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**Working Paper**

## Criminals on the Field: A Study of College Football

IES Working Paper, No. 13/2017

**Provided in Cooperation with:**

Charles University, Institute of Economic Studies (IES)

*Suggested Citation:* Janhuba, Radek; Cechova, Kristyna (2017) : Criminals on the Field: A Study of College Football, IES Working Paper, No. 13/2017, Charles University in Prague, Institute of Economic Studies (IES), Prague

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**Bibliographic information:**

Janhuba R., Cechova K. (2017). "Criminals on the Field: A Study of College Football" IES Working Paper 13/2017. IES FSV. Charles University.

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# Criminals on the Field: A Study of College Football

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July 2017

## **Abstract:**

Economists have found mixed evidence on what happens when the number of police increases. On the one hand, more law enforcers means higher probability of detecting a crime, which is known as monitoring effect. On the other hand, criminals incorporate this increase into their decision making process and thus may commit less crimes, constituting the deterrence effect. This study analyzes the effects of an increase in the number of on-field college football officials, taking players as potential criminals and officials as law enforcers. Analyzing a novel play by play dataset from two seasons of college football, we report evidence of a monitoring effect being present in the overall dataset. This effect is mainly driven by offensive penalties which are called in the area of jurisdiction of the added official. The decomposition of the effect provides a limited evidence for the presence of the deterrence effect in the case of penalties with severe punishment and committed by teams with moderately high ability.

**Keywords:** Football, Official, Crime, Deterrence

**JEL:** H43, K14, Z29

**Acknowledgements:** We would like to thank Jan Hanousek, Stepan Jurajda, and an anonymous referee for helpful comments and suggestions. All remaining errors are our own. This study was supported with institutional support RVO 67985998 from the Czech Academy of Sciences.

# 1 Introduction

What is the effect of increasing the number of policemen on crime rates? Based on the economic model of crime founded by Becker (1968), engagement in crime activities depends on the expected utility of committing a crime. More specifically, potential criminals make their decision based on possible benefits, costs (punishment), probability of conviction, and lastly accounting for individual specific characteristics such as education.

A change in the number of policemen can cause an increase in probability of being caught and therefore convicted. If this increase is unobserved by potential criminals, it leads to an increase in crime rates, constituting a monitoring effect. However, potential criminals will likely observe the increase in the number of policemen. They will therefore incorporate it into their decision making process, change their behavior and decrease the number of committed crimes (as their expected utility has decreased). This is called the deterrence effect. As the monitoring and deterrence effects have opposite directions, the total effect of increasing the number of policemen on crime rates can be either positive or negative depending on the magnitude of both effects.

Our study looks at sports as an environment where players are potential criminals and officials take the role of law enforcers.<sup>1</sup> Examining a novel play-by-play dataset, we evaluate what were the effects of increasing the number of officials from seven

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<sup>1</sup>For the purpose of keeping the terminology clear, we abstain from using the term *referee* for a general term of a person observing the game and policing the rules. Instead, the term *official* is used. The reason is that in football there are seven or eight officials on the field while one of these is called the Referee.

to eight in the 2014 and 2015 National Collegiate Athletic Association (NCAA) football seasons.<sup>2</sup> Up to our knowledge, this is the first study to examine this policy change.

In the context of sports,<sup>3</sup> the economic model of crime founded by Becker (1968) has been examined by several studies modeling fouls committed by players and the number of officials. McCormick & Tollison (1984) show that adding a third official in college basketball led to decrease in the number of penalties called and serves as a strong evidence in favor of the existence of the deterrence effect. Levitt (2002) and Heckelman & Yates (2003) analyze the experiment in the National Hockey League where during the 1999-2000 season games were observed by either one or two referees.<sup>4</sup> Both of the papers find that the number of penalties increased and thus show that the monitoring effect was stronger than the deterrence effect (if there was any deterrence effect at all). Levitt (2002) argues that the change in probability of detection was too small to result in an observable deterrence effect. Heckelman & Yates (2003) concludes that breaking rules in sports might not be well thought off but rather impulsive.

By nature the closest sports policy change evaluation was carried out by Kitchens (2014) who analyzes a natural experiment where the National Football League moved the position of the official known as Umpire from behind the defense to be-

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<sup>2</sup>Note that throughout this study, the word *football* indicates specifically American football.

<sup>3</sup>Models of actual criminal behavior have been examined by several studies, many of them however suffered from endogeneity. General studies on crime are not reviewed in this study which is focused on testing the deterrence effect in sports environment. For a thorough review on economics of crime see Paternoster (2010) or Chalfin & McCrary (2014).

<sup>4</sup>In hockey terminology, the term official is not widely used. Instead, the game is supervised by referees and linesmen.

hind the offense, keeping the number of officials fixed at seven.<sup>5</sup> The results reveal that after the change in the spatial distribution of officials the number of penalties called on offense (which was observed by additional official) increased by 20 % while the number of penalties called on defense decreased.

Interestingly, the eighth official added in college games, the Center Judge, was added to the same spot where the NFL moved its Umpire, while the college Umpire stayed at his original spot. Thus, our results may be viewed as complementary to the results of Kitchens (2014) in a sense that the policy change we analyze added an official to a specific location while Kitchens's analysis combined this intervention with removing an official from a different location at the same time.

Contributions of our study are threefold. First, up to our knowledge this is the first study to evaluate the recent change in the number of officials in the NCAA football. Second, none of the previous literature on the number of officials and penalties includes fixed effects on specific officials working at the game. And third, our study develops the analysis performed by Kitchens (2014).

Our results indicate presence of the monitoring effect in the overall dataset. This result is strengthened by performing a decomposition based on area of officials' jurisdiction. We also find limited evidence on the existence of the deterrence effect in two scenarios. First, we find an indication of the deterrence effect canceling out with the monitoring effect in case of a type of penalty with severe punishment. This may be explained by a between-season change in team behavior. Second, we find limited evidence of the deterrence effect present when only teams with moderately

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<sup>5</sup>The experiment may be viewed as natural due to the fact that the primary reason for moving Umpire's position was his safety, which is unrelated to the number of penalties called.

high ability are considered. This is consistent with highly skilled teams being able to strategically adapt their behavior following the policy change.

The remainder of this study is structured as follows. Section 2 provides a brief introduction to rules of football and to the intervention. Section 3 describes the dataset. Section 4 considers used methodology. Section 5 presents results. Section 6 concludes.

## 2 Football Specifics and Intervention Details

This section first introduces the sport of football and its specifics that are important for this study. It then follows with the description of the intervention and discussion of its implications. Readers familiar with the game of football may skip the next section and proceed directly to Section 2.2.

### 2.1 The Game of Football

Football is a collective sport played by 11 players on each team on a rectangular field divided by lines into a grid. The last zone on each side of the field is known as the end zone.

The game is played in short consecutive plays lasting only several seconds. After each play, the ball is placed either to the spot of the end of the play, or to the spot where the previous play started, depending on the outcome of the play. The team which initiates the ball into play is called an *offense* and its goal is to get the ball into the opponent's end zone. The opposing team protects its end zone in order to keep the offense from scoring and is labeled the *defense*.

