Division of Economics
A.J. Palumbo School of Business Administration and
McAnulty College of Liberal Arts
Duquesne University
Pittsburgh, Pennsylvania

Moral Hazard in Baseball: Does Relief Pitching Increase the Number of Hit Batsmen?

Kevin Baldini

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Faculty Advisors Signature Page

Mark T. Gillis Date
Instructor of Economics

Matt E. Ryan, Ph. D. Date
Assistant Professor of Economics

Previous research argues that the adoption of the designated hitter in baseball creates a moral hazard problem. By having designated hitters bat in place of pitchers, such pitchers become insured from retaliation when batting, and are consequently more likely to hit a batter when they are pitching. However, past research has only accounted for moral hazard in the form of the designated hitter. This paper analyzes the possibility of two other forms of moral hazard by controlling for the number of relief pitchers used in a game and the number of games remaining against an opposing team. Game-level results for these additional variables are consistent with the moral hazard hypothesis, while player-level results are not.

JEL classifications: D81, L83

Key words: Moral Hazard, Baseball, Relief Pitching, Games Remaining, Designated Hitter,

Retaliation

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I. Introduction

Prior to 1973, both the American League and the National League[1] required each team's pitcher to bat like any other position player. However, in 1973, Major League Baseball introduced the designated hitter rule for the American League. The designated hitter rule allowed for a player on the team to bat in place of the pitcher. Since pitchers are generally poor hitters, Major league Baseball believed that replacing pitchers with good hitters would enhance the offensive side of the game and increase fan interest. What Major League Baseball did not account for was the creation of a possible moral hazard situation.

The moral hazard in baseball hypothesis, originated by Goff, Shughart, and Tollison (1997), is that when pitchers do not bat regularly, they do not face the possibility of retaliation for their actions when pitching, and consequently pitch more recklessly. Past research has typically tested the moral hazard hypothesis by comparing games in which the designated hitter is present, such as the American League after the designated hitter rule was adopted, to games where the designated hitter is not present, such as in the National League and the American League prior to adopting the designated hitter rule. In most cases, the designated hitter is found to be positively correlated with the number of hit batsmen, lending support to the moral hazard hypothesis.

Using game-level data, this paper attempts to identify other forms of moral hazard in Major League Baseball, and in particular looks at whether there is moral hazard in relief pitching and the number of games remaining against an opponent. Since a relief pitcher in the National League rarely bats, and in turn faces little threat of retaliation, going from a starter to a reliever in the National League should also introduce moral hazard. Therefore, the effect of an additional

[1] The American League and the National League are the two leagues that make up Major League Baseball. For a description of these and other baseball terms, see Appendices 1A and 1B.

relief pitcher on the number of batters hit in the National League should be greater than in the American League. Similar to relief pitching, the moral hazard hypothesis predicts that an additional game remaining against an opponent in the American League should have more of an effect on the number of batters hit in a game than in the National League because a National League pitcher may face retaliation not only in the current game, but also in a future game. Since pitchers in the American League also do not have to bat in future games, this retaliation possibility is not an issue in the American League. Game-level results suggest that the number of relief pitchers and the number of games remaining against an opponent are consistent with the moral hazard in baseball hypothesis.

This paper also looks at player-level data in order to test the robustness of the game-level results in this paper and previous research. Since a National League reliever faces little threat of retaliation, and an American League starter and American League reliever face no threat of retaliation, the moral hazard hypothesis predicts that these three types of pitchers should hit more batters than a National League starter who regularly faces the threat of retaliation. Unlike the game-level results, player-level results do not support the moral hazard hypothesis.

II. Literature Review

Moral hazard occurs whenever an individual is insured against a risk and that individual acts in a manner differently than he would if not insured from that risk. In economics, moral hazard is most commonly discussed in the context of insurance and financial markets. For example, Arrow (1963) considers moral hazard in health insurance markets and claims that health insurance often leads to an increase in the demand for medical care. When insured individuals no longer bear the full cost of medical care, they have an incentive to undertake riskier health activities (such as smoking) and also to request pricier and more elaborate health services. Stiglitz and Weiss (1981) argue that in credit markets, limited liability can lead borrowers to undertake riskier projects than they otherwise would, since limited liability limits the amount that borrowers can be legally forced to repay lenders in the case of bankruptcy.

The behavior-altering effects of moral hazard situations have also been applied to numerous other economic situations beyond insurance and financial markets. Peltzman (1975) looks at the effect of mandatory seat belt laws and finds that while seat belt laws decrease the number of fatal car accidents, they also increase the number of non-fatal car accidents. Peltzman suggests that when people are insured against fatal accidents, they begin to drive more recklessly, leading to more non-fatal accidents. Sobel and Nesbitt (2007) and Pope and Tollison (2009) find similar results with safety regulations in NASCAR. Their results suggest that increases in safety regulations result in more car accidents during events.

Clark and Lee (1997) consider the moral hazard created by government-funded rescue teams on Mt. McKinley. Before the government funded rescue attempts of climbers on Mt. McKinley, there were very few deaths on the mountain. However, once safety regulations and rescue teams were funded by the government, the number of deaths increased on the mountain, as untrained and inexperienced climbers were more willing to attempt climbing the mountain. Viscusi (1984) finds that child resistant packaging on dangerous medications often leads adults to be more careless in storing such medicines. Viscusi claims that this can actually lead to such medicines being easier for children to get to and can thus lead to more child deaths.

Moral hazard has also been explored in baseball. In particular, in how pitchers make decisions about how to pitch. For a pitcher, there are costs and benefits to hitting a batter. The possible benefits to hitting a batter include decreasing the batters chances of hitting the ball during future at-bats, seeking revenge for a player who was hit on the pitcher's team, and gaining utility from hitting another player. The costs involved in hitting a batter include automatically allowing the batter to go to first base (which also increases the likelihood of the opposing team scoring), possibly being thrown out of the game and suspended from future games, possibly being retaliated against himself, and possibly having one of the pitcher's teammates being retaliated against.

After the introduction of the designated hitter in 1973, a pitcher in the American League did not have to worry about being retaliated against, and hence, the marginal cost of hitting a batter was lower than that of a pitcher in the National League (where pitchers have to bat).[2] Since an American League pitcher never bats, and is thus insured against retaliation at the plate, the moral hazard hypothesis predicts that games with a designated hitter would have more hit batsmen than games without one. In the 35 years since the inclusion of the designated hitter, the American League has had a higher hit batsmen rate than the National League in all but five years. Figