tournament. Consistent with the basic intuition from the raw data, this compounded effect is greater in rounds 4 and 5 than in the earlier rounds. For the decisive rounds, the marginal effect for the second team (the only one that exists in these rounds) is 6.98%. This effect is sizeable, although somewhat smaller than the compound effect in round 5.

In Panel B the marginal effects of kicking first rather than second net of other effects are positive, though small in magnitude, ranging from 0.26% to 1.37% for the first five rounds, and rising to 2.53% in the decisive rounds.

Finally, it is important to remark that a penalty kick involves two players: a kicker and a goalkeeper. Hence, it is theoretically possible to consider that it is not that the kicker's performance is hindered by a negative partial score, but rather that the goalkeeper's performance is enhanced when his team's partial score is positive. Although this is theoretically possible, in the survey presented earlier professional players systematically report that the effect is to put psychological pressure on the kicker. Not a single player mentions the possibility that the performance of the first team's goalkeeper may be enhanced when the partial score is in his favor. In addition, for a subset of all the penalty shoot-outs in the sample we have detailed information on whether the no-goals are due to "saves" by the goalkeeper or "misses" by the kicker. In online Appendix A we report the basic features of this subset of the data and the results of a multinomial logit specification with goals, misses and saves. The raw data show that both teams have basically the same proportion of saves, and hence that the difference in scoring rates between the first and the second team basically corresponds to their difference in misses. The logit regressions then show that lagging in the score predicts more misses by the kicker but predicts no more saves by the goalkeeper. Hence, these results are also consistent with the idea that the psychological effects may operate mainly through the kicker.[15]

## D. Policy Implications

We have found that in a dynamic competitive setting, when information on the performance of the competing agents is available or released in the interim periods or stages, the state of competition may have an impact on performance. Thus, these results highlight the role of performance information in competitive settings and also show that, in terms of the theory of optimal incentive provision, the timing of tasks can be important exclusively for psychological reasons: even when the order of the tasks is determined through a perfect randomized trial, the outcome can be ex-post unfair. One way to accomplish an ex-post fair outcome would be to require that the

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[15]When kickers miss the goal, the goalkeeper's performance is irrelevant and so he may perform worse (or better) under pressure. Since most penalties are scored, the upside for the goalkeeper is always greater but less likely than the downside. The opposite is the case for the kicker: his upside is smaller but more likely than the downside. Hence, a greater pressure on the kicker may be explained in terms of some form of probabilistic loss aversion, that is if losses are perceived disproportionally larger than gains. We are indebted to a referee for these suggestions.

agents perform their task simultaneously. Another would be to require that interim performance be only privately observed and not publicly. In our specific setting it may even be optimal to require that agents perform their task *before* the game starts.[16] In more general settings where other factors such as the choice of effort levels and risky strategies may play a role, it is entirely an empirical question how the psychological effects we have documented interact with decision-making processes and how they then jointly determine performance.[17] Hence, the results have implications for the merits of different incentive schemes and for the choice of performance information revelation rules. For instance, school officials can decide whether or not to reveal the scores of the students in each round of a contest; in political competitions, election commissions may design specific policies about the release of information regarding voting tendencies before the date of the election, and in competitions for promotion in internal labor markets principals may decide whether or not to reveal their (partial) assessment of the performance of workers before the competition is over.[18]

## V. Concluding Remarks

Nature seldom creates circumstances that allow a transparent view of psychological elements at work. And, when it does, the phenomena are typically too complex to clearly discern the impact of these elements on human behavior. The randomized experiment we have studied provides an unusual opportunity and involves highly incentivized professionals performing a simple, familiar task, in a real world strictly competitive situation.

The results provide support for a source of psychological pressure that has a detrimental effect on performance, and that is different from others such as high stakes,

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[16]We are indebted to a referee for this suggestion. Juan D. Carrillo (2007) shows that the timing of the shoot-out may affect the incentives to exert and allocate effort in the game, and that the attractiveness (appropriately defined) of the game could increase if the shoot-out would take place before rather than after the match is over. Although it is a priori unclear in which direction and to what extent the order of events might affect strategies, effort levels, and final outcomes, it is theoretically possible that changing the timing of the shoot-out might induce the winning and losing teams to adopt strategies that will make the shoot-out ex-post fair.

[17]Intuitively, subjects treated unfairly by the random draw of order would tend to fall behind and then react by exerting more effort and/or taking more risks than would otherwise do for precisely the same reasons as in the literature cited earlier (see footnote 2).

[18]In online Appendix B we provide a simple theoretical model that is consistent with the evidence we have presented. The model can be easily generalized to more general settings, and is also useful to study specific policy implications for penalty shoot-outs such as the optimal allocation of players when they are heterogeneous in quality.

social pressure or peer pressure previously documented in the literature. Since this is a source that is endogenous to the course of the competition, the results are relevant both from a theoretical and empirical perspective for competitive environments at large. In particular, R&D races, political elections, competitions for promotion within certain firms and organizations, student competitions in schools and others represent competitive settings that share some or all of the main characteristics of the setting we have studied: they are strictly competitive (zero-sum) situations and feedback information on performance and the state of competition is available to the participants during the competition. Whether or not psychological elements are important, or even critical, is entirely an empirical question. What the results in this paper indicate is that they are critical in the setting that we have studied, and hence that future theoretical and empirical research on dynamic competitive settings that incorporate psychological elements associated with the state of the competition may offer insights that otherwise would be lost.

Lastly, from the perspective of the recent behavioral economics literature, we find a significant and quantitatively important type of psychological effect not previously documented. From the perspective of rational choice theory, we find that individuals are aware of this effect and they rationally respond to it.

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TABLE 1– DESCRIPTION OF THE DATASET

| Competition | Type | 1970-2003 | | 2003-2008 | | All | All |
|---|---|---|---|---|---|---|---|
| | | Shoot-outs N | Kicks N | Shoot-outs N | Kicks N | Shoot-outs N | Kicks N |
| World Cup | National Teams | 16 | 153 | 4 | 33 | 20 | 186 |
| European Championship | National Teams | 9 | 97 | 4 | 42 | 13 | 139 |
| American Cup | National Teams | 12 | 116 | 3 | 31 | 15 | 147 |
| African Nations Cup | National Teams | 9 | 110 | 4 | 58 | 13 | 168 |
| Gold Cup | National Teams | 5 | 55 | 2 | 17 | 7 | 72 |
| Asian Nations Cup | National Teams | -- | -- | 7 | 74 | 7 | 74 |
| Champions League | Clubs | 8 | 82 | 13 | 127 | 21 | 209 |
| UEFA Cup | Clubs | 12 | 101 | 20 | 221 | 32 | 322 |
| Spanish Cup | Clubs | 29 | 308 | 26 | 259 | 55 | 567 |
| German Cups | Clubs | 24 | 273 | 48 | 521 | 72 | 794 |
| English Cups | Clubs | 5 | 48 | 9 | 94 | 14 | 142 |
| All | | 129 | 1,343 | 140 | 1,477 | 269 | 2,820 |

*Notes:* The dataset includes all the shoot-outs in the history of the World Cup, European Championship, American Cup, African Nations Cup (except one), and Gold Cup. All these are international competitions for national teams. The European Champions League and European UEFA Cup are international club competitions in Europe. For these two competitions the dataset includes all the shoot-outs that ever took place in the final match and all those that took place in any of the rounds in the period 2000-2008. The Spanish Cup, the German Cups, and the English Cups are national club competitions. For the Spanish Cup and the German Cup the data set has all the shoot-outs that took place in a final match, plus all the shoot-outs in all the rounds in the period 1999-2008 (Spanish Cup) and in the period 2001-2008 (German Cup). For the German Supercup it includes all those that ever took place. The English Cups include data on the F.A. Cup, League Cup and the F.A. Community Shield.