When a team is awarded the ball, it has four opportunities (*downs*) to move the



ball at least 10 yards closer to the opponent's end zone. If the offense succeeds to do so, the down count resets and the offense again has first down and 10 yards to go.<sup>6</sup> If the offense fails to get the first down during the four attempts, the ball turns over to the defense at the spot where the fourth attempt ends.<sup>7</sup> The defense is then awarded a 1st down and hence becomes the offense, and vice versa.

The goal of the game is to score more points than the opponent. Kicking the ball through the uprights of the "Y" shaped goal results in a field goal worth 3 points. A touchdown worth 7 points is scored by moving the ball into the opponent's end zone by either carrying it there or catching it there.<sup>8</sup> Last but not least, a safety worth 2 points is awarded to the opposing team if a team is stopped in its own end zone (this occurs very rarely).

The games are governed by seven, and recently eight, officials.<sup>9</sup> These officials observe the game and in case they see rule violations,<sup>10</sup> they throw a yellow flag to indicate a penalty. After the play ends, they confer together and then the referee (which is the official responsible for the whole crew) informs the teams and spectators about the decision which has been made. The usual form of penalty is a loss of 5,

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<sup>6</sup>For example if the situation is labeled as *2nd* (down) & *5*, the team has second down and has to advance the ball at least 5 yards to get the first down. If the team advances the ball 3 yards only, the next down will be labeled as *3rd* & *2*. If the team advances the ball 10 yards, they will get *1st* & *10* at the spot where the play ends.

<sup>7</sup>Teams will very rarely attempt to get the first down on fourth down. Instead, they usually elect to try a field goal (see the next paragraph) or *punt* the ball, in which case they kick it towards the opponent's end zone so that the other team will need to gain bigger distance to score.

<sup>8</sup>Technically, a team receives 6 points for a touchdown. Afterwards, the scoring team attempts one more play (so called "extra point" or "try") for which it can receive one point for kicking a field goal, an option that happens almost all the time, or two points in case it scores another touchdown. An unsuccessful try for either a field goal or touchdown means that the team receives 6 points for the touchdown.

<sup>9</sup>Note that this holds for the highest level of college football games. Lower level college and professional games are governed by seven officials.

<sup>10</sup>Although the basic rules of the game are quite simple, the specifics of play are governed by a complex and difficult set of rules (e.g., the 2016 official NCAA football rule book contains 218 pages of text).

10, or 15 yards, according to the severity of the foul. This penalty is then assessed against the fouling team and the down is repeated.<sup>11</sup>

## 2.2 Change in the Number of Officials

We analyze a policy change where the number of officials present at a football game increased from seven to eight. The intervention was implemented gradually over three seasons. In the 2013 season eight-member officiating crews oversaw exclusively games governed by the Big 12 conference. In the 2014 season, additional three conferences adopted the same rule change, while in 2015 it applied to the whole FBS.<sup>12</sup> The gradual introduction enables us to study the intervention as a natural experiment.

The first policy change of such kind since 1983 reacted on an increase in the speed of the game in the preceding years and related issues.<sup>13</sup> The officials started having problems to prepare for the next play quickly enough to assure proper observation of the game. Also safety of players and potential holes in coverage were widely discussed topics.<sup>14</sup>

Generally, officials have divided areas of coverage, meaning that each official has specific area to look at and detailed instructions on which fouls to particularly watch

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<sup>11</sup>For example, if offense commits a holding foul on 2nd & 10 which resulted in a gain of 15 yards, the gain is canceled and the next down will be 2nd & 20.

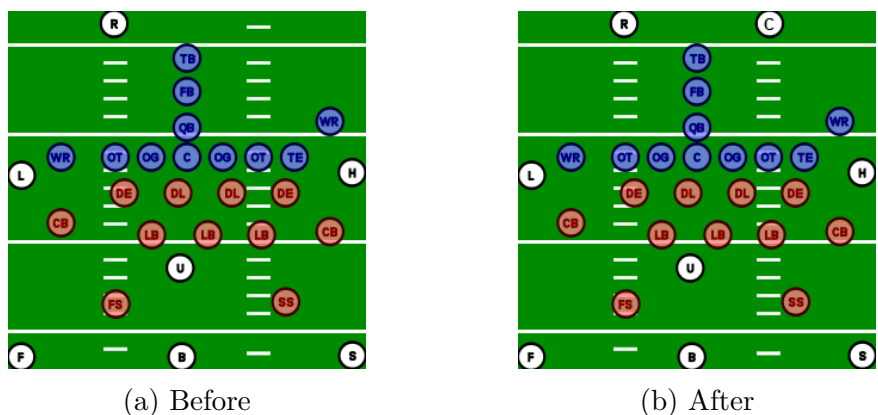
<sup>12</sup>FBS is the highest level of college football played in the United States.

<sup>13</sup>The increase in pace was associated with the implementation of the 40-second clock. The 40-second clock rule introduced in 2008 sets an interval between the end of a play and beginning of a new one to be no more than 40 seconds. Previously, the clock was only 25 seconds but counted only after the officials made the ball ready for play. The aim of the rule was to increase the pace of games (Source: <http://bleacherreport.com/articles/35981-2008-rule-changes-what-every-fan-needs-to-know>).

<sup>14</sup>For examples see: <http://www.cbssports.com/college-football/news/big-12-adds-eighth-official-just-to-keep-up-with-up-tempo-offenses/> or <http://www.cbssports.com/college-football/news/sec-to-experiment-with-8-football-officials-but-whats-right-number/>

for. By holes in this coverage it is meant that specific fouls were missed due to the seven officials not being able to observe all the actions that take place on the field.

A graphical illustration of the change in the composition of officials is depicted in Figure 1.



Source: [https://en.wikipedia.org/wiki/Official\\_\(American\\_football\)](https://en.wikipedia.org/wiki/Official_(American_football))

Figure 1: Schematics of Policy Change

In order to check that the policy can be viewed as exogenous (as the implementation of intervention was voluntary in the 2014 season), we performed balancing tests for penalty related statistics before the intervention took place. Specifically, we examined the overall season levels of penalty related statistics of the 2013 season and analyzed whether their distribution differs for conferences that initiated the eighth official in 2014. Both the t-tests and Kolmogorov-Smirnov tests for equality of distributions suggest that the number of penalties and penalty yards per play do not differ across conferences which did and did not implement the policy change in 2014. Therefore, although it could be argued that the conferences did not adopt the policy change randomly in the 2014 season, the balancing tests presented in Table 2.1 based on the number of penalties per play and penalty yardage per play indi-

cate that the intervention may be viewed as exogenous to penalty characteristics. Moreover, we have also checked if the two conference groups differed in the pace of games before the intervention. Again, both the t-tests and Kolmogorov-Smirnov tests suggest that there was no such difference.

