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General Ability and Specialization: Evidence From Penalty Kicks in Soccer

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Abstract

This article revisits the 2 $\times$ 2 penalty kick game and seeks to explain differences in mixed strategies associated with different player types and the relative performance of these player types. The authors show that (a) a kicker's general ability is a reliable indicator of his success rate, (bi) a kicker's specialization rate increases with his general ability, and (c) left-footed kickers who present a minority within the total population are characterized by a higher success rate. Consequently, the authors establish that more able kickers show a higher degree of specialization. Their greater specialization, however, has neither an adverse nor a beneficial impact on their success rate. All the theoretical predictions are in line with empirical evidence from the German national soccer league.

Keywords

game theory, mixed strategy, soccer, penalty kicks

Introduction

There are numerous social interactions in which it pays to be unpredictable. For instance, if an enforcer of the law specializes such that he only checks some types

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of agents, agents may succeed in outwitting the enforcer. Similarly, another classic example is that of the penalty kick. Because the ball travels so fast, the goalkeeper must decide which way to dive before the kicker touches the ball. If the goalie knows what the kicker will do, this will presumably worsen the outcome for the kicker. Thus, one might argue that successful penalty kickers are those whose behavior is difficult to predict. The following citation from the *New York Times* (June 18, 2006) puts this succinctly: "Clearly, a kicker ... who always plays to the same side will not be worth too much to his team ... ."

This article shows the contrary. We establish that kickers with a high general ability will be more likely to repeatedly choose specific actions than less able kickers and that these kickers, despite their specialization, are more successful than others. Consequently, more able players tend to stick to a specific side more often. In a situation in which specialization is usually considered bad, the strength of the player may compensate more for the potential adverse effects.

In addition to kicker specialization with regard to their choices, we consider that there might be a kind of goalie specialization. Given that there are left-footed and right-footed kickers, goalies can tailor penalty training more to one type or to the other.[1] We show that goalies prefer to prepare for the type comprising the majority of kickers and that this goalie specialization adversely affects the success rates of kickers belonging to this majority.

We first derive these predictions within the framework of a version of the classic 2×2 zero-sum game to provide a theoretical basis for our empirical analysis. Subsequently, we test the hypotheses using a large data set for the German national soccer league. We establish that all the findings in the empirical section are indeed in line with our hypotheses.

The article focuses on penalty kicks in soccer. There are several arguments that suggest that an analysis of this situation could be applied to similar social interactions. In the context of soccer, the set of alternatives can be easily described and data are readily available. It is thus not surprising that there are other studies to which the current one is related. Studies so far have tried to establish the empirical relevance of game theory predictions and mixed-strategy play in particular. Chiappori, Levitt, and Groseclose (2002) use penalty kick data to establish that mixed strategies are indeed used in reality. Coloma (2007) builds on this article by repeating the analysis with the same data but different methodology, without arriving at qualitatively different conclusions. Palacios-Huerta (2003) similarly uses penalty kick data to provide evidence for the fact that game theory sheds tremendous light on real-life phenomena. Moschini, (2004) uses data from soccer games but studies goal shots taken from off-center positions instead of penalty kicks. In such instances, the goalie needs to decide which post to defend most, while the kicker needs to single out one corner for the shot. Again, play can be found that is consistent with Nash equilibrium.

Our study is not intended to provide support for the relevance of game theory or to establish the fact that mixed strategies are played. This rather serves as our

Table 1. The Game in Reduced Form

Goalie (*G*) Kicker (*K*)	Natural Side (*N*)	Nonnatural Side (*O*)
Natural Side (*N*)	($\delta^i X$; $1-\delta^i X$)	(1;0)
Nonnatural Side (*O*)	(1;0)	(γX; $1-\gamma X$)

starting point and indeed, our findings in the empirical section give no reason to doubt the predictive power of game theory in the setting considered. In contrast, we are interested in explaining the differences in mixed strategies associated with different player types and the relative performance of these player types.

The balance of the article is as follows. The section on The Model and Analysis details the model and the analysis thereof. In the section on Data, we describe the data used in the empirical analysis and in the section on Results, we present the results. Concluding remarks complete this study.

The Model and Analysis

In the following, we use a simple game-theoretical setup to provide the theoretical basis for our empirical analysis and to derive testable hypotheses.

Description

We consider a one-stage game with two players (kicker, K, and goalie, G), each of whom can choose between two actions (natural side of the kicker, N, or nonnatural side, O).[2] Both players move simultaneously. The payoffs are summarized in Table 1.

The game comprises the situation of a penalty in a soccer match but is representative of other zero-sum settings as well. Kickers choose the corner in which to place the shot. At the same time, the goalie decides which corner to choose to fend off the ball.

There are two aspects specific to our representation of the penalty kick game: (a) kickers are heterogeneous with respect to the foot used naturally and with respect to their general ability x and (b) goalies can, given the distribution of kicker types, adapt accordingly.

First of all, kickers may be either right-footed or left-footed, where kicker type is indexed by i, $i = L, R$. This distinction gives rise to differentiation with respect to the corner that represents the natural side. For a right-footed player, it is more natural to take the left corner (from the kicker's perspective) and vice versa for a left-footed player. Accordingly, the natural side is to be defined as right (left) for a left-(right-)footed player. The model depicts this fact in the following respect: we follow the usual assumption that if the kicker and the goalie choose different sides, the kicker scores a goal.[3] The payoff in that contingency is one (zero) for the kicker (goalie). If, however, the two players choose the same corner, the outcome will depend on whether the kicker has chosen his natural side. To reflect the effect of the natural side, we assume that the scoring probability is higher in the case in which kicker and goalie choose the kicker's natural corner. This is supported by available empirical evidence (e.g., Palacios-Huerta 2003) and implies $0 \leq \gamma < \delta^i \leq 1$. Additionally, kickers have differing general ability levels as soccer players, captured by $x \in (0, 1)$.[4] The higher the general ability, the higher the probability of scoring. The assumption is that more able players can place shots with more strength and/or precision, resulting in a higher scoring probability even if the goalie chooses the same corner. Finally, δ^i takes into account the fact that the goalie can tailor preparations with respect to kicker type, should kicker types differ in terms of shooting behavior. The idea is that penalty training will be undertaken with primarily left-footed or right-footed kickers. If goalies specialize with regard to right-footed kickers, $\delta^R < \delta^L$ holds. The idea of this goalie specialization will be outlined below. In sum, $\delta^i x$ (γx) represents the compound probability of a player of type i and ability x scoring a goal when the goalie also chooses the natural (nonnatural) corner.