## TABLE 2– PRE-TREATMENT CHARACTERISTICS

| Criterion | N | First Team | Second Team | Difference |
|---|---|---|---|---|
| FIFA rankings | 35 | 0.46 | 0.54 | -0.08 |
| | | (0.50) | (0.50) | (1.01) |
| UEFA rankings | 20 | 0.35 | 0.65 | -0.30 |
| | | (0.49) | (0.49) | (0.99) |
| Category | 58 | 0.50 | 0.50 | 0.00 |
| | | (0.35) | (0.35) | (0.70) |
| Position (when same category) | 30 | 0.4 | 0.6 | -0.20 |
| | | (0.50) | (0.50) | (0.996) |
| Experience | 128 | 0.48 | 0.52 | -0.03 |
| | | (0.32) | (0.32) | (0.65) |
| Home team | 82 | 0.57 | 0.43 | 0.14 |

*Notes:* FIFA publishes ranks on national teams since 1993. The UEFA ranking applies to international club team competitions (Champions League and UEFA Cup), and it is published since 1959. Teams taking part in national cup competitions--Spanish Cup, German Cups, and English Cups--may or may not belong to the same category (division) in the national league competition. If they belong to the same one, we consider their standings ("Position") in the league table at the time of the shoot-out. Experience refers to the number of previous shoot-outs in which a team has participated in which we observe in our dataset. The table reports the proportion of times in which each team shows a better entry in the respective criterion (=1 if higher, =0 if lower, =.5 if same). Home team equals 1 if the team plays in its own stadium. Std. deviations in parentheses.

# TABLE 3– DETERMINANTS OF WINNING THE TOURNAMENT

|  | Probit | Probit | Probit | Logit | Logit | Logit |
|---|---|---|---|---|---|---|
| Constant | -0.265** | -0.275 | -0.263 | -0.424** | -0.441 | -0.421 |
|  | (0.111) | (0.197) | (0.436) | (0.180) | (0.320) | (0.708) |
| **Team kicks first** | **0.530\*\*\*** | **0.645\*\*\*** | **0.629\*\*\*** | **0.849\*\*\*** | **1.035\*\*\*** | **1.009\*\*\*** |
|  | (0.158) | (0.171) | (0.172) | (0.254) | (0.278) | (0.278) |
| Home field |  | -0.087 | -0.110 |  | -0.1421 | -0.178 |
|  |  | (0.208) | (0.209) |  | (0.337) | (0.338) |
| Neutral field |  | -0.043 | -0.055 |  | -0.070 | -0.089 |
|  |  | (0.250) | (0.274) |  | (0.399) | (0.434) |
| Category (1 if higher) |  | -0.008 | 0.008 |  | -0.012 | 0.014 |
|  |  | (0.171) | (0.172) |  | (0.277) | (0.278) |
| Home x Category |  |  | 0.000 |  |  | 0.001 |
|  |  |  | (0.255) |  |  | (0.406) |
| Neutral x  Category |  |  | 0.001 |  |  | 0.004 |
|  |  |  | (0.072) |  |  | (0.186) |
| *Team kicks first Interacted with:* |  |  |  |  |  |  |
| Home field |  |  | 0.002 |  |  | 0.005 |
|  |  |  | (0.569) |  |  | (0.928) |
| Neutral field |  |  | 7.89e-05 |  |  | -6.2e-06 |
|  |  |  | (0.508) |  |  | (0.817) |
| Category |  |  | 0.030 |  |  | 0.0001 |
|  |  |  | (0.536) |  |  | (0.876) |
| <u>Fixed effects for:</u> |  |  |  |  |  |  |
| Champions League | No | No | Yes | No | No | Yes |
| UEFA Cup | No | No | Yes | No | No | Yes |
| National Teams | No | No | Yes | No | No | Yes |
| National Cups | No | No | Yes | No | No | Yes |
| *N* (teams) | 258 | 224 | 224 | 258 | 224 | 224 |
| Adjusted R$^2$ | 0.031 | 0.046 | 0.048 | 0.031 | 0.046 | 0.048 |
| Log-Likelihood | -173.14 | -148.10 | -147.10 | -173.14 | -148.10 | -147.10 |

*Note:* Missing observations for "Category" for 17 shoot-outs. Standard errors in parentheses.
    *** Significant at the 1 percent level.
     ** Significant at the 5 percent level.

# TABLE 4– SURVEY RESULTS

The following questions were asked to soccer coaches and players:

Q1: "Assume you are playing a penalty shoot-out. You win the coin toss and have to choose whether to kick first or second. What would you choose: first; second; either one, I am indifferent; or, it depends?"

| | Observations | First | Second | Indifferent | Depends |
|---|---|---|---|---|---|
| **Coaches:** | | | | | |
| Professional | 21 | 90.5% | 0 | 0 | 9.5% |
| Amateur | 37 | 94.6% | 0 | 0 | 5.4% |
| **Players:** | | | | | |
| Professional | 67 | 97.0% | 0 | 1.5% | 1.5% |
| Amateur | 117 | 96.5% | 0 | 2.5% | 1.0% |
| All: | 242 | 95.9% | 0 | 1.6% | 2.5% |

Q2: "Please explain your decision. Why would you do what you just said?"

*Notes:* Professional coaches and players come from the professional leagues in Spain (Primera Division and 2A and 2B Divisions). Amateur coaches and players come from Division 3 and Regional Leagues in Spain. The four coaches that answered "Depends," further explained that they would let their players choose what they preferred to do.