Table 2.1: Balancing Tests

	Control <sup>1</sup>		Treatment <sup>1</sup>		t-test		K-S test	
	Mean	SD	Mean	SD	t-stat	p-val	D stat	p-val
Penalties per game	5.56	1.16	5.69	1.24	-0.52	0.60	0.10	0.96
Penalties per play	0.04	0.01	0.04	0.01	-0.88	0.38	0.13	0.81
Penalty yards per game	48.03	10.73	48.44	11.44	-0.18	0.85	0.10	0.96
Penalty yards per play	0.34	0.07	0.34	0.08	-0.56	0.58	0.11	0.92
Plays per game	143.33	8.98	141.05	7.65	1.30	0.19	0.15	0.67
Plays in season	1817.27	167.03	1797.14	114.48	0.65	0.52	0.20	0.27

Calculation excludes independent and Big 12 teams.

<sup>1</sup> Treatment includes teams that adopted the intervention in 2014. Control includes teams that did not. Source: Own calculation; Data from <http://www.cfbstats.com/2013/team/index.html>

Note that in order to keep the decision as clean as possible, the reported results exclude Big 12 teams and independent teams.<sup>15</sup> Keeping the Big 12 it in the dataset would mean that one of the balancing groups would already include data that were caused by the “trial run” of the intervention. Nevertheless, results from balancing tests including the Big 12 teams in the control group are qualitatively the same.<sup>16</sup>

### 3 Data

The data on football games have been downloaded from the [NCAAsavant.com](http://NCAAsavant.com) website.<sup>17</sup> The data include play by play information of NCAA football games in 2014 and 2015 seasons.<sup>18</sup> Note that the dataset was mainly created as a base of an inter-

<sup>15</sup>In 2013 there were six so called independent teams. These teams are not governed by any conference.

<sup>16</sup>These results are available upon request.

<sup>17</sup><http://ncaasavant.com>

<sup>18</sup>More precisely, the data present a subsample of football games in each season.

active website which and unfortunately does not cover the games from 2013 season (when all games were governed by seven officials), which causes methodological issues (see below).<sup>19</sup>

The dataset includes basic variables about each play such as which team is at the offense, the type of play, the result of the play, the player involved in the play, as well as a detailed text description of the play. More importantly, the dataset includes information about whether there was a penalty called during the play, and if so, penalty type, team, player, and whether it was called on offense or defense.

The data on officiating assignments were downloaded from collegiate athletics websites of all 128 universities that were part of FBS in 2014 and 2015 seasons.

After matching the two data sources together, the main dataset includes 148,097 plays from 1,011 games. Note that in order to simplify the analysis, we decided to restrict the dataset to basic plays from scrimmage (rushes and passes).<sup>20</sup>

The descriptive statistics for play-by-play data are presented in Table 3.1. The first two rows show the proportions of run and pass plays. The last three rows show unconditional probability of a penalty appearing, followed by probabilities of offensive holding and roughing the passer penalties. These are the two specific types of fouls we are particularly interested in (see the next section for explanation).<sup>21</sup>

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<sup>19</sup>We tried to contact the owner of the website to get access to codes used to compile the dataset, which would allow us to obtain the same data for the 2013 season (as well as missing games from 2014 and 2015). Our inquiries did not meet with a response.

<sup>20</sup>Thus, we eliminate plays including kicks. Although these are undoubtedly an important part of a football game, the behavior of players during kick plays is substantially different and their inclusion would introduce noise into the analysis.

<sup>21</sup>Note that the number of observations for the roughing the passer penalties is approximately half of the number for other variables. This is due to the fact that the roughing the passer penalty can only appear in case of passing plays, while the other types can appear in runs as well as in passes.

Table 3.1: Descriptive Statistics

	Mean	S.D.	Min	Max	N
Running play	0.5107	0.4999	0	1	148,097
Passing play	0.4893	0.4999	0	1	148,097
Any penalty	0.0463	0.2100	0	1	148,097
Offensive holding	0.0125	0.1109	0	1	148,097
Roughing the passer	0.0029	0.0536	0	1	72,462

Source: Own calculation

## 4 Methodology

Utilizing the advantage of having play-by-play information, we examine probabilities of a penalty being called within every single play. The basic model takes the form

$$y_{ighvr} = \lambda_1 [\text{eight}_g] [2014] + \lambda_2 [\text{eight}_g] [2015] + \beta X_{ig} + \theta_h + \theta_v + \theta_r + \varepsilon_{ighvr} \quad (1)$$

where the subscript  $ig$  can be read as “play  $i$  in game  $g$  of home team  $h$  and visiting team  $v$  under supervision of Referee  $r$ ”. The dependent variable  $y$  is an indicator equal to one if a penalty was called within a play. The variables in brackets mark indicators equal to one in case when the condition described by the inside of the bracket is specified. Specifically,  $\text{eight}$  is an indicator equal to one if the game was supervised by eight officials, and  $2014$  with  $2015$  are indicators equal to one if the game was played in particular season.  $X$  is a vector of football specific variables for each play, namely, distance to first down, field position, and indicator variables for down, quarter, and whether the play was a run or pass. Last but not least,  $\theta_h$ ,  $\theta_v$ , and  $\theta_r$  are fixed effects for the home team, the visiting team, and the officiating crew represented by the Referee.

The particular regression methodology has been selected in order to perform two type of comparisons. First, the coefficient  $\lambda_1$  captures the within-season variation of

adding an extra official and can thus capture the immediate adjustment to the policy. Second, the coefficient  $\lambda_2$  captures the between-season variation and measures the effect of introducing the policy to all games in the 2015 season.

Note that while such methodology would be ideal, it is not plausible to estimate the effect using the standard difference-in-differences framework, as the dataset we possess does not have information on games played in the 2013 season.

Note, moreover, that as the policy change influenced all observations in the second year of the sample, it is difficult to disentangle between the effect of the intervention and a potential time trend in the dependent variable. More specifically, if there is a time trend in the dependent variable, one should look at the coefficient and then deduct this time trend from the estimated value of the effect. Figure 2 shows the values of the number of penalties divided by the number of offensive plays and its evolution in years 2008 through 2013.<sup>22</sup> The figure reveals that there is a negative time trend in the number of penalties per play.<sup>23</sup> Therefore, as the regression design inherently assumes that there is a zero time trend, the empirical results will likely tend to underestimate the true effect rather than overestimate it. In other words, as there likely is a negative time trend in the dependent variable, a potentially positive regression coefficient should arguably be viewed more credible than if it would have a negative value.

In combination with the specific characteristics of several types of football fouls,

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<sup>22</sup>Note that due to data limitations the unconditional probabilities of penalties are measured in a different settings and are therefore not comparable to values in Table 3.1. The reason is that the play by play data for previous seasons is not available and we can therefore only make inferences based on the total number of penalties called on each team including dead-ball fouls such as false start and/or penalties that are called during kicking plays.

<sup>23</sup>The existence of the negative trend is supported by ordinary least squares results of average penalty rates on time.

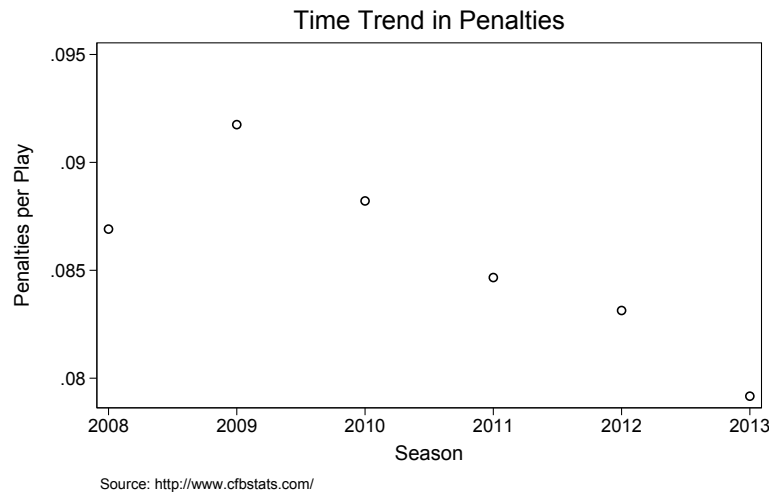


Figure 2: Time Trend in Penalties

the intervention allows us to shed light on the difference between the monitoring and deterrence effects. Specifically, these are offensive holdings and roughing the passer penalties, both of which occur predominantly in the area of the new official's jurisdiction. The following paragraphs explain why these two types of penalties can be used for a deeper analysis.

First, holding seems to be the appropriate foul which might be influenced by the policy change. Specifically, before the change, the umpire and the referee were assigned responsibility over fouls that happen in the area of the offensive line. The basic assignment decomposition was that the umpire was observing fouls committed by the three interior linemen, while the referee was observing fouls by both exterior linemen. Clearly, this was often an impossible job, so the referee was observing only one of the two suspects. The introduction of the third observer in the area means that all potential suspects can be observed at all times.

Moreover, while it is impossible to prove that there will be no deterrence effect



at all, it is also arguably likely that such effect is negligible in case of offensive holding. The reason for this is that offensive holding in practice occurs when the defensive player outplays the offensive one, who turns into illegal holding in order not to let the opponent continue towards the ball carrier. In fact, coaches often instruct the players that, especially in case of passing plays, they should rather hold the opponent than let him continue towards the quarterback, as a holding penalty punishes the team by 10 yards but avoids the potential tragedy of having the key player injured.<sup>24</sup>

Given the information from the preceding paragraphs, we find it feasible to suspect that the number of called offensive holdings would have risen following the introduction of the extra official. In terms of the economic model of crime, while there is a higher probability of being caught, the benefits of committing a crime overvalue the potential penalty.

The second type of penalty we are interested is *roughing the passer* which occurs when the defender hits the quarterback after he has released the ball. The reason is that the second backfield official sees the passer from a second angle and can thus help with coverage of this safety related foul, therefore the officials are less likely to miss them (constituting a higher probability of detection).

Additionally, such penalties carry an automatic first down for the offense and a risk of disqualification from the remainder of the game in case of a serious misconduct. Therefore, due to severity of the punishment, roughing the passer penalties should arguably be associated with a stronger deterrence effect. Thus, in terms

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<sup>24</sup>The quarterback is the most important player on the team and his injury may have catastrophic consequences for the team in question.

of the economic model of crime, roughing the passer fouls are crimes with a high punishment.

## 5 Results

### 5.1 All Penalties

The results of the linear probability model regressions for all penalties are presented in Table 5.1.<sup>25</sup> The results indicate that although the number of penalties increased

Table 5.1: Linear Probability Model: All Penalties

	(1)	(2)	(3)	(4)
Eight-men crew in 2014	-0.0009 (0.0018)	-0.0007 (0.0017)	-0.0006 (0.0019)	-0.0006 (0.0021)
Eight-men crew in 2015	0.0026 (0.0017)	0.0029* (0.0017)	0.0035** (0.0017)	0.0043** (0.0020)
Yards to 1st down		0.0007*** (0.0002)	0.0006*** (0.0002)	0.0006*** (0.0002)
Field position		-0.0001*** (0.0000)	-0.0001*** (0.0000)	-0.0001*** (0.0000)
Passing play		0.0276*** (0.0012)	0.0273*** (0.0012)	0.0273*** (0.0012)
Constant	0.0455*** (0.0015)	0.0229*** (0.0024)	0.0012 (0.0140)	0.0192 (0.0154)
Down and Quarter	No	Yes	Yes	Yes
Teams	No	No	Yes	Yes
Referee	No	No	No	Yes
N	148,097	147,192	147,192	147,192

Standard errors adjusted for clusters by the referee in parentheses.

Significance levels: \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Source: Estimation of the model.

in the 2015 season following the policy change, this increase is not visible in the

<sup>25</sup>We present linear probability model regressions due to the direct interpretation of regression coefficients as marginal effects and their lower computational time required. Robustness of the estimation method is discussed in section 5.4.3.

games supervised by eight officials during the 2014 season, hence the result may not be attributed solely to the presence of the new official. As there hasn't been any other major rule change between the two seasons, one possible interpretation of this result is that the officials may have known that the policy change presents an issue for the teams and subsequently "went easy" during the course of the 2014 season. A second possible interpretation is linked with the fact that increasing the number of officials necessarily meant that the newly added official did not have experience with the same level of competition.

## 5.2 Area of Officials' Coverage

Due to the specific spatial allocation of football officials and their areas of coverage, results on all penalties stacked together may be imprecise as they include fouls happening in areas not observed by the extra official. Specifically, as the new official was added into the area behind the offense, he would be expected to typically call more penalties on the offense and less on the defense.<sup>26</sup> Therefore, we redefined the dependent variable into two separate indicators equal to one in case the penalty was called on offense or on defense, and repeated the estimation.

Moreover, in order to analyze the situation in a highest possible detail, we further switched attention to two types of penalties which should arguably be most influenced by the extra official. Namely, these are offensive holding and roughing the passer penalties. As explained in Section 4, analysis of these specific penalties may also reveal insights on the existence of the deterrence effect.

The results are presented in Table 5.2. The first two columns reveal that, as

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<sup>26</sup>An exception are roughing the passer penalties which will be explored below.

Table 5.2: Linear Probability Model: Area of Coverage

	Offensive Penalties (1)	Defensive Penalties (2)	Offensive Holding (3)	Offensive PI <sup>1</sup> (4)	Roughing the Passer (5)
Eight-men crew in 2014	0.0021 (0.0014)	-0.0027 (0.0016)	0.0000 (0.0011)	-0.0011 (0.0008)	0.0014** (0.0007)
Eight-men crew in 2015	0.0045*** (0.0014)	-0.0002 (0.0014)	0.0020** (0.0009)	-0.0006 (0.0006)	0.0006 (0.0006)
Yards to 1st down	0.0006*** (0.0001)	0.0000 (0.0001)	0.0005*** (0.0001)	-0.0002*** (0.0001)	0.0001 (0.0001)
Field position	-0.0000 (0.0000)	-0.0001*** (0.0000)	0.0000 (0.0000)	-0.0000* (0.0000)	-0.0000 (0.0000)
Passing play	0.0007 (0.0009)	0.0267*** (0.0009)	-0.0063*** (0.0007)		
Constant	0.0109 (0.0074)	0.0357*** (0.0086)	-0.0062 (0.0058)	0.0146*** (0.0038)	0.0083** (0.0033)
N	147,192	147,192	147,192	71,964	71,964

The dependent variable is specified by the column heading.

All columns include full set of fixed effects for down, quarter, teams, and referee.

Standard errors adjusted for clusters by the referee in parentheses.

Significance levels: \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

<sup>1</sup> PI stands for “Pass Interference”.

Source: Estimation of the model.

expected, the effect can be mainly contributed to increase in offensive penalties.

Specifically, while the effect is statistically insignificant in the 2014 season, the probability of a penalty called within a play supervised by seven officials is 0.0215, the effect of 0.0045 presents an increase of 21.1 percent called under the supervision of eight officials in the 2015 season.

Due to the spatial allocation of the officials, the regression reported in the second column may be viewed as a placebo test. We can see that as the defensive penalties stay the same following the adoption of the eighth official, the placebo test indicates that the increase in penalties is indeed driven by fouls on the offensive side of the

ball.<sup>27</sup>

The offensive holding results, in case of which the deterrence effect is expected to be very small, are presented in the third column. We can see that the results for offensive holding penalties are qualitatively similar to the overall results for all penalties, in the sense that there is an effect of more penalties being called, but only after all of the conferences adopted the eighth official in the 2015 season.<sup>28</sup> Specifically, while the effect is statistically insignificant in the 2014 season, the probability of the offensive holding called within a play supervised by seven officials is 0.0121, the effect of 0.002 presents an increase of 16.8 percent called under the supervision of eight officials in the second season. This result is qualitatively similar to the result of Kitchens (2014) who finds an increase of 14% following the relocation of the umpire from behind the defense to behind the offense.

The fourth column provides another placebo test in sense of looking at offensive pass interference penalties, which are arguably the only type of offensive fouls that should not be even theoretically influenced by the eighth official.<sup>29</sup> The fact that the coefficients are insignificant in both periods validates the finding from regression in the third column.

The results reported in the fifth column suggest that the number of roughing the passer penalties increased following the policy change, however, only in the 2014

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<sup>27</sup>Following Kitchens (2014) we also performed a placebo test for defensive holding on runs. As the coefficient on both variables in question was insignificant at the 5% level, the qualitative implications of this alternative placebo specification stay the same.

<sup>28</sup>We also tried to restrict the sample to offensive holdings called during passing plays only. The results are qualitatively identical.

<sup>29</sup>The reason is that when a pass is thrown, all officials except for the referee and center judge look towards where the ball will land. The two remaining officials observe the quarterback in looking for the roughing the passer penalty. Thus, there is no spillover effect based on the presence of the new official.

season where there were still games supervised by seven officials as well. More precisely, while the effect is statistically insignificant in the 2015 season, the point estimate of the effect with a value of 0.0014 would present an increase of 46.8 percent called under the supervision of eight officials in the 2014 season, as the probability of the roughing the passer called within a play supervised by seven officials is 0.003.

The situation may be explained by the fact that in case of roughing the passer penalties it is hard to change your behavior when only selected games are supervised by eight officials, while it is more possible to establish such behavioral change between the two seasons. Thus, a possible interpretation of the coefficients is that within the 2014 season players were not able to change their behavior and thus the monitoring effect was stronger than the deterrence. When the policy change was about to be implemented universally, teams adjusted their behavior in the off-season. Therefore, while the overall number of roughing the passer penalties remains the same, this may be explained by a mutual elimination of the monitoring and deterrence effects.

Overall, the results in this section present evidence of a monitoring effect and a limited evidence for existence of the deterrence effect in the case of crimes with the most serious punishment.

### **5.3 Role of Team Quality**

We now extend the analysis to let the effect of the intervention on the two specific types of penalties differ based on team quality. This is motivated by a possibility that highly and lowly skilled teams differ in their game strategies and ability to

adjust their behavior following the policy change.

In order to distinguish between offensive ability of the teams, we took the total yards gained by each team's offense in the previous season and ranked the teams according to their performance. Analogously, we took the total offensive yards gained by the opposing teams to evaluate defensive abilities. We then defined the best teams as the top 25 teams in each category. This selection is motivated by the fact that college sports usually rank the best 25 teams overall. Robustness of the number of teams belonging to the top category is discussed in Section 5.4.2.

The results are shown in Table 5.3. The first two columns suggest that the number of offensive holdings decreased with an addition of eighth official already in 2014, however, only for the teams with a high offensive quality. This result indicates presence of the deterrence effect within teams with high offensive ability.

The third and fourth columns report the roughing the passer analysis broken down to whether the defensive team belongs to the top 25 teams or not. We can see that the effect is insignificant for the teams with the highest defensive quality. This can either mean that there was no effect for these teams, or that (similarly as it seems to be with offensive holding) the high-quality teams alter their behavior. However, given that the overall roughing the passer rates are the same across the two categories of teams, the difference between the two coefficients could arguably be caused by teams' ability to change their strategic behavior after the policy change. In other words, if there is a deterrence effect, it likely is present for the relatively highly skilled teams.

Table 5.3: Breakdown by Team Quality (LPM)

	Offensive Holding		Roughing the Passer	
	Top 25	Other	Top 25	Other
	Offense	Offense	Defense	Defense
	(1)	(2)	(3)	(4)
Eight-men crew in 2014	-0.0078*** (0.0026)	0.0007 (0.0011)	0.0023 (0.0021)	0.0016** (0.0007)
Eight-men crew in 2015	-0.0033 (0.0025)	0.0028*** (0.0011)	0.0008 (0.0018)	0.0010* (0.0006)
Yards to 1st down	0.0007*** (0.0002)	0.0005*** (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)
Field position	0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)
Passing play	-0.0084*** (0.0014)	-0.0057*** (0.0007)		
Constant	-0.0445*** (0.0106)	0.0035 (0.0051)	0.0050 (0.0082)	-0.0002 (0.0049)
N	30,282	116,910	15,220	56,744

Columns are separated by the rankings based on own (opponents') yards gained (allowed) in the previous season.

All columns include full set of fixed effects for down, quarter, teams, and referee.

Standard errors adjusted for clusters by the referee in parentheses.

Significance levels: \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Source: Estimation of the model.

## 5.4 Robustness Checks

### 5.4.1 Match Pair Fixed Effects

In this section we perform alternative specification of the regressions. Instead of including a set of fixed effects for the home team and a second set of fixed effects for the visiting team, we only keep those games where teams played with each other in both of the years and include a fixed effect for a match-pair combination, ignoring which team played at home and which on the road.

The results are reported in Table 5.4. Interestingly, all coefficients almost double



in magnitude. Moreover, the results for all penalties and offensive holding are more precisely estimated due to the benchmark being more specifically set utilizing match-pair fixed effects.<sup>30</sup>

In the case of roughing the passer coefficients, its value is larger but less precisely estimated.<sup>31</sup> Nevertheless, the reported value is qualitatively consistent with other results.