Equilibrium

In general, the game described above does not exhibit an equilibrium in pure strategies. To solve for the Nash equilibrium in mixed strategies, we start by describing the expected payoffs of the two players, where α_i (β_i) is the probability that the kicker (goalie) chooses the natural side, N. This probability takes into account the kicker type with respect to the general ability and the natural side. For instance, the way in which kickers take the run-up usually reveals information about the natural side. The expected payoffs of the kicker, E_i^K, and the goalie, E_i^G, are given by

$$E_i^K = \alpha_i\left[\beta_i\delta^i x + (1-\beta_i)\right] + (1-\alpha_i)[\beta_i + (1-\beta_i)\gamma x] \tag{1}$$

and

$$E_i^G = \beta_i\left[\alpha_i(1-\delta^i x)\right] + (1-\beta_i)[(1-\alpha_i)(1-\gamma x)]. \tag{2}$$

Differentiating E_i^K (E_i^G) with respect to α_i (β_i) yields, after gathering terms,

$$\frac{\partial E_i^K}{\partial \alpha_i} = [1-\gamma x] - \beta_i[2-(\delta^i+\gamma)x] \tag{3}$$

and

$$\frac{\partial E_i^G}{\partial \beta_i} = -[1-\gamma x] + \alpha_i[2-(\delta^i+\gamma)x]. \tag{4}$$

The unique and symmetric equilibrium of the game is given by the combination of probabilities

$$(\alpha_i^*, \beta_i^*) = \left(\frac{1-\gamma x}{2-(\delta^i+\gamma)x}, \frac{1-\gamma x}{2-(\delta^i+\gamma)x}\right). \tag{5}$$

Given β_i^* (α_i^*), the kicker (goalie) is indifferent with regard to the probability allocated to the action N because $\frac{\partial E_i^K}{\partial \alpha_i} = 0$ $\left(\frac{\partial E_i^G}{\partial \beta_i} = 0\right)$ holds irrespective of the choice of α_i (β_i). The effect of the natural side ensures that $\alpha_i^* > 1/2$, that is, the kicker chooses his natural side more often than not.

Using the values for α_i^* and β_i^* in Equations 1 and 2, we attain the respective equilibrium payoffs

$$E_i^{K^*} = \alpha_i^* + \gamma x(1-\alpha_i^*) = \frac{1+\delta^i\gamma x^2}{2-x(\delta^i+\gamma)} \tag{6}$$

and

$$E_i^{G^*} = 1 - E_i^{S^*} = (1-\alpha_i^*)(1-\gamma x) = \frac{(1-\gamma x)(1-\delta^i x)}{2-x(\delta^i+\gamma)}. \tag{7}$$

Comparative Statics

Of prime interest to us is the impact that general ability bears on kicker specialization. First, we derive the influence that a higher general ability has on the kicker's expected payoff.

Proposition 1. The kicker's success rate is an increasing function of his general ability as a soccer player.

Proof. To arrive at this conclusion, we differentiate the kicker's payoff in equilibrium with respect to ability and find that

$$\frac{dE_i^{K^*}}{dx} = -\frac{dE_i^{G^*}}{dx} = \frac{4\delta^i\gamma x + (\delta^i+\gamma)(1-\delta^i\gamma x^2)}{[2-(\delta^i+\gamma)x]^2} > 0. \tag{8}$$

This result confirms what intuition might suggest in that a higher general ability increases the expected payoff, which here is identical to the kicker's success rate. Note that due to the zero-sum nature of the game considered, the effect on the goalie is the same with the reversed sign.

Our interest primarily resides in the interaction of a kicker's general ability and specialization in favor of the natural side. Thus, we now turn to the kicker's equilibrium strategy, represented by α_i^*, which is the percentage of shots taken on the kicker's natural side.

Proposition 2. The kicker's specialization toward his natural side increases with his general ability as a soccer player.

Proof. To arrive at this conclusion, we differentiate the kicker's equilibrium strategy with respect to ability and find that

$$\frac{d\alpha_i^*}{dx} = \frac{\delta^i - \gamma}{[2 - x(\delta^i + \gamma)]^2} > 0. \tag{9}$$

This theoretical result is of overriding importance and implies that the better the player, the more the player will tend to specialize when it comes to a penalty kick. An increase in the likelihood of choosing one's natural side decreases the probability in equilibrium that the kicker and the goalie will select different corners. In equilibrium with $\alpha_i = \beta_i$, this probability is given by $2\alpha_i(1 - \alpha_i)$ with a unique maximum for $\alpha_i^+ = 1/2$. As $\alpha_i^* > 1/2$ for all x, an increase in α_i^* always decreases this probability.

Before considering the goalie's calculation with regard to goalie specialization, we will detail the payoff consequences of changes in this dimension. If there is indeed goalie specialization with regard to one type, we assume that this implies that the goalie cannot handle the other type as well. This should be reflected in the kicker's expected payoff.

Proposition 3. Kickers whose type constitutes the minority in the total population are characterized by a higher success rate, all else being equal.

Proof. To arrive at this conclusion, we differentiate the kicker's expected payoff in equilibrium with respect to the parameter indicating goalie specialization to find

$$\frac{dE_i^{K^*}}{d\delta^i} = -\frac{dE_i^{G^*}}{d\delta^i} = \frac{x(1 + 2\gamma - \gamma^2 x^2)}{[2 - (\delta^i + \gamma)x]^2} > 0 \tag{10}$$

Consequently, if the goalie specializes with regard to the type at hand, that is, decreases δ^i, this will adversely affect the kicker's expected payoff.