## TABLE 5– OBSERVATIONS BY ROUND AND WINNING RATES

| Round | Number of Shoot-outs | | If decided, percentage in which the | |
| --- | --- | --- | --- | --- |
| | | | first team | second team |
| Regular rounds | Observed | Decided | wins | wins |
| Round 1 | 128 | 0 | - | - |
| Round 2 | 128 | 0 | - | - |
| Round 3 | 128 | 1 | 100 | 0 |
| Round 4 | 127 | 30 | 76.6 | 23.3 |
| Round 5 | 97 | 63 | 60.3 | 39.7 |
| | Total decided: | 94 | 65.9 | 34.1 |
| Decisive rounds | | | | |
| Round 6 | 34 | 18 | 38.8 | 61.2 |
| Round 7 | 16 | 4 | 75.0 | 25.0 |
| Round 8 | 12 | 5 | 80.0 | 20.0 |
| Round 9 | 7 | 1 | 0 | 100 |
| Round 10 | 6 | 3 | 100 | 0 |
| Round 11 | 3 | 1 | 0 | 100 |
| Round 12 | 2 | 2 | 50.0 | 50.0 |
| | Total decided: | 34 | 52.9 | 47.1 |
| All rounds | Total decided: | 128 | 60.2 | 39.5 |

*Notes:* We are missing the round by round data of one shoot-out which was won by the first team in five rounds.

## TABLE 6– SCORING PROBABILITIES AND WINNING FREQUENCIES BY TEAM, ROUND AND PARTIAL SCORE

| | First Team | | | Second Team | | |
|---|---|---|---|---|---|---|
| | Behind | Even | Ahead | Behind | Even | Ahead |
| **Round 1** | | | | | | |
| Scoring Probability | - | 78.9 | - | 75.2 | 59.3 | - |
| Percent Win Shoot-out | - | 60.2 | - | 32.7 | 66.7 | - |
| Penalty Kick Importance | | 56.5 | | 93.4 | 39.3 | |
| $N$ | - | 128 | - | 101 | 27 | - |
| **Round 2** | | | | | | |
| Scoring Probability | 100 | 74.7 | 96.0 | 82.2 | 65.8 | - |
| Percent Win Shoot-out | 31.3 | 57.5 | 88.0 | 32.2 | 57.9 | - |
| Penalty Kick Importance | -- | 32.2 | 30.6 | 62.7 | 61.2 | |
| $N$ | 16 | 87 | 25 | 90 | 38 | 0 |
| **Round 3** | | | | | | |
| Scoring Probability | 80.0 | 76.8 | 76.5 | 63.2 | 69.4 | 40.0 |
| Percent Win Shoot-out | 24.0 | 59.4 | 88.2 | 23 | 72.2 | 100 |
| Penalty Kick Importance | 115.7 | 67.3 | 21.9 | 62.7 | 66.4 | 14.3 |
| $N$ | 25 | 69 | 34 | 87 | 36 | 5 |
| **Round 4** | | | | | | |
| Scoring Probability | 76.7 | 71.7 | 75.0 | 66.2 | 69.4 | 77.8 |
| Percent Win Shoot-out | 13.3 | 62.3 | 88.6 | 21.1 | 75.0 | 100 |
| Penalty Kick Importance | 150.0 | 68.2 | 19.8 | 125.1 | 50.1 | 14.8 |
| $N$ | 30 | 53 | 44 | 71 | 36 | 9 |
| **Round 5** | | | | | | |
| Scoring Probability | 74.1 | 76.2 | 71.4 | 62.5 | 70.0 | - |
| Percent Win Shoot-out | 14.8 | 52.4 | 96.4 | 30.0 | 83.3 | - |
| Penalty Kick Importance | 112.5 | 101.8 | 31.1 | 156.9 | 63.5 | |
| $N$ | 27 | 42 | 28 | 40 | 30 | - |
| **Rounds 6+** | | | | | | |
| Scoring Probability | - | 67.5 | - | 68.5 | 65.4 | - |
| Percent Win Shoot-out | - | 58.8 | - | 24.1 | 76.9 | - |
| Penalty Kick Importance | | 90.0 | | 153.5 | 84.7 | |
| $N$ | - | 80 | - | 54 | 26 | - |

*Notes:* For each team-score-round situation, the "Scoring Probability" is the percentage of teams that scored a goal in that situation, "Percent Win Shoot-out" is the percentage of teams observed in that situation that *eventually* won the shoot-out, and "Penalty Kick Importance" is the probability of winning the shoot-out when the penalty kick is scored minus the probability when it is not scored divided by the probability of winning the shoot-out (that is, by "Percent Win Shoot-out"). $N$ is the number of observations. In Rounds 6+ $N$ is computed as the sum of the number of teams that in rounds 6 and beyond are observed at a given partial score. That is, since the first team can be observed in various rounds with an even partial score and the second team can be observed in various rounds with the same or different (behind and even) score, the same team may be observed at multiple occasions. The scoring probabilities and the percentage of teams that win the shoot-out are computed using these as the number of observations for these rounds. We are missing the round by round data in one shoot-out.

## TABLE 7– RANDOM EFFECTS DYNAMIC PANEL DATA MODEL

|  | [1] | [2] | [3] |
|---|---|---|---|
| Constant | 0.95*** | 0.87*** | 0.82*** |
|  | (6.77) | (3.03) | (2.92) |
| Lagged penalty outcome | -0.27 | -0.25 | 0.10 |
|  | (1.02) | (1.12) | (0.93) |
| Partial Score +1 | 0.98 | 0.67 | 1.77 |
|  | (1.23) | (0.50) | (0.82) |
| Partial Score 0 | 2.34 | 1.44 | 1.25 |
|  | (0.45) | (0.53) | (0.45) |
| **Partial Score -1** | **-0.21*** | **-0.17*** | **-0.14*** |
|  | (5.21) | (3.18) | (3.19) |
| Second Team |  | -0.04** | -0.02 |
|  |  | (1.70) | (1.60) |
| Partial Score -1 x Second Team |  | 0.02** | 0.02** |
|  |  | (1.65) | (1.68) |
| Penalty Kick Importance |  | -0.23 | -0.09 |
|  |  | (1.10) | (1.18) |
| Potential Winner Penalty Kick |  | -0.94 | -0.03 |
|  |  | (1.03) | (1.09) |
| Potential Loser Penalty Kick |  | -0.88 | -0.53 |
|  |  | (1.05) | (1.20) |
| International Competition | -0.03 | 0.44 | -0.01 |
|  | (0.38) | (0.27) | (0.32) |
| Final match | -1.20 | -0.05* | -0.06 |
|  | (0.99) | (1.32) | (1.07) |
| Semifinal match | -0.23 | -0.33 | -0.42 |
|  | (0.19) | (0.09) | (0.08) |
| Field Fixed Effects | Yes | Yes | Yes |
| Round Fixed Effects | Yes | Yes | Yes |
| Goalkeeper Fixed Effects | No | No | Yes |
| Competition Type Fixed Effects | No | No | Yes |

*Notes:* The endogenous variable equals 1 if the penalty is scored and 0 otherwise. "Partial Score X" are dummy variables for penalties where the score from the perspective of the kicking team is X at the time of kicking. "Potential Winner Penalty Kick" and "Potential Loser Penalty Kick" are dummy variables for penalty kicks which if scored or missed mean that the shoot-out will be won or lost respectively. Field fixed effects refer to home field, neutral field or opponent's home team field. The sample has 1,343 individual penalty kick observations. Absolute, choice–biased sampling, heteroskedastic–consistent, *t*–statistics are reported in parentheses. The model is estimated by GMM.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

## TABLE 8– MARGINAL EFFECTS

*Panel A: Partial Score*

|  | Round 1 | Round 2 | Round 3 | Round 4 | Round 5 | Round 6+ |
|---|---|---|---|---|---|---|
| **From 0 to 1:** | | | | | | |
| First team | - | 1.46% | 1.63% | 1.41% | 3.74% | - |
| Second team | - | 2.35% | 2.50% | 3.55% | - | - |
| | | | | | | |
| **From 0 to -1:** | | | | | | |
| First team | - | -1.73% | -2.17% | -3.85% | -5.82% | - |
| Second team | -3.12% | -0.39% | -1.42% | -2.35% | -4.46% | -6.88% |

*Panel B: Kicking First instead of Kicking Second*

| Round 1 | Round 2 | Round 3 | Round 4 | Round 5 | Round 6+ |
|---|---|---|---|---|---|
| 0.26% | 0.35% | 0.57% | 1.05% | 1.37% | 2.53% |

*Notes:* These marginal effects represent the percentage change in the probability of scoring conditional on each transition among states $i$ to $j$. In Panel A, the states are partial scores; the current state is represented by $i = 0$ at a given round, and $j = +1, -1$. In Panel B, the state is the kicking order and current state is represented by kicking second. These effects are computed from specification [3] in Table 7.
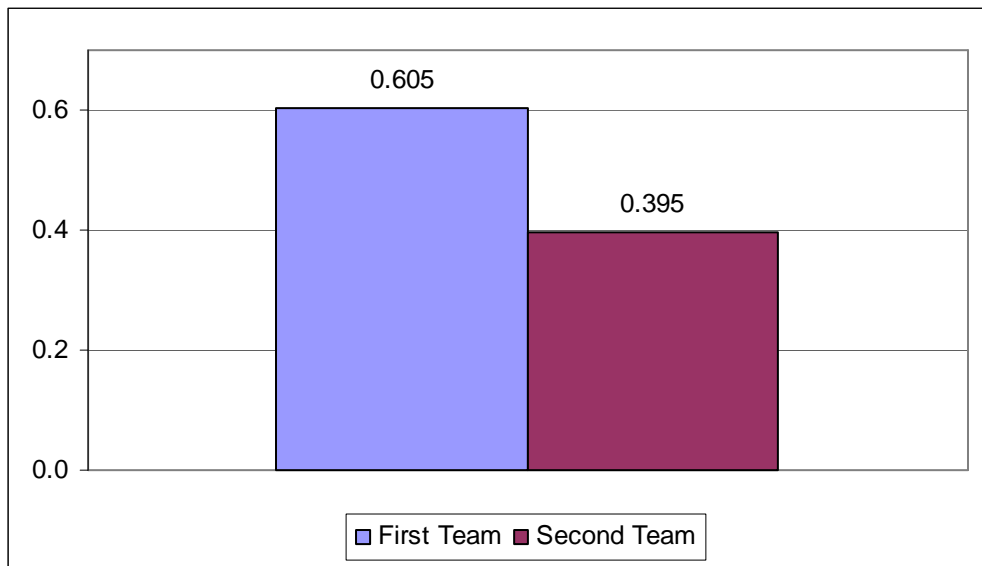
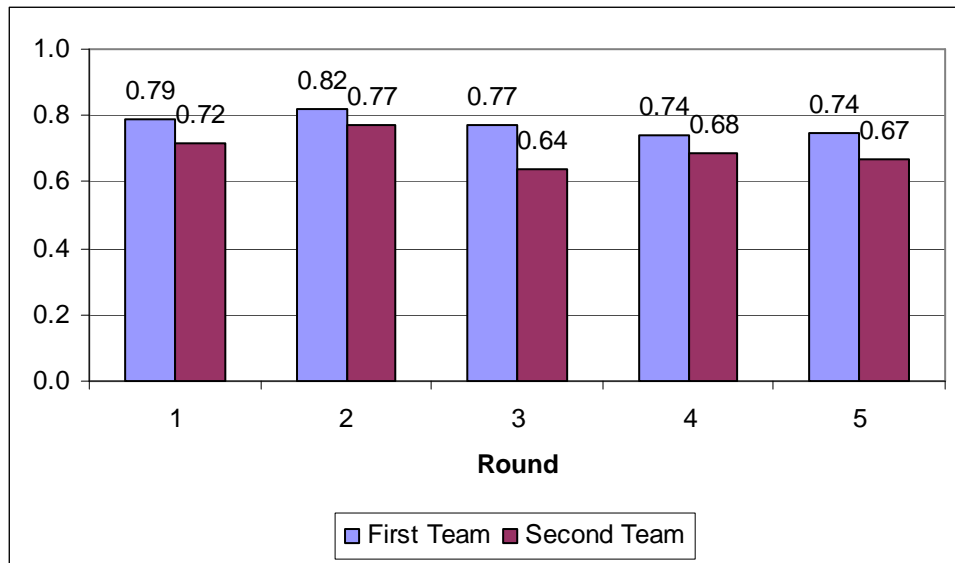FIGURE 1. WINNING FREQUENCIES IN AGGREGATE DATA

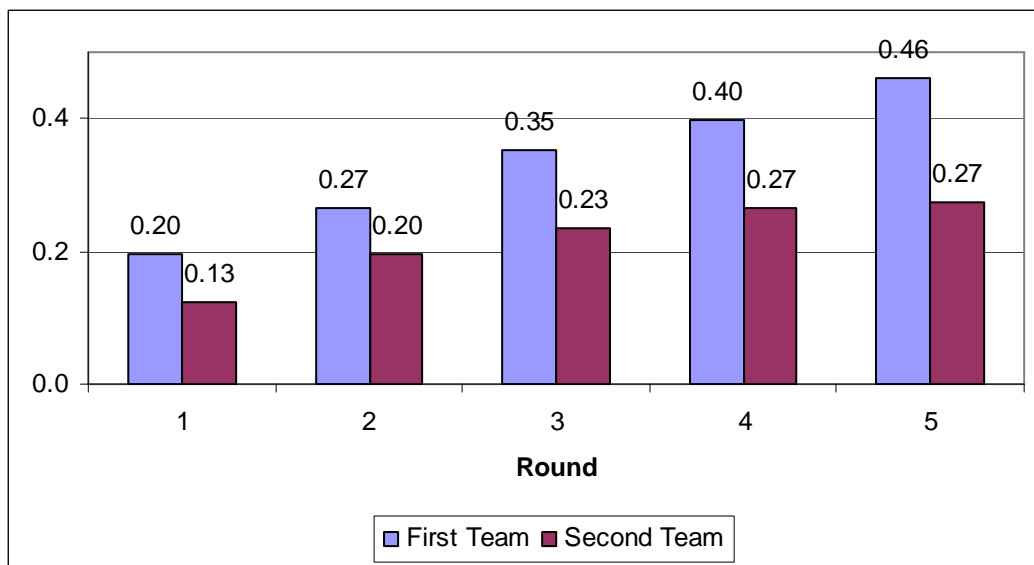FIGURE 2A. SCORING PROBABILITIES PER ROUND



FIGURE 2B. FREQUENCY WITH WHICH A TEAM LEADS
IN THE SCORE AT THE END OF A ROUND

*Notes:* If before both teams have taken five penalty kicks, one has score more goals than the other could possibly score even if it were to complete its five kicks, no more kicks are taken. The percentage of times in which a team is leading in the score at the end of a round in Figure 2B includes these cases, that is, cases in which the shoot-out already ended before this round, whereas in Figure 2A the scoring rate is only computed for the teams that are observed to kick in the corresponding round.

# WEB APPENDICES
## for
## "Psychological Pressure in Competitive Environments: Evidence from a Randomized Natural Experiment"

September 2009

**Table of Contents**

1

**APPENDIX A. Dynamic Panel Data Analysis with Lagged Endogenous Variables.**

As is well known, in the presence of lagged endogenous variables in linear models with additive effects the standard response is to consider instrumental-variables estimates which exploit the lack of correlation between lagged values of the variables and future errors in first differences. In non-linear models, however, very few results are available.[1] In this appendix we describe the Manuel Arellano and Raquel Carrasco (2003) model and how it is applied to the setting we study. We also report the results of the multinomial logit analysis applied to the penalty shoot-outs for which we have data on "goals," "misses" and "saves."

The basic idea of the Arellano-Carrasco model is to define conditional probabilities for every possible sequence of realizations of the state variables. Then, the estimator computes the probability of a given outcome along every possible path of past realizations of the endogenous regressors. The panel data structure allows the identification of the effect of individual unobserved heterogeneity since outcomes can be different even when teams share the same history of realizations of the state variables.

Consider two discrete outcomes (score, no score) denoted $y_{it} = \{1, 0\}$. The probability of each of them depends on the specific sequence of past outcomes and the state of the shoot-out tournament. Since outcomes can be different, different experiences change the information set and the expected realizations of future outcomes. To be more specific, the probability of a given outcome may depend on certain intrinsic characteristics of the teams involved in the shoot-out, as well as on their expectation on the realization of the final outcome. This can be written as follows:

$$y_{it} = \mathbf{1}\left\{\beta z_{it} + E\left(\eta_i \mid w_i^t\right) + \varepsilon_{it} \geq 0\right\},$$

$$\varepsilon_{it} \mid w_i^t \sim N\left(0, \sigma_t^2\right),$$

where $z_{it}$ includes the set of time–invariant characteristics of the teams and the shoot-out, $x_{it}$, plus the state of the shoot-out and the previous outcomes $y_{i(t-1)}$. Denote

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[1]For fixed effects the few available methods are case-specific (logit and Poisson) and, in practice, lead to estimators that do not converge at the usual $\sqrt{n}$-rate. In the case of random effects, the main difficulty is the so-called initial conditions problem: if one begins to observe subjects after the "process" in question is already in progress, it is necessary to isolate the effect of the first lagged dependent variable from the individual-specific effect and the distribution of the explanatory variables prior to the sample.

by $w_i^t = \{w_{i1}, \ldots, w_{it}\}$ the history represented by a sequence of realizations $w_{it} = \{x_{it}, y_{i(t-1)}\}$, and by $\eta_i$ an individual effect (future outcome realization for team $i$) whose forecast is revised each period $t$ as the information summarized by the history $w_i^t$ accumulates.[2] The conditional distribution of the sequence of expectations $E\left(\eta_i \mid w_i^t\right)$ is left unrestricted, and hence the process of updating expectations as information accumulates is not explicitly modeled. This is the only aspect that makes the model semi–parametric. Given the history of past outcomes, since errors are normally distributed, the conditional probability of $y_{it} = 1$ at time $t$ for any given history $w_i^t$ is:

$$\Pr\left(y_{it} = 1 \mid w_i^t\right) = \Phi\left[\frac{\beta z_{it} + E\left(\eta_i \mid w_i^t\right)}{\sigma_t}\right].$$

Since the model has discrete support, any individual history can be summarized by a cluster of nodes $j = 1, \ldots, J$ representing the sequence of realizations for each vector of characteristics. Thus, the conditional probability can be rewritten as:

$$p_{jt} = \Pr\left(y_{it} = 1 \mid w_i^t = \phi_j^t\right) \equiv h_t\left(w_i^t = \phi_j^t\right), \qquad j = 1, \ldots, J.$$

The estimation relies on an intuitive idea. In order to remove the unobserved individual effect, we account for the proportion of teams with identical characteristics and history up to time $t$ that realize a given outcome at time $t$. We then repeat this procedure for every cluster of combinations of demographics and histories in our data. For each cluster we compute the percentage of times that outcome $y_{it} = 1$ occurs. This provides a simple estimate of the unrestricted probability $\hat{p}_{jt}$ for each possible history in the sample. Then, by taking first differences of the inverse of the equation above we get:

$$\sigma_t \Phi^{-1}\left[h_t\left(w_i^t\right)\right] - \sigma_{t-1} \Phi^{-1}\left[h_{t-1}\left(w_i^{t-1}\right)\right] - \beta\left(x_{it} - x_{i(t-1)}\right) = \xi_{it},$$

and, by the law of iterated expectations, we have:

$$E\left[\xi_{it} \mid w_i^{t-1}\right] = E\left[E\left(\eta_i \mid w_i^t\right) - E\left(\eta_i \mid w_i^{t-1}\right) \mid w_i^{t-1}\right] = 0.$$

This conditional moment condition serves as the basis of the GMM estimation of parameters $\beta$ and $\sigma_t$ (subject to the normalization restriction that $\sigma_1 = 1$). Arellano

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[2]The specification of Arellano and Carrasco (2003) is more general in the sense that it also includes a time-varying component, $\gamma_t$, common to all individuals. In our case all "demographic" variables are time–invariant.

and Carrasco (2003) show that there is no efficiency loss in estimating these parameters by a two–step GMM method where in the first step the conditional probabilities $p_{jt}$ are replaced by unrestricted estimates $\hat{p}_{jt}$, which in our case are the proportion of teams with given characteristics and a given history. Then:

$$\hat{h}_t\left(w_i^t\right) = \sum_{j=1}^{J} \mathbf{1}\left\{w_i^t = \phi_j^t\right\} \cdot \hat{p}_{jt},$$

can be used to define the sample orthogonality conditions of Arellano–Carrasco's GMM estimator:[3]

$$\frac{1}{N}\sum_{i=1}^{N} d_{it}\left\{\sigma_t \Phi^{-1}\left[\hat{h}_t\left(w_i^t\right)\right] - \sigma_{t-1}\Phi^{-1}\left[\hat{h}_{t-1}\left(w_i^{t-1}\right)\right] - \beta\left(x_{it} - x_{i(t-1)}\right)\right\} = 0, \quad t = 2,\ldots,T,$$

where $d_{it}$ is a vector containing the indicators $\mathbf{1}\left\{w_i^t = \phi_j^t\right\}$ for $j = 1,\ldots,J$.

With respect to the magnitude of the effects, the marginal effects associated with the transition among different states can be computed as follows. Arellano and Carrasco (2003) show that the probability of a given outcome when we compare two states $z_{it} = z^0$ and $z_{it} = z^1$ changes by the proportion:

$$\hat{\triangle}_t = \frac{1}{N}\sum_{i=1}^{N}\left\{\Phi\left(\hat{\sigma}_t^{-1}\hat{\beta}\left(z^1 - z_{it}\right) + \Phi^{-1}\left[\hat{h}_t\left(w_i^t\right)\right]\right) - \Phi\left(\hat{\sigma}_t^{-1}\hat{\beta}\left(z^0 - z_{it}\right) + \Phi^{-1}\left[\hat{h}_t\left(w_i^t\right)\right]\right)\right\}.$$

Since this proportion depends on the history of past $\omega_i^t$, these marginal effects are different for each partial score in the sample, and for each team.

Finally, a reason why the Arellano-Carrasco is preferred in our setting is that alternative fixed-effects approaches such as Bo Honoré and Arthur Lewbel (2002) and Honoré and Ekaterini Kyriazidou (2000) are far more demanding in terms of data. In particular, they require the exogenous regressors to vary over time, something that does not occur in our data. Honoré and Kyriazidou (2000) include one lagged dependent variable but require that the remaining explanatory variables should be strictly exogenous, thus excluding the possibility of a lagged dependent regressor. Further, their estimator does not converge at the usual $\sqrt{n}$–rate. Honoré and Lewbel (2002)

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[3]We use the orthogonal deviations suggested by Arellano and Olympia Bover (1995) instead of first differences among past values of the state variables.

allow for additional predetermined variables but at the cost of requiring a continuous, strictly exogenous, explanatory variable that is independent of the individual effects. See Ivan Fernandez-Val (2009) for a characterization of the bias of fixed effect estimators in non-linear panel data models.

Finally, as indicated in the main text of the article, for a subset of all the penalty shoot-outs in the sample we have detailed information on whether the no-goals are due to "saves" by the goalkeeper or "misses" by the kicker. Table A1 reports the results of a multinomial logit specification with goals, misses and saves using these data.

[Table A1 here]

Panel A reports the raw data in scoring, misses and saving rates for the first and second team. We find that both teams have basically the same proportion of saves, and hence that the difference in scoring rates between the first and the second team basically corresponds to their difference in misses.

In Panel B we report the results of different regression specifications. We find that the coefficient on "Partial score -1" is positive and highly significant (beyond the 1 percent level) for misses, but insignificant for saves in all the specifications. This means that lagging in the score predicts more misses by the kicker but no more saves by the goalkeeper. The interaction with the "Second team" variable is negative and significant, which means that when the partial score is -1 the first kicking team is more likely to miss. This, as in Table 7, is likely the result of being in an objectively worse situation than the second team (it has had the same number of chances of scoring, whereas, at every kick, the second team has always had one less chance). No variable except the constant term is significant for saves. The variable "Penalty Kick Importance," although not significant at the conventional significance levels, has a fairly high $t$-statistic for misses.

We take these results as consistent with the idea that the decrease in the scoring rate for the second team, which is the one more likely to be behind in the partial score, can be mainly attributed to an increase in misses by the kicker rather than to an increase in saves by the goalkeeper of the opposing team.

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## APPENDIX B. A Theoretical Framework

In this appendix we study a simple model that is consistent with the empirical evidence, *always* predicts a first-mover advantage, and relies on a reference point associated with the partial score (score at the time of kicking). After the presentation of the model, various extensions are discussed.

Let $(s, r)$, with $s \in \mathbb{Z}$, $r \geq 1$, denote the *score at the end of a round* $r$. The score measures the difference in goals between the team that kicks first $F$ and the one that kicks second $D$. A round involves one penalty kick for $F$ and one for $D$. The total number of rounds is $n$. The *partial score* for a team $\alpha \in \{F, D\}$ in round $r$ is the difference between the goals scored by $\alpha$ and those scored by the opponent, immediately before team $\alpha$ is about to take its penalty kick in round $r$. That is, for team $F$ the partial score at $r$ is $(s, r - 1)$, while, for team $D$, it is $(-s - x, r - 1)$, where $x = 1$ if $F$ scores in round $r$ and $x = 0$ otherwise. In what follows we will use the terms team and player indistinctly.

Denote by $p \in [0, 1]$ the probability of player $\alpha$ scoring a goal when the partial score is tied or positive for him, and by $q \in [0, 1]$ the probability of player $\alpha$ scoring a goal when he is behind in the partial score by at least one goal. Under psychological pressure $p > q$, while under no psychological pressure $p = q$.

For any given $(s, r)$ with $r < n$ there are exactly four possible outcomes at the end of round $r$: (i) both players score a goal, (ii) the first scores and the second fails, (iii) the first fails and the second scores, and (iv) both fail. The probability vectors associated to these outcomes depend on $(s, r)$. There are three possible cases:

1. If $s = 0$, then $(p \cdot q, p(1 - q), (1 - p)p, (1 - p)^2)$;

2. If $s > 0$, then $(p \cdot q, p(1 - q), (1 - p)q, (1 - p)(1 - q))$;

3. If $s < 0$, then $(q \cdot p, q(1 - p), (1 - q)p, (1 - q)(1 - p))$.

To simplify notation we write $a = p \cdot q$, $b = p(1 - q)$, $c = (1 - p)p$, $d = (1 - p)^2$, $e = (1 - p)q$, and $f = (1 - p)(1 - q)$. The above defines a Markov chain. Since we are interested in rank-order tournaments, we need to refine the notion of maximum and minimum scores. If $n$ is even, the maximum and minimum scores are $\frac{n}{2} + 1$ and $-(\frac{n}{2} + 1)$, while if $n$ is odd the maximum and minimum scores are $\frac{n+1}{2}$ and $-(\frac{n+1}{2})$. The

state space is formed by all possible scores $S = \{s_{max}, s_{max}-1, \ldots, -1, 0, 1, \ldots, s_{min}-1, s_{min}\}$ with $s_{max}$ and $s_{min}$ defined as above. Typical elements of $S$ are denoted by $s, t$ or $s_0, s_1, \ldots, s_n$. The transition matrix $P$ follows from the single-step transition probabilities $p_{st}$:

$$p_{00} = a + d; \; p_{01} = b; \; p_{0,-1} = c$$

$$s \in \{s_{min}, s_{max}\}, \; p_{ss} = 1$$

$$s \in S \setminus \{0, s_{min}, s_{max}\}, \; p_{ss} = a + f$$

$$s \in S \setminus \{0, s_{min}, s_{max}\}, \; p_{s,s+1} = p_{-s,-s-1} = b$$

$$s \in S \setminus \{0, s_{min}, s_{max}\}, \; p_{s,s-1} = p_{-s,-s+1} = e$$

and $p_{st} = 0$ otherwise. The initial distribution $\mu$ puts all the probability mass in state 0. Denote by $T(n, P)$ the $n$-round sequential tournament between $F$ and $D$ with transition matrix $P$. Denote by $p_{st}^{(n)}$ the $(s, t)$ entry in the $n$-th power of the transition matrix $P$. Since the Markov chain is stationary, $p_{st}^{(n)}$ represents the probability of reaching state $t$ starting from state $s$ in $n$ rounds.