Table 5.4: Match Pair Fixed Effects

	All penalties		Offensive Holding		Roughing the Passer	
	Team	Match-pair	Team	Match-pair	Team	Match-pair
	(1)	(2)	(3)	(4)	(5)	(6)
Eight-men crew in 2014	-0.0006 (0.0021)	0.0036 (0.0039)	0.0000 (0.0011)	0.0014 (0.0015)	0.0014** (0.0007)	0.0021* (0.0011)
Eight-men crew in 2015	0.0043** (0.0020)	0.0082*** (0.0029)	0.0020** (0.0009)	0.0044*** (0.0012)	0.0006 (0.0006)	0.0014 (0.0009)
Yards to 1st down	0.0006*** (0.0002)	0.0002 (0.0002)	0.0005*** (0.0001)	0.0006*** (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)
Field position	-0.0001*** (0.0000)	-0.0001** (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)
Passing play	0.0273*** (0.0012)	0.0283*** (0.0019)	-0.0063*** (0.0007)	-0.0069*** (0.0011)		
Constant	0.0192 (0.0154)	0.0288* (0.0154)	-0.0062 (0.0058)	0.0072 (0.0063)	0.0083** (0.0033)	0.0034 (0.0043)
N	147,192	45,211	147,192	45,211	71,964	22,394

Columns headed by “Team” come from the baseline specification. Columns headed by “Match-pair” only include teams that played each other twice during the sample period.

All columns include full set of fixed effects for down, quarter, teams, and referee.

Standard errors adjusted for clusters by the referee in parentheses.

Significance levels: \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Source: Estimation of the model.

<sup>30</sup>Note that the term “more precisely estimated” is meant in connection with the absolute value of the coefficient. In other words, it does not correspond to a tighter confidence interval, but rather to a result with a higher statistical significance.

<sup>31</sup>Note that because it was the 2014 coefficient that was significant for roughing the passer regressions, the alternative specification with match-pair fixed effects brings less precision into the estimation of this coefficient. The reason for this is that due to the structure of the competition no two teams played twice with each other during the course of one season.

Note also that due to the data being available only for a subsample of games, the reduction in sample size is substantial. The fact that the results hold even after such decrease in the number of observations strengthens the validity of our results.

### 5.4.2 Number of Top Teams Considered

Even though it is customary to rank the top 25 teams in college sports, the choice of splitting the sample to the best 25 teams remains arbitrary. The sensitivity of the coefficient on eight officials in the second season based on the number of top offensive teams is depicted in Figure 3. Full regression results are presented in Table A.1 in Appendix A.

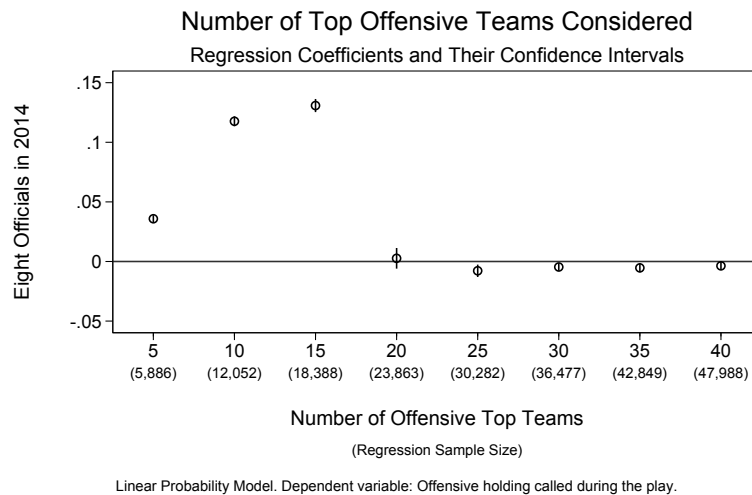


Figure 3: Offensive Holding and Number of Top Teams

We can see that the result found for the top 25 teams holds if we relax the condition for the 25 teams towards a higher number, but, somewhat surprisingly, does not hold if we constrain the estimation to only few teams with the strongest offense. Even more surprisingly, analysis of 5, 10 and 15 top teams suggests exactly the opposite scenario for these teams. A possible explanation of this finding is that

the best teams are so good that they do not need to adjust their behavior in sense of not being afraid of a penalty being called. Alternatively, it may be that the top 15 teams are the most skilled and aggressive ones, hence the addition of the extra official means that there is a stronger monitoring effect.

The sensitivity of the coefficient for the effect during the 2014 season on the roughing the passer penalties is examined in Figure 4. Similarly as in the previous case, the full regression results are reported in Table A.2 in Appendix A.

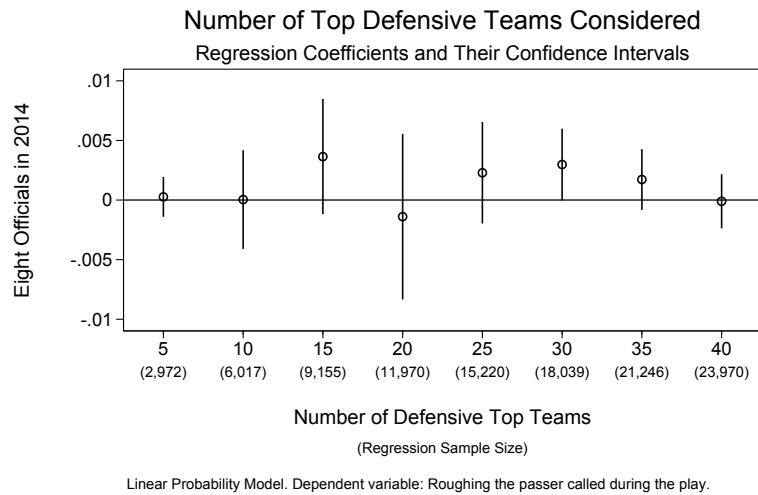


Figure 4: Roughing the Passer and Number of Top Teams

We can see that in the roughing the passer case the interpretation of a possible presence of the deterrence effect holds regardless of how many of the top defensive teams are considered. Interestingly, the very top teams show an increase in the number of roughing the passer penalties in the second season (see Table A.2 in Appendix A).

### 5.4.3 Logit Specification

Due to the direct interpretation of regression coefficients and its lower computational time required, all results reported in the main text come from a linear probability model. In order to check for robustness to alternative functional form, the analysis was re-estimated using a logit specification.

Note that, unfortunately, some of the specifications are not estimable with a logit specification while keeping a full set of fixed effects. The reason is that in case there are either a very few observations where the dependent variable is equal to one (such as is the case with the roughing the passer penalties) and/or the sample size is not large enough, including all sets of fixed effects into the analysis causes the model likelihood to be flat, hence convergence is not achieved while estimating the full form of the model.

In order to overcome this issue, we re-estimated these models without referee fixed effects. The problem, however, persisted in the specific case of defensive team quality regressions, where there was a combination of both small sample size and very small proportion of penalties in the sample. Therefore, in these regressions we kept the referee fixed effects in the model but excluded team fixed effects. In all cases where the logit estimation was performed using a different set of fixed effects, we estimated the same regression using the linear probability model as well. The comparison can be found in Table B.5 in Appendix B.

The marginal effects from the logit estimation are reported in tables in Appendix B. All results are qualitatively identical to their linear probability model counterparts. Therefore, we conclude that there is not a severe functional form specification

issue in the whole analysis.

## 6 Conclusions

This study is the first to evaluate the policy change of increasing the number of collegiate football officials from seven to eight in the highest level of NCAA football and at the same time the first to examine the effect of the number of officials on penalties called using a football dataset. Comparing our results with the previous literature, this is the first study to find evidence of both the monitoring and deterrence effect.