Before we turn to the goalie's calculation when determining his specialization, it should be emphasized that Propositions 1–3 constitute the central hypotheses to be tested in the following empirical analysis.

With regard to goalie specialization, goalies have to determine δ^i, given the distribution of kicker types. This means that, neglecting the influence of general ability for the sake of simplicity, δ^L is chosen to maximize

$$\widetilde{E^G} = pE_R^{G^*} + (1-p)E_L^{G^*}, \tag{11}$$

where p represents the share of right-footed kickers. We obtain

$$\frac{\partial \widetilde{E^G}}{\partial \delta^L} = p\frac{\partial E_R^{G^*}}{\partial \delta^R}\frac{d\delta^R}{d\delta^L} + (1-p)\frac{\partial E_L^{G^*}}{\partial \delta^L}. \tag{12}$$

To take into account the fact that specialization with regard to left-footed players comes at a cost in terms of how prepared the goalie is for right-footed players, we assume $\frac{d\delta^R}{d\delta^L} < -1$. Given that $\frac{\partial E_R^{G^*}}{\partial \delta^R} = \frac{\partial E_L^{G^*}}{\partial \delta^L}$ at $\delta^L = \delta^R$, we deduce that goalies focus preparations on right-footed kickers whenever $p > 1/2$, that is, $\delta^R < \delta^L$ for $p > 1/2$.

Data

Our data comprise 999 penalty kicks taken by 267 players in the first German soccer league (*Bundesliga*) during the 13 seasons from 1995 to 2007. Table 2 summarizes the data.[5] Although 102 players in the data performed only one penalty kick during the observation period, the average number of penalties per kicker in our data is 3.7. More than 81% of all penalties in the sample were executed by players with more than 2 penalty kick, and we have 3 players and 17 goalies involved in at least 20 penalty kicks.

Besides the number of shots, the data include information on the success of the penalty, the foot with which the penalty was executed, the direction of the shot, the direction in which the goalie jumped, and a grade for each player and goalie indicating their overall quality on the pitch. The variable *Goal* is one when the penalty is scored and 0 otherwise. Clearly, the majority of penalties end with a success for the kicker, who scores in 74% of all penalty kicks.

Player Quality is the grade assigned to each player by the specialist magazine *kicker*. More specifically, each soccer match is attended by two trained representatives of the magazine, who are experts for the respective teams. The experts assign grades to each player based on their individual performance and their position during the match.[6] In addition, statistical evaluations and TV footage is used to grade players. The grade attempts to take into account all relevant dimensions of the player's performance such as goals, assists, and the like. The grade varies between one and six. We used the normalized grade from one to six with a grade of six indicating the best performance. The average grade of the kickers in our sample is 3.48. We compared the grades with kickers that have not participated in penalties. The Wilcoxon Rank-Sum test indicates that the distributions of the grades are not identical. Although players that shot penalties obtained on average better grades, neither the

Table 2. Summary Statistics

Variable	Obs	*M*	*SD*	Min	Max
Goal	999	0.74	0.44	0.00	1.00
Player Quality	999	3.48	0.38	2.00	4.62
Goalie Quality	999	3.97	0.26	2.67	5.00
Goalie Correct	999	0.43	0.50	0.00	1.00
Left Foot	999	0.35	0.48	0.00	1.00
Natural Side	999	0.44	0.50	0.00	1.00
Shots per Player	999	3.74	4.08	1.00	30.00

players with the highest nor the lowest grades shot penalties. We use season averages for each player instead of grades for the specific game in which the penalty was shot to avoid the outcome of the penalty kick affecting the grades of the players. In addition, we tested three alternative proxies of player experience, which seem at least equally reasonable. These measures are the number of all Bundesliga penalties since 1992 kicked by a player before the current penalty, the number of soccer seasons a player has been playing in the German soccer league, and the age of the player at the time of the penalty. None of these proxies had any explanatory power with respect to penalty success.

The variable *Goalie Correct* is a dummy that is one if the goalie jumped to the side toward which the kicker shot the ball. The goalie chose the correct corner in 43% of all penalties. However, most penalty kicks were successful (74% of all penalties). This supports our setup in the section on The Model and Analysis.

Over the entire sample period, 35% of all penalty kicks were shot with the *Left Foot*, which is well above the typically encountered share of left-handed individuals in statistical studies but common in interactive sports (Davis & Annett, 1994; Gilbert & Wysocki, 1992).[7] The relatively high proportion of left-footed kickers may be attributed to the specific requirements of players on the left side of the pitch. Alternatively, a frequency-dependent advantage that provides these players with a competitive advantage that has been identified as a possible source of the large proportion of left-footed players in sport games (Raymond, Pointier, Dufour, & Moller, 1996). With regard to the direction of the penalty, the statistics indicate that kickers chose the natural side in 44% of penalties taken, that is, the left side for players kicking with the right foot and vice versa for left-footed kickers. The center was chosen in 15% and the nonnatural side in 41% of all penalties. The apparent contrast to the theoretical prediction $\alpha^* > .5$ follows from the fact that we disregarded the center in our theoretical setup to simplify the discussion without qualitative consequences (Table 2).

We show the 2×2 payoff matrix in Table 3. Football players in our sample score in 62% of all penalties kicked to their natural side when the goalie jumps to the same side. This payoff exceeds the payoff of 56% in situations where the player kicks to

Table 3. Kicker Payoff Matrix

		Goalie	
		Natural Side	Nonnatural Side
Player	Natural side	62%	92%
	Nonnatural side	86%	56%

his nonnatural side and the goalie also jumps to this side. The payoff is also higher for the player when choosing the natural side and the goalie the nonnatural side, that is, $92\% > 86\%$.

In addition, Tables A1 and A2 in the Appendix show the distribution of kicks and jumps for players and goalies separately. Of the 999 penalties, 650 were kicked with the right foot, which resulted in 469 goals or a success rate of 72%. In comparison, the left foot was used in 349 penalties, leading to 266 goals and a success rate of 76%. As expected, we observe in Table A1 that players using the left (right) foot kick more often to the right (left). From this aggregate perspective, the success rates for kicks to the natural and nonnatural side are statistically identical, with 79% for kicks with the left foot and 73% for kicks with the right foot. With regard to the goalie, in Table A2 we show that goalies jump more often to the natural side of the player, for example, 186 times of the 349 penalties kicked with the left, which corresponds to 53% of all goalie jumps when penalties were kicked with the left foot. Goalies rarely remain in the center of the goal. Only on 11 occasions do we observe that the goalie remains in the center. The success rates of the goalie suggest that goalies are more successful in preventing goals when they jump to the nonnatural side of the player. For penalty kicks with the left, the success rate of the goalie is 25% when jumping to the nonnatural side, which exceeds the success rate when jumping to the natural side by 2 percentage points. Correspondingly, jumping to the nonnatural side when penalties are kicked with the right foot results in a success rate of 31%, which is 5 percentage points higher than that for choosing the natural side. The higher success rate of the goalie for the nonnatural side potentially reflects that it is more difficult for players to kick to their nonnatural side.

Table A3 in the Appendix contains the correlations of the variables. Clearly, the correlation between player quality and goal is positive and significant, providing initial indicative evidence that better players score more often. In contrast, correlation between goal and the goalie's quality is negative and significant. Apparently, goalies who obtain better grades are also more able at avoiding goals.[8] As expected, the correlation of a correct jump made by the goalie with goal is negative and significant. The remaining correlations of *Goal* with the variables for the natural side and left foot are both insignificant.

We further tested the behavior for a sample of players and goalies as follows. In Table A4 we show the names, number of penalties, and goals for kickers with at least

10 and goalies with at least 20 penalties. The players in the sample account for almost 32 and the goalies 48% of the 999 penalties in our data. We tested the equality of the payoff rates dependent on the strategy of shooting to the natural side for each player individually. Likewise we tested the payoff rate for each goalie jumping to the player's natural side. In most cases, we find that the mean payoff between the strategies is not statistically different, except for Stefan Effenberg and Michael Ballack, who scored more often when choosing their nonnatural side. Finally, we also tested whether the strategy chosen by each player and goalie are indeed random, using the runs test.[9] In most cases, the strategies chosen appear to be random. However, for Mario Basler, Timo Hildebrand, and Frank Rost, the test is significant, indicating that their behavior was not truly random.

Results

Player Quality and Penalty Success

To test our first hypothesis regarding the players' quality and their probability of success in penalties, we use a logistic regression model. The odds ratio form of the standard logistic model is

$$\log\left[\frac{P_i}{1-P_i}\right] = \alpha + \beta Quality_i + X_i\gamma + \varepsilon_i, \tag{13}$$

where P_i is the probability of a goal, $Quality_i$ is the grade of the player, and X_i is a vector of control variables for penalty kick i.[10] Given that our dependent variable assumes only the values 0 and 1, linear regression models are inappropriate and we use logit regression.[11] Column 1 of Table 4 contains the baseline result using *Quality* as the sole explanatory variable for penalty kick success. The coefficient of player quality is significant and positive, indicating that players who receive better grades are more successful in penalty kicks. To demonstrate the robustness of the results, we add further control variables in Columns 2–6. In Column 2, we add a dummy that is equal to 1, if the player kicked to his natural side. The coefficient is positive and insignificant. The kicker is indifferent as regards corners, given that the goalie adheres to a mixed strategy that equates expected payoffs from available actions. Next, in Column 3, we add goalie quality to the specification. The negative and significant coefficient of goalie quality suggests that goalies with higher grades are better at avoiding goals.[12] As a third control variable, we include the dummy for correct jumps made by the goalie. Clearly, a correct goalie jump reduces the scoring probability significantly. Notably, our variable for kicks to the natural side also becomes significant. Penalty kicks to the natural side increase the scoring probability, even if the goalie has correctly anticipated the corner. This fully supports the assumption used in the section on The Model and Analysis that $\delta^i > \gamma$. In Column 5, we add a dummy for left-footed players and obtain a positive and significant

Table 4. Individual Penalty Success

	(1)	(2)	(3)	(4)	(5)	(6)
Player Quality	0.655***	0.660***	0.672***	0.597***	0.614***	0.703***
	(3.26)	(3.28)	(3.33)	(2.89)	(3.01)	(3.26)
Natural Side		0.17	0.154	0.561***	0.567***	0.573***
		(1.26)	(1.15)	(3.61)	(3.62)	(3.65)
Goalie Quality			−0.999***	−1.031***	−1.015***	−1.005***
			(3.33)	(3.43)	(3.32)	(3.31)
Goalie Correct				−1.659***	−1.677***	−1.702***
				(10.40)	(10.35)	(10.43)
Left Foot					0.323**	0.333**
					(2.02)	(2.08)
Top Rank × Final Days						−1.362**
						(2.45)
Constant	−1.238*	−1.328*	2.618*	3.694***	3.469**	3.171**
	(1.79)	(1.92)	(1.82)	(2.62)	(2.44)	(2.18)
No. of observations	999	999	999	999	999	999
Pseudo R^2	.01	.01	.02	.12	.12	.13
HL test	0.003***	0.068*	0.286	0.396	0.415	0.421

Note: HL test is the Hosmer-Lemeshow test statistic for goodness of fit. Robust z statistics in parentheses.
* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

coefficient. This suggests that there is a strong frequency-dependent advantage for left-footed kickers. Apparently, goalies are less accustomed to left-footed kickers in penalty kicks, which leads to a higher probability of scoring. With regard to the marginal effect of player quality, an improvement in the grade of one standard deviation increases the probability of a positive outcome by about 4%.