The probability that team $F$ wins the $n$-round sequential tournament $T(n, P)$ is:

$$W(F, n) = \sum_{s=1}^{s=s_{max}} P(s, n),$$

with $P(s, n)$ denoting the probability of a final score $s$. To calculate $P(s, n)$ we have to correct for the probability of reaching a *final state* in some previous round. A final state is a pair $(s, r)$ where there is no possibility of turning around the sign of the score $s$ in the remaining time $n - r$. Then we have that:

$$P(1, n) = p_{01}^{(n)} - p_{02}^{(n-1)} p_{21},$$

$$P(s_{max}, n) = p_{0,s_{max}-1}^{(n+1-s_{max})} p_{s_{max}-1,s_{max}} + p_{0s_{max}}^{(n+1-s_{max})},$$

and for $1 < s < s_{max}$ :

$$P(s, n) = p_{0,s-1}^{(n+1-s)} p_{s-1,s} + p_{0s}^{(n+1-s)} - p_{0,s+1}^{(n-s)} p_{s+1,s}.$$

In principle, these probabilities can be obtained using standard matrix algebra. The probability of team $D$ winning at the end of the $n$-round contest $W(D, n)$ is obtained analogously.

Denote by $W(\alpha, r)$ the probability that $\alpha$ is either ahead of its opponent at the end of round $r \le n$ or has already won the tournament by then. We are now ready to derive convenient formulations for $W(F, r)$ and $W(D, r)$.

**Proposition 1**. Let $T(n, P)$ be an $n$-round sequential tournament. Then, for every $r \le n$, $W(F, r) = \frac{b}{b+c}(1 - p_{00}^{(r)})$ and $W(D, r) = \frac{c}{b+c}(1 - p_{00}^{(r)})$.

***Proof:*** Take any path ending in state $s > 0$ in round $r$, and denote it by $s_0 s_1 \cdots s_{r-1} s_r$ with $s_0 = 0$ and $s_r = s$. The probability measure of such path is $p_{s_0 s_1} \cdots p_{s_{r-1}, s_r}$. We distinguish two cases:

(1) First, the path $s_0 s_1 \cdots s_{r-1} s_r$ does not reach a final state $s'$ in some previous round $h < r$. We construct a unique symmetric path to the original one, ending in state $-s$. If $s_{r-1} = 0$, stop. Otherwise, proceed backwards until reaching a $k$, $0 \le k \le r-1$, such that $s_k = 0$. Clearly, such a $k$ exists. Then, for every $l \ge k$ write $s'_l = -s_l$, and write $s'_l = s_l$ otherwise. It is immediate that the constructed path $s'_0 s'_1 \cdots s'_{r-1} s'_r$ starts with $s'_0 = 0$, ends in $s'_r = -s$, does not go through any final state, and has an associated probability measure of $p_{s'_0 s'_1} \cdots p_{s'_{r-1}, s'_r}$, where $p_{s'_l, s'_{l+1}} = p_{s_l, s_{l+1}}$ for every $l \ne k$, while $b = p_{s_k, s_{k+1}} \ge p_{s'_k, s'_{k+1}} = c$. That is, the difference in the probability measures between the two paths is $(b - c) p_{s_0 s_1} \cdots p_{s_{k-1}, s_k} p_{s_{k+1}, s_{k+2}} \cdots p_{s_{r-1}, s_r}$.

(2) Second, the path $s_0 s_1 \cdots s_{r-1} s_r$ does reach a final state $s'$ in a previous round $h < r$. First, we modify the path $s_0 s_1 \cdots s_{r-1} s_r$ to correct for the sub-path following the final state $s'$ by writing $s_h = s_{h+1} = \cdots = s_{r-1} = s_r = s'$, with associated probability measure $\bar{p}_{s_l, s_{l+1}} = p_{s_l, s_{l+1}}$ whenever $s_l \le h - 1$, and $\bar{p}_{s_l, s_{l+1}} = 1$ whenever $s_l > h - 1$. Second, we apply the same argument as before to the modified path to show that there exists a unique symmetric path ending in final state $-s'$, and where the difference in the probability measures between the two paths is $(b - c) \bar{p}_{s_0 s_1} \cdots \bar{p}_{s_{k-1}, s_k} \bar{p}_{s_{k+1}, s_{k+2}} \cdots \bar{p}_{s_{r-1}, s_r}$.

Consequently, it is immediate that there exists a probability mass $\gamma(r)$ such that $W(A, r) = b\gamma(r)$ and $W(B, r) = c\gamma(r)$. Note that by definition of final states, $p_{00}^{(r)}$ does not reach any final state in some previous round $h \le r$. Now since $W(A, r) + W(B, r) + p_{00}^{(r)} = 1$, it follows that $\gamma(r) = \frac{1}{b+c}(1 - p_{00}^{(r)})$, and hence $W(A, r) = \frac{b}{b+c}(1 - p_{00}^{(r)})$ and $W(B, r) = \frac{c}{b+c}(1 - p_{00}^{(r)})$. $\square$

Since under no psychological pressure $p = q$ implies $b = c$, it directly follows from

Proposition 1 that $W(F,n) = W(D,n)$. On the other hand, under psychological pressure, that is when $p > q$, we have that $b > c$, and hence Proposition 1 implies that $W(F,n) > W(D,n)$. We summarize the above in the following corollary:

**Corollary.** Let $T(n,P)$ be an $n$-round sequential tournament. Then, for every $p, q \in [0,1]$, and for every $r \le n$, if $p = q$ then $W(F,r) = W(D,r)$, and when $p > q$, $W(F,r) > W(D,r)$.

The main merit of the model is that it only takes two parameters to predict a greater probability of the first team winning. This simplicity involves strong assumptions and is not without limitations which further generalizations of the model may address. For instance, in order to capture the possibility of order-dependent technologies, it is possible to consider the difference $p - q$ to be team-specific or alternatively a four-parameter model $(p_\alpha, q_\alpha)$, $\alpha = F, D$. For example, a partial score of 0 is better news for the second team than for the first team, and this may have an impact on performance. These considerations will readily enrich the model and can be easily incorporated. In the latter case, for instance, it can be shown that the advantage of one team over the other depends on the parameter range of the $(p_\alpha, q_\alpha)$ values, and that it is possible to find parameter values where *both* the first team has an advantage over the second and vice versa. Examples are available upon request.