Analyzing a play by play dataset from two seasons of college football games, we report evidence of a monitoring effect being present in the overall dataset. Moreover, analysis of offensive holding and roughing the passer penalties which constitute misconduct that is especially likely to be observed by the added official also suggest that there is a monitoring effect present.

We also report limited evidence of the deterrence effect being present in two scenarios. First, we find an indication of a deterrence effect canceling out with the monitoring effect in the roughing the passer penalties during the second observed season. This is likely caused by between-season change in team behavior. Second, we find limited evidence of the deterrence effect being present in both types of penalties when only teams with moderately high ability are considered. This indicates that teams with high skills are able to strategically interact based on the policy change.

The results are robust to alternative specification of fixed effects, functional form of the estimation, and the number of teams considered in the relatively high-skilled group.

## References

- Becker, G. S. (1968). Crime and punishment: An economic approach. In *The Economic Dimensions of Crime* (pp. 13–68). Springer.
- Chalfin, A. & McCrary, J. (2014). Criminal deterrence: A review of the literature. *Journal of Economic Literature*. In press.
- Heckelman, J. C. & Yates, A. J. (2003). And a hockey game broke out: Crime and punishment in the nhl. *Economic Inquiry*, 41(4), 705–712.
- Kitchens, C. (2014). Identifying changes in the spatial distribution of crime: Evidence from a referee experiment in the national football league. *Economic Inquiry*, 52(1), 259–268.
- Levitt, S. D. (2002). Testing the Economic Model of Crime: The National Hockey League’s Two-Referee Experiment. *The B.E. Journal of Economic Analysis & Policy*, 1(1), 1–21.
- McCormick, R. E. & Tollison, R. D. (1984). Crime on the Court. *Journal of Political Economy*, 92(2), 223–35.
- Paternoster, R. (2010). How much do we really know about criminal deterrence? *The Journal of Criminal Law and Criminology*, 765–824.

## A Appendix A: Number of Teams in Top Quality Category

Tables A.1 and A.2 show full regression results from regressions on subsamples on the top teams discusses in Section 5.4.2. Specifically, the coefficients in the first row of Table A.1 are depicted in Figure 3. Figure 4 shows coefficients in the second row of Table A.2.

The sample restriction was performed based on the total number of offensive yards gained in the previous season, with the highest number of own yards being the best for in case of offensive ranking and the lowest number of opponents' yards evaluated the best for ranking of the defense.

Table A.1: Offensive Holding Regression: Number of top offensive teams considered

	Top 5	Top 10	Top 15	Top 20	Top 25	Top 30	Top 35	Top 40
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Eight-men crew in 2014	0.0358*** (0.0015)	0.1176*** (0.0021)	0.1308*** (0.0028)	0.0027 (0.0044)	-0.0078*** (0.0026)	-0.0046*** (0.0016)	-0.0053*** (0.0018)	-0.0037** (0.0018)
Eight-men crew in 2015	0.0477*** (0.0015)	0.1933*** (0.0030)	0.2134*** (0.0042)	0.0104*** (0.0034)	-0.0033 (0.0025)	-0.0001 (0.0017)	-0.0019 (0.0017)	-0.0015 (0.0017)
Yards to 1st down	0.0006 (0.0006)	0.0008** (0.0003)	0.0010*** (0.0003)	0.0008*** (0.0003)	0.0007*** (0.0002)	0.0007*** (0.0002)	0.0006*** (0.0002)	0.0007*** (0.0002)
Field position	0.0000 (0.0001)	-0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)
Passing play	-0.0081** (0.0033)	-0.0086*** (0.0022)	-0.0075*** (0.0018)	-0.0081*** (0.0016)	-0.0084*** (0.0014)	-0.0091*** (0.0013)	-0.0082*** (0.0012)	-0.0077*** (0.0012)
Constant	-0.0296*** (0.0057)	-0.2217*** (0.0040)	0.1170*** (0.0061)	-0.0244*** (0.0077)	-0.0445*** (0.0106)	-0.0325*** (0.0106)	-0.0306*** (0.0107)	-0.0281*** (0.0089)
N	5,886	12,052	18,388	23,863	30,282	36,477	42,849	47,988

Standard errors adjusted for clusters by the referee in parentheses.

Significance levels: \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Source: Estimation of the model.



Table A.2: Roughing the Passer Regression: Number of defensive top teams considered

	Top 5	Top 10	Top 15	Top 20	Top 25	Top 30	Top 35	Top 40
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Eight-men crew in 2014	0.0003 (0.0008)	0.0000 (0.0021)	0.0036 (0.0024)	-0.0014 (0.0035)	0.0023 (0.0021)	0.0030* (0.0015)	0.0017 (0.0013)	-0.0001 (0.0011)
Eight-men crew in 2015	0.0007 (0.0009)	0.0129*** (0.0032)	0.0183*** (0.0038)	-0.0011 (0.0026)	0.0008 (0.0018)	0.0007 (0.0016)	-0.0001 (0.0013)	-0.0014 (0.0011)
Yards to 1st down	0.0003 (0.0005)	0.0003 (0.0003)	0.0003 (0.0002)	0.0001 (0.0002)	0.0001 (0.0001)	0.0000 (0.0001)	0.0001 (0.0001)	0.0000 (0.0001)
Field position	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)
Constant	-0.0049 (0.0062)	0.0016 (0.0044)	-0.0144** (0.0059)	0.0153 (0.0106)	0.0050 (0.0082)	0.0090 (0.0071)	-0.0002 (0.0071)	0.0035 (0.0066)
N	2,972	6,017	9,155	11,970	15,220	18,039	21,246	23,970

Standard errors adjusted for clusters by the referee in parentheses.

Significance levels: \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Source: Estimation of the model.

## B Appendix B: Logit Results

Tables in this section present regression results based on alternative functional form using logit estimation. Otherwise specification of all tables is identical. The particular sub-number of all tables corresponds to sub-numbers of tables in Section 5.<sup>32</sup>

Note that in columns marked by subscripts <sup>R</sup> or <sup>T</sup> in the heading of the columns, the regression does not include referee or team fixed effects and is therefore not directly comparable to the appropriate regression in the main text. The reason is that some of the specifications were not estimable using a logit while keeping a full set of fixed effects due to either small number of observations with the dependent variable equal to one or insufficient sample size causing the likelihood function to become flat.

As discussed in Section 5.4.3, in order to establish validity of comparisons in the case described in the previous paragraph, we decided to re-estimate these models without referee or team fixed effects using both the linear probability model and logit specifications. Results of these regressions are shown in Table B.5.

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<sup>32</sup>Thus, for example, Table B.2 corresponds to Table 5.2.