In summary, we find empirical support for our Propositions 1 and 3.

To measure the goodness of fit, we use the Hosmer-Lemeshow (HL) test. The test is insignificant for most specifications and thus provides support for our overall model. Additionally, we measure the predictive power of the specification in Column 5 of Table 4 using the area under the receiver operating characteristic (ROC) curve. The ROC curve plots the sensitivity, that is, the rate of correctly predicted goals over all goals, against the 1-specificity, that is, the rate of falsely predicted goals over all penalties that ended without a goal, for all possible threshold values. The area under the ROC indicates the predictive power of the chosen model. In our case, the area under the curve is equal to 0.74, which shows that the predictive power is at an adequate level (see Figure 1).

We tested various further control variables, which are given in Table A5 in the Appendix. The variables tested were:

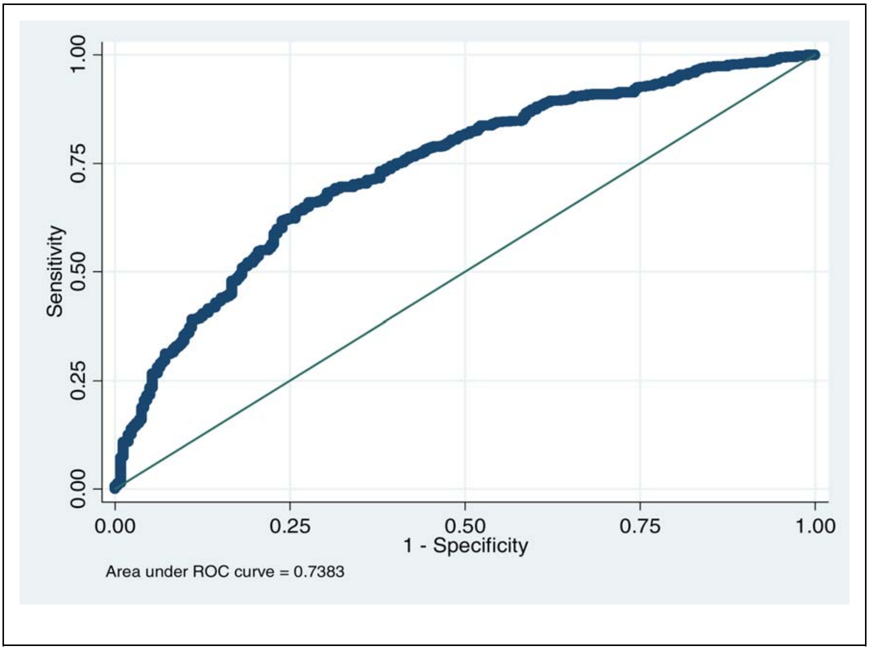

Figure 1. Receiver operating curve.

- the score at the time of the penalty measured by a dummy equal to one for a *Draw* or if the kicker's team was *Behind*,
- a dummy when the penalty was awarded to the *Home* team,
- the *Rank Difference* between the two teams in the league,
- the *Absolute Ranks* in the league,
- a dummy for the four *Final Days* of the season,
- dummies if the team that was awarded the penalty was in a *Top Rank*, that is, a team that is in one of the four top positions of the league, or *Relegation Rank*, that is, a team that is in one of the lowest four positions of the league,
- interaction terms for the top and relegation ranks with the final days of the season,
- dummies for the *Matchday*,
- football *Season Dummies*, and
- dummies for the *Quarter* in which the penalty took place.

None of these additional variables was significant except the interaction of the dummy for top ranking teams and the dummy for the finals days, which is negative.[13] This additional result is shown in Column 6 of Table 4. The pressure on players of top teams, that is, a choking effect, may be a reason for the lower scoring

Table 5. Summary Statistics for Aggregated Data

Variable	Obs	*M*	*SD*	Min	Max
Success Rate	105	0.76	0.18	0.20	1.00
Player Quality	105	3.47	0.27	2.72	4.18
Specialization	105	0.07	0.25	0.00	1.00
Left Foot	105	0.34	0.48	0.00	1.00
Goalie Quality	105	3.99	0.14	3.40	4.42

Table 6. Determinants of Player Specialization

	(1)	(2)	(3)	(4)	(5)
Player Quality	2.517***	2.595***	2.286**	2.311**	0.138*
	(2.68)	(2.75)	(2.55)	(2.37)	(1.93)
Goalie Quality		1.776	2.344	2.379	0.086
		(1.05)	(1.41)	(1.38)	(0.85)
Left Foot			−1.069	0.032	−0.05
			(1.01)	(0.01)	(1.19)
Player Quality × Left Foot				−0.312	
				(0.21)	
Constant	−11.573***	−18.978***	−19.906***	−20.136**	−0.74
	(3.43)	(2.79)	(2.73)	(2.52)	(1.63)
No. of observations	105	105	105	105	105
R^2					.04
Pseudo R^2	.06	.06	.08	.08	

Note: Logit regression in Columns 1–4 and Ordinary least squares (OLS) in Column 5.
* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

probability during the final days of the tournament (Dohmen, 2008; Jordet, Hartman, Visscher, & Lemmink, 2007).

Most importantly, the inclusion of these variables neither affects the significance of player quality nor the dummy for left-footed players.