Finally, the assumption that all team players use the same $(p,q)$ technology can be generalized to introduce heterogeneity in player quality: $\{(p_h, q_h)\}_{h \in Q}$, where $Q$ is the set of players of a team ordered by quality. This opens up the possibility of investigating the strategic placement of players throughout the tournament, a decision that is taken before the toss out. We have studied this extension by having the two teams with (the same) two types of players differing in their $(p,q)$ technology compete in a tournament with just 2 rounds. We have found that, even in this simple case, it is possible to find parameters within an empirically sensible range of values that make *each* of the 4 possible combinations of the players a Nash equilibrium. That is, in theory, any combination could be optimal. This means that without precise information regarding the technologies of each player, it is not possible to have a sharp, testable implication on the strategic allocation of players.

For instance, consider the two teams $F$ and $D$ competing in a tournament with only 2 rounds. Each team has two players: $H$ and $L$. Player $H$ plays with technology

$(p_h, q_h)$, $p_h \geq q_h$, and player $L$ plays with $(p_l, q_l)$, $p_l \geq q_l$, where $p_h > p_l$. Assume that one of the players is vulnerable to psychological pressure, and hence plays with $p_i > q_i$, and the other player is not vulnerable, and hence he plays with $p_j = q_j$; $i, j \in \{H, L\}$, $i \neq j$. Denote by $(\beta_\alpha, \gamma_\alpha)$ the order in which team $\alpha \in \{F, D\}$ places the players $H$ and $L$ in the 2 rounds. For example, $(\beta_F, \gamma_F) = (L, H)$ means that the first team $F$ places player $L$ in round 1 and player $H$ in round 2. Let $W(\alpha, (\beta_F, \gamma_F), (\beta_D, \gamma_D))$ denote the probability of winning for team $\alpha$ when the first team chooses the order $(\beta_F, \gamma_F)$ and the second team chooses the order $(\beta_D, \gamma_D)$. It is immediate to show that:

$$W(F, (H, L), (H, L)) - W(F, (L, H), (H, L)) = (p_h - p_l)(1 - q_l)(p_h - q_h) \quad (1)$$

$$W(F, (H, L), (L, H)) - W(F, (L, H), (L, H)) = (p_h - p_l)(1 - q_h)(p_l - q_l) \quad (2)$$

$$\begin{aligned}
W(D, (H, L), (H, L)) - W(D, (H, L), (L, H)) &= (p_h - p_l)(1 - p_h)(p_l - q_l) \\
&+ p_h(1 - p_l)(q_h p_l - q_l p_h) \quad (3)
\end{aligned}$$

$$\begin{aligned}
W(D, (L, H), (H, L)) - W(D, (L, H), (L, H)) &= (p_h - p_l)(1 - p_l)(p_h - q_h) \\
&+ p_l(1 - p_h)(q_h p_l - q_l p_h) \quad (4)
\end{aligned}$$

It then follows that:

(i). When player $L$ is the vulnerable player, and hence $p_h = q_h > p_l > q_l$, equation (1) is equal to 0, and equations (2), (3), and (4) are all strictly positive. Hence, there are two pure strategy Nash equilibria: $((H, L), (H, L))$ and $((L, H), (H, L))$.

(ii). When player $H$ is the vulnerable player, and hence $p_h > q_h$ and $p_h > p_l = q_l$, equation (1) is strictly positive, equation (2) is equal to 0, equation (3) is strictly negative, and the sign of equation (4) is equal to the sign of $A = (p_h - p_l + p_h p_l(p_l - 1))$.[4] Consequently, $((H, L), (L, H))$ is a pure strategy Nash equilibrium, and $((L, H), (L, H))$ will be another pure strategy Nash equilibrium when $A \leq 0$.

Therefore, even in this simple version of a penalty shootout, the four possible placements of the players could be a pure strategy Nash equilibrium. Hence, without

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[4]Empirically plausible parameters for each potential case can be readily found. For example, $A < 0$ when $p_h = 0.8$ and $p_l = 0.7$; $A > 0$ when $p_h = 0.85$ and $p_l = 0.65$; and $A = 0$ when $p_h = 0.65/0.7725 \simeq 0.841$ and $p_l = 0.65$.

precise information on who is the vulnerable player (and when $H$ is the vulnerable player, on the specific values of $p_h$ and $p_l$) no testable prediction on the strategic allocation of players obtains.

## TABLE A.1– DETERMINANTS OF MISSES AND SAVES

### Panel A:  Proportions of Penalties Scored, Saved and Missed

|  | N (penalties) | Scored | No Scored | |
|---|---|---|---|---|
|  |  |  | Saved | Missed |
| First team | 234 | 75.6% | 17.1% | 7.3% |
| Second team | 220 | 68.6% | 16.8% | 14.6% |
|  | Difference: | -7.0% | -0.3% | +7.3% |

### Panel B:  Panel Data Analysis for Misses and Saves

|  | Misses | | Saves | |
|---|---|---|---|---|
|  | [1] | [2] | [3] | [4] |
| Constant | -1.57*** | -1.70*** | -0.98** | -0.67** |
|  | (3.01) | (2.57) | (2.15) | (2.23) |
| **Partial Score -1** | **0.09*** | **0.17*** | **-0.17** | **-0.12** |
|  | (2.65) | (2.85) | (0.44) | (0.36) |
| Partial Score 0 | 0.46 | 0.33 | 0.15 | 0.06 |
|  | (0.33) | (0.12) | (0.27) | (0.16) |
| Partial Score +1 | 0.09 | 0.17 | 0.88 | -0.47 |
|  | (0.93) | (0.77) | (0.38) | (0.36) |
| Second Team | 0.27 | 0.15 | 0.10 | -0.22 |
|  | (0.67) | (0.49) | (0.55) | (0.68) |
| Partial Score -1 x Second Team | -0.009** | -0.005** | 0.006 | 0.015 |
|  | (2.06) | (1.90) | (1.03) | (0.70) |
| Penalty Kick Importance | 1.05 | 1.17 | 0.44 | 0.83 |
|  | (1.12) | (1.10) | (0.88) | (0.47) |
| Round Fixed Effect | No | Yes | No | Yes |
| Goalkeeper Fixed Effect | No | Yes | No | Yes |
| N | 454 | 454 | 454 | 454 |

*Notes:* Misses by kicker are penalty kicks shot to the upright posts, the horizontal crossbar or outside the goal. Saves are penalty kicks stopped by the goalkeeper. All the specifications include Field, Competition and Match type fixed effects, as well as controls for "Potential Winner" and "Potential Loser" penalty kicks. Absolute, choice–biased sampling, heteroskedastic-consistent, $t$–statistics are reported in parentheses.
      *** Significant at the 1 percent level.
     ** Significant at the 5 percent level.