Table B.1: Marginal Effects from Logit Model: All penalties

	(1)	(2)	(3)	(4)
Eight-men crew in 2014	-0.0009 (0.0018)	-0.0008 (0.0017)	-0.0007 (0.0020)	-0.0002 (0.0021)
Eight-men crew in 2015	0.0025 (0.0017)	0.0028* (0.0017)	0.0035** (0.0017)	0.0046** (0.0020)
Yards to 1st down		0.0006*** (0.0001)	0.0005*** (0.0001)	0.0005*** (0.0001)
Field position		-0.0001*** (0.0000)	-0.0001*** (0.0000)	-0.0001*** (0.0000)
Passing play		0.0285*** (0.0013)	0.0281*** (0.0013)	0.0282*** (0.0013)
N	148,097	147,192	147,192	147,192

Standard errors adjusted for clusters by the referee in parentheses.

Significance levels: \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Source: Estimation of the model.

Table B.2: Marginal Effects from Logit Model: Area of Coverage

	Offensive Penalties (1)	Defensive Penalties (2)	Offensive Holding (3)	Offensive PI <sup>1R</sup> (4)	Roughing the Passer <sup>R</sup> (5)
Eight-men crew in 2014	0.0024* (0.0014)	-0.0033* (0.0017)	0.0002 (0.0012)	-0.0014 (0.0012)	0.0009 (0.0013)
Eight-men crew in 2015	0.0047*** (0.0013)	-0.0007 (0.0015)	0.0022** (0.0009)	-0.0009 (0.0009)	-0.0001 (0.0012)
Yards to 1st down	0.0005*** (0.0001)	-0.0000 (0.0001)	0.0005*** (0.0001)	-0.0003*** (0.0001)	0.0001 (0.0001)
Field position	-0.0000 (0.0000)	-0.0001*** (0.0000)	0.0000 (0.0000)	-0.0000** (0.0000)	-0.0000 (0.0000)
Passing play	0.0008 (0.0009)	0.0301*** (0.0011)	-0.0064*** (0.0007)		
N	147,192	146,639	145,402	44,484	43,918

The dependent variable is specified by the column heading.

All columns include full set of fixed effects for down, quarter, teams, and referee.

Standard errors adjusted for clusters by the referee in parentheses.

Significance levels: \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

<sup>1</sup> PI stands for “Pass Interference”.

<sup>R</sup> Robust regression estimated without referee fixed effects.

Source: Estimation of the model.

Table B.3: Breakdown by Team Quality (Logit MEs)

	Offensive Holding		Roughing the Passer	
	Top 25 Offense <sup>R</sup> (1)	Other Offense (2)	Top 25 Defense <sup>T</sup> (3)	Other Defense <sup>T</sup> (4)
Eight-men crew in 2014	-0.0089*** (0.0028)	0.0012 (0.0013)	0.0017 (0.0040)	0.0001 (0.0008)
Eight-men crew in 2015	-0.0021 (0.0027)	0.0032*** (0.0011)	-0.0024 (0.0029)	0.0004 (0.0008)
Yards to 1st down	0.0006*** (0.0002)	0.0004*** (0.0001)	0.0001 (0.0003)	0.0001 (0.0001)
Field position	0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)
Passing play	-0.0100*** (0.0017)	-0.0058*** (0.0007)		
N	25,630	115,353	7,479	45,269

Columns are separated by the rankings based on own (opponents') yards gained (allowed) in the previous season.

All columns include full set of fixed effects for down, quarter, teams, and referee.

Standard errors adjusted for clusters by the referee in parentheses.

Significance levels: \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

<sup>R</sup> Robust regression estimated without referee fixed effects.

<sup>T</sup> Robust regression estimated without team fixed effects.

Source: Estimation of the model.

Table B.4: Match Pair Fixed Effects (Logit MEs)

	All penalties		Offensive Holding		Roughing the Passer	
	Team	Match-pair	Team	Match-pair	Team <sup>R</sup>	Match-pair <sup>R</sup>
	(1)	(2)	(3)	(4)	(5)	(6)
Eight-men crew in 2014	-0.0002 (0.0021)	0.0024 (0.0041)	0.0002 (0.0012)	0.0011 (0.0017)	0.0009 (0.0013)	-0.0000 (0.0027)
Eight-men crew in 2015	0.0046** (0.0020)	0.0079** (0.0031)	0.0022** (0.0009)	0.0046*** (0.0015)	-0.0001 (0.0012)	-0.0002 (0.0020)
Yards to 1st down	0.0005*** (0.0001)	0.0001 (0.0002)	0.0005*** (0.0001)	0.0005*** (0.0001)	0.0001 (0.0001)	0.0003 (0.0003)
Field position	-0.0001*** (0.0000)	-0.0001** (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	-0.0000 (0.0000)	-0.0001 (0.0000)
Passing play	0.0282*** (0.0013)	0.0294*** (0.0021)	-0.0064*** (0.0007)	-0.0071*** (0.0012)		
N	147,192	45,410	145,402	42,603	43,918	8,003

Columns headed by “Team” come from baseline specification. Columns headed by “Match-pair” only include teams that played each other twice during the sample period.

All columns include full set of fixed effects for down, quarter, teams, and referee.

Standard errors adjusted for clusters by the referee in parentheses.

Significance levels: \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

<sup>R</sup> Robust regression estimated without referee fixed effects.

Source: Estimation of the model.

Table B.5: Regressions with Different Sets of Fixed Effects: Comparison of LPM and Logit Marginal Effects

	(1) to (8): Without Referee Fixed Effects						(9) to (12): Without Team Fixed Effects					
	Offensive PI <sup>1</sup>		Rough. the Passer		Rough. the Passer (Match-pair FE)		Offensive Holding (Top 25 Offense)		Rough. the Passer (Top 25 Defense)		Rough. the Passer (Other Defense)	
	LPM (1)	Logit (2)	LPM (3)	Logit (4)	LPM (5)	Logit (6)	LPM (7)	Logit (8)	LPM (9)	Logit (10)	LPM (11)	Logit (12)
Eight-men crew in 2014	-0.0009 (0.0008)	-0.0014 (0.0012)	0.0007 (0.0007)	0.0009 (0.0013)	-0.0001 (0.0010)	-0.0000 (0.0027)	-0.0007 (0.0023)	-0.0089*** (0.0028)	0.0008 (0.0017)	0.0017 (0.0040)	0.0001 (0.0006)	0.0001 (0.0008)
Eight-men crew in 2015	-0.0007 (0.0005)	-0.0009 (0.0009)	-0.0000 (0.0005)	-0.0001 (0.0012)	-0.0001 (0.0008)	-0.0002 (0.0020)	0.0011 (0.0021)	-0.0021 (0.0027)	-0.0011 (0.0011)	-0.0024 (0.0029)	0.0003 (0.0006)	0.0004 (0.0008)
Yards to 1st down	-0.0002*** (0.0001)	-0.0003*** (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)	0.0003 (0.0003)	0.0008*** (0.0002)	0.0006*** (0.0002)	0.0001 (0.0001)	0.0001 (0.0003)	0.0001 (0.0001)	0.0001 (0.0001)
Field position	-0.0000* (0.0000)	-0.0000** (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0001 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)
Passing play							-0.0081*** (0.0014)	-0.0100*** (0.0017)				
N	71,964	44,484	71,964	43,918	22,511	8,003	30,282	25,630	15,220	7,479	56,744	45,269

Standard errors adjusted for clusters by the referee in parentheses.

Significance levels: \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Source: Estimation of the model.

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