Player Specialization

We next examine the determinants of players' penalty kick specialization. To this purpose, we require a variable that indicates a player's specialization with regard to penalties. We specify a variable that is one if all penalty shots by a player have been directed either to the left, the right, or the center. This procedure implies that we need to aggregate the data across penalties for each player. To avoid distortionary effects of players with only one penalty, we use players with at least four penalty shots. We are left with 105 players for which we have sufficient information. Table 5

Table 7. Player Specialization and Success in Penalties

	(1)	(2)	(3)	(4)	(5)	(6)
Player Quality	0.793***	0.806***	0.809***	0.864***	0.856***	0.869***
	(0.270)	(0.278)	(0.247)	(0.284)	(0.212)	(0.267)
Specialization		−0.167	−0.159	−0.0951	−3.183	−0.199
		(0.264)	(0.274)	(0.234)	(18.31)	(0.233)
Goalie Quality			−0.185	−0.227	−0.217	−0.259
			(0.405)	(0.437)	(0.453)	(0.440)
Left Foot				0.405**	0.408***	0.386**
				(0.163)	(0.158)	(0.166)
Player Quality × Specialization					0.853	
					(5.167)	
Left Foot × Specialization						0.621
						(0.384)
Constant	−1.612*	−1.652*	−0.92	−1.109	−1.124	−0.992
	(0.963)	(0.998)	(1.965)	(2.340)	(1.945)	(2.218)
No. of observations	87	87	87	87	87	87
R^2	.09	.09	.09	.17	.178	.17

Note: z statistics in parentheses.
* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

contains the summary statistics of the variables in the aggregated set.[14] Overall, there are seven players whose penalty kicks were directed to the same side.

Table 6 shows the results when we regress our dummy for specialization on a set of control variables using logit estimation. In the first column, we only use player quality. The coefficient is significant and positive, confirming our second proposition that players with a higher general ability are more likely to repeatedly perform certain possible actions. We subsequently add further variables for goalie quality, a dummy for left-footed players, and an interaction term for player quality with left-footedness. None of these additional variables is significant while individual player quality remains unchanged.

Are Specialists More or Less Successful in Penalties?

Finally, we use the aggregated data on the 105 players with at least 4 penalties to examine whether kickers who specialize were less successful in penalties. To this end, we use weighted least squares on grouped data, that is, the number of goals in penalties over total penalties for each player.[15] The results in all columns of Table 7 confirm that the quality effect remains positive and significant for all specifications. However, with regard to specialization, in Columns 2–4, there is no evidence that specialization has an independent effect on the players' success in penalties.[16] In light of the evidence in Table 6, the effect of specialization appears to be already incorporated in the players' quality effect, that is, better players are more likely to specialize. The inclusion of a dummy for left-footed players again reveals an improvement in the scoring success, which confirms the frequency-dependent advantage of left-footed players. We also used an interaction term for quality and specialization in Column 5 to examine this potential effect but obtained an insignificant coefficient. In addition, we interacted the dummy for left-footed players with specialization in Column 6 but again obtained an insignificant result.

Estimations based on grouped data are subject to an important caveat. Given that we have only a relatively limited number of penalties for each player, our estimate of the true probability may be imprecise. For this reason, we also run the regression using only players with at least six penalties and provide the results in Table A6 in the Appendix. The number of players for whom we have data drops to 54. However, the evidence for player quality remains robust.

Conclusion

This article shows that more able kickers specialize more than less able ones when it comes to penalty kicks. However, a higher ability dominates any possible drawbacks following from specialization; that is, more able kickers feature a higher success rate. This result is derived in a theoretical framework and supported by data from the German soccer league. It holds that players with a higher ability focus shots to a greater extent on one corner and that this preference for a particular side is not at all detrimental to success rates being higher for more able players.

Appendix

Table A1. Player Choices

		Direction of Shot			
No. of Penalties		Left	Center	Right	Total
Foot	Left	140	55	154	349
	Right	283	103	264	650
No. of goals		Left	Center	Right	
Foot	Left	110	35	121	266
	Right	208	67	194	469
Success rates		Left	Center	Right	
Foot	Left	79%	64%	79%	76%
	Right	73%	65%	73%	72%

Table A2. Goalie Choices

		Direction of Jump			
No. of Penalties		Left	Center	Right	
Foot	Left	157	6	186	349
	Right	357	5	288	650
					999
In percentage		Left	Center	Right	
Foot	Left	45%	2%	53%	100%
	Right	55%	1%	44%	100%
					100%
Goalie success rate		Left	Center	Right	
Foot	Left	25%	33%	23%	
	Right	26%	0%	31%	

Note: Foot refers to foot used by the player to shoot the penalty.

Table A3. Correlation Matrix

	Goal	Player Quality	Natural Side	Goalie Quality	Goalie Correct	Left Foot
Goal	1.00					
Player Quality	0.11 (0.00)	1.00				
Natural Side	0.03 (0.28)	−0.02 (0.47)	1.00			
Goalie Quality	−0.11 (0.00)	0.00 (0.88)	0.03 (0.35)	1.00		
Goalie Correct	−0.32 (0.00)	−0.07 (0.03)	0.21 (0.00)	0.01 (0.64)	1.00	
Left Foot	0.04 (0.17)	−0.06 (0.07)	0.01 (0.86)	−0.03 (0.38)	0.04 (0.24)	1.00

Note: *p* values in brackets.

Table A4. Statistics for a Sample of Players and Goalies

Player	No. Penalties	Percent	Means Test	Randomness Test	Goalie	No. Penalties	Percent	Means Test	Randomness Test
Michael Ballack	10	1	0.06*	0.89					
Michael Zeyer	10	1	0.45	0.4					
Miroslav Klose	10	1	0.55	0.51					
Oliver Neuville	10	1	0.55	0.33					
Rafael van der Vaart	10	1	0.35	0.18					
Rene Rydlewicz	10	1	0.36	0.07*	Tomislav Piplica	20	2	0.36	0.57
Stefan Beinlich	10	1	NA	0.62	Mathias Schober	21	2.1	0.54	0.31
Ervin Skela	11	1.1	0.84	0.73	Oka Nikolov	21	2.1	0.05*	0.11
Mario Basler	12	1.2	1.00	0.02**	Timo Hildebrand	21	2.1	0.18	0.02**
Stefan Effenberg	12	1.2	0.06*	0.68	Robert Enke	23	2.3	0.58	0.63
Levan Kobiashvili	13	1.3	0.15	0.6	Dirk Heinen	24	2.4	0.66	0.65
Andreas Herzog	14	1.4	0.24	0.34	Jens Lehmann	24	2.4	0.58	0.7
Jörg Böhme	14	1.4	0.85	0.11	Gabor Kiraly	25	2.5	0.68	0.95
Bernhard Winkler	15	1.5	0.45	0.16	Oliver Reck	25	2.5	0.24	0.34
Horst Heldt	16	1.6	0.79	0.95	Martin Pieckenhagen	27	2.7	0.72	0.35
Toni Polster	16	1.6	0.88	0.28	Jörg Butt	29	2.9	0.85	0.22
Ulf Kirsten	16	1.6	0.42	0.48	Simon Jentzsch	32	3.2	0.39	0.41
Marcelinho	18	1.8	0.55	0.63	Georg Koch	33	3.3	0.43	0.39
Thomas Hässler	19	1.9	0.22	0.66	Claus Reitmaier	34	3.4	0.59	0.31
Ailton	21	2.1	0.92	0.26	Richard Golz	36	3.6	0.64	0.45
Krassimir Balakov	21	2.1	0.73	0.32	Oliver Kahn	38	3.8	0.44	0.24
Jörg Butt	30	3	0.67	0.54	Frank Rost	44	4.4	0.9	0.02**
	318	31.8				477	47.7		

Note: Percent indicates the percentage of penalties of specific player (goalie) in total sample. Means test on equality of the distribution of success for the strategy shot/jump to the natural side. The test for randomness tests if the observations are serially dependent, that is, if they occur in random order.
* Significant at 10%; ** Significant at 5%; *** Significant at 1%

Table A5. Robustness: Individual Penalty Success

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Player	0.614***	0.611***	0.740***	0.668***	0.628***	0.681***	0.612***	0.612***	0.695***	0.669***	0.613***	0.605***
Quality	(2.99)	(2.99)	(3.32)	(2.80)	(3.04)	(3.13)	(2.84)	(2.99)	(3.06)	(2.91)	(2.93)	(2.97)
Natural Side	0.568***	0.568***	0.542***	0.547***	0.564***	0.566***	0.567***	0.566***	0.573***	0.579***	0.565***	0.579***
	(3.63)	(3.64)	(3.36)	(3.40)	(3.61)	(3.60)	(3.62)	(3.61)	(3.62)	(3.46)	(3.64)	(3.70)
Goalie	−1.012***	−1.017***	−0.988***	−1.026***	−1.006***	−1.011***	−1.015***	−1.014***	−0.982***	−0.958***	−1.058***	−1.027***
Quality	(3.33)	(3.34)	(3.20)	(3.32)	(3.31)	(3.31)	(3.31)	(3.32)	(3.26)	(3.02)	(3.43)	(3.37)
Goalie	−1.678***	−1.675***	−1.683***	−1.700***	−1.677***	−1.678***	−1.678***	−1.678***	−1.720***	−1.785***	−1.699***	−1.692***
Correct	(10.33)	(10.33)	(10.38)	(10.30)	(10.36)	(10.33)	(10.27)	(10.33)	(10.37)	(10.78)	(10.17)	(10.37)
Left Foot	0.321**	0.322**	0.351**	0.357**	0.330**	0.324**	0.323**	0.323**	0.352**	0.342**	0.302*	0.324**
	(2.01)	(2.01)	(2.13)	(2.17)	(2.06)	(2.03)	(2.02)	(2.02)	(2.21)	(2.01)	(1.88)	(2.03)
Draw	−0.076											
	(0.40)											
Behind	0.065											
	(0.43)											
Home		−0.045										
		(0.27)										
Rank			0.009									
Difference			(0.82)									
Rank				−0.004								
Awarded				(0.21)								
Rank				−0.02								
Punished				(1.39)								
Final Days					−0.233							
					(1.08)							
Relegation						0.221			0.272			
Rank						(1.21)			(1.34)			
Top Rank							0.006		0.25			
							(0.03)		(1.08)			

(continued)

Table A5 (continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Relegation × Final Days								−0.08	−0.276			
								(0.18)	(0.59)			
Top × Final Days									−1.509***			
									(2.60)			
Constant	3.453**	3.514**	2.917**	3.551**	3.416**	3.175**	3.475**	3.475**	3.009**	3.093*	3.668**	4.066***
	(2.44)	(2.47)	(2.03)	(2.29))	(2.40)	(2.17)	(2.44)	(2.44)	(2.05)	(1.87)	(2.54)	(2.66)
No. of observations	999	999	964	964	999	999	999	999	999	999	999	999
Pseudo R^2	.12	.12	.13	.13	.12	.12	.12	.12	.13	.15	.13	.12
Wald Test χ^2 value	0.26								7.86*	38.75	3.07	.93

Note: Matchday (Column 10), season (Column 11) and quarterly hour dummies (Column 12) included but not shown. Wald test for column-specific additional variables. Robust z statistics in parentheses.

* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

Table A6. Robustness: Player Specialization and Success in Penalties for Players With at Least Six Penalties

	(1)	(2)	(3)	(4)	(5)	(6)
Player Quality	0.673** (0.327)	0.676** (0.338)	0.682** (0.286)	0.732** (0.335)	0.728** (0.304)	0.736** (0.307)
Specialization		−0.088 (0.331)	−0.0532 (0.449)	−0.0476 (0.334)	−6.437 (43.68)	−0.244 (0.371)
Goalie Quality			−0.378 (0.531)	−0.448 (0.578)	−0.435 (0.502)	−0.474 (0.543)
Left Foot				0.341** (0.148)	0.347* (0.199)	0.323** (0.161)
Player Quality × Specialization					1.78 (12.32)	
Left Foot × Specialization						0.646 (0.430)
Constant	−1.082 (1.169)	−1.088 (1.209)	0.404 (2.160)	0.36 (2.540)	0.32 (2.503)	0.457 (2.521)
No. of observations	54	54	54	54	54	54
R^2	.077	.078	.088	.162	.164	.168

Note: z statistics in parentheses.
* Significant at 10%; ** Significant at 5%; *** Significant at 1%

Table A7. Robustness: Probit Estimates for Individual Penalty Success

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Player	0.381***	0.383***	0.393***	0.349***	0.360***	0.360***	0.358***	0.430***	0.393***	0.368***	0.402***	0.362***	0.409***
Quality	(3.24)	(3.27)	(3.33)	(2.88)	(3.00)	(2.99)	(2.97)	(3.29)	(2.81)	(3.02)	(3.17)	(2.85)	(3.07)
Natural Side		0.1	0.092	0.336***	0.339***	0.340***	0.340***	0.325***	0.328***	0.338***	0.338***	0.339***	0.338***
		(1.25)	(1.16)	(3.68)	(3.70)	(3.71)	(3.72)	(3.44)	(3.48)	(3.68)	(3.66)	(3.70)	(3.67)
Goalie			−0.574***	−0.592***	−0.584***	−0.584***	−0.585***	−0.567***	−0.588***	−0.578***	−0.582***	−0.584***	−0.561***
Quality			(3.38)	(3.40)	(3.32)	(3.33)	(3.33)	(3.20)	(3.32)	(3.29)	(3.31)	(3.31)	(3.19)
Goalie				−0.979***	−0.987***	−0.988***	−0.986***	−0.992***	−0.999***	−0.986***	−0.988***	−0.987***	−1.010***
Correct				(10.67)	(10.63)	(10.61)	(10.61)	(10.67)	(10.61)	(10.64)	(10.60)	(10.57)	(10.71)
Left-Foot					0.182*	0.180*	0.180*	0.198**	0.202**	0.185**	0.184**	0.181*	0.201**
					(1.93)	(1.91)	(1.91)	(2.04)	(2.07)	(1.96)	(1.96)	(1.93)	(2.16)
Draw						−0.047							
						(0.43)							
Behind						0.038							
						(0.43)							
Home							−0.034						
							(0.36)						
Rank								0.005					
Difference								(0.79)					
Rank									−0.002				
Awarded									(0.15)				
Rank									−0.011				
Punished									(1.27)				
Final Days										−0.13			
										(1.02)			
Relegation											0.144		0.17
Rank											(1.33)		(1.43)

(continued)

Table A7 (continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Top Rank												−0.004	0.145
												(0.04)	(1.08)
Relegation × Final Days													−0.142
													(0.50)
Top × Final Days													−0.876***
													(2.58)
Constant	−0.686*	−0.739*	1.517*	2.130***	2.000**	2.000**	2.036**	1.686**	2.017**	1.968**	1.818**	1.996**	1.706**
	(1.69)	(1.82)	(1.85)	(2.59)	(2.42)	(2.42)	(2.46)	(2.02)	(2.24)	(2.37)	(2.15)	(2.41)	(1.97)
No. of observations	999	999	999	999	999	999	999	964	964	999	999	999	999
Pseudo R^2	.01	.01	.02	.12	.12	.12	.12	.13	.13	.12	.12	.12	.13
Wald Test χ^2 value						0.28							8.01*

Note: Wald test for column specific additional variables.
Robust z statistics in parentheses. * Significant at 1%. ** Significant at 10%. *** Significant at 5%.

Notes

1. Right-footed players usually prefer to shoot into the left corner, all else being equal, and vice versa for left-footed players. This holds for simple anatomical reasons. Consequently, the preferred side will be labeled "natural side."
2. Similarly, Palacios-Huerta (2003) restricts the set of alternatives to two.
3. This is a simplifying assumption as it is also possible that the shot will miss the goal with a certain positive probability. However, assuming some probability of scoring lower than one would not alter the hypotheses derived from the model, as long as this probability is of sufficient size.
4. In the empirical section, the general ability will be measured by the average grade of the player for the season, where the grading is undertaken by the specialist magazine *kicker*. The grade attempts to take into account all relevant dimensions of the player's performance throughout the season, which is why we speak of general ability.
5. A number of these players were involved in penalties during international games. Unfortunately, we do not have data on these games.
6. The evaluation depends on the position of the player, given that different qualities are expected in different positions—for example, more goals are expected from strikers, while defenders are expected to excel in tackling, and so on.
7. The majority of players in our sample used either their right or left foot when kicking penalties. The only exceptions are two players who each changed their foot once.
8. The theoretical setup focuses on kicker ability. However, goalie ability could be included in a similar fashion.
9. Testing individual players choices requires a sufficiently large number of penalties, which is the main reason why we focused on kickers with at least 10 penalties. The run-test then tests whether the kicker (goalie) kicked (jumped) to the natural side in a random order by counting how many runs there are above and below a threshold. If the choice between kicking (jumping) to the natural side is truly random, then there should be a large number of runs, that is, the decision changes frequently.
10. We also considered estimating a random effects model treating the data set as a panel. However, we do not provide the results, given that the point estimates are virtually identical and the variance of the random effects is very small. Results can be obtained upon request from the authors.
11. Probit regressions yield similar results and are shown in Table A7.
12. Given that the outcome of a penalty is jointly determined by the quality of the player and that of the goalie, we also included an interaction term for these two quality measures. However, the correlation of the interaction term and the individual quality measures lead to the insignificance of all three variables.
13. The insignificance for the dummy indicating a penalty awarded to the home team signals a deviation from the previous literature on the home-field effect (Carmichael & Thomas, 2005). Apparently, the home-field effect is not equally applicable to penalties. In fact, the negative coefficient of *Home* may rather point to a choking effect when players are confronted with a large presence of supporters of their team (Dohmen, 2008).
14. The effective number of penalties of the 105 players is 738.

15. This estimation method only includes players that have not scored on every penalty and thus the number of observations drops to 87. We also run the regression after subtracting one goal for each player that scored on all penalties. The results for this admittedly crude procedure remain unaltered.
16. We also used the Herfindahl-Hirschman Index to investigate the effect of kicker specialization on scoring success. However, the result did not materially change, wheras the use of this index for the limited number of observations per player may be subject to criticism.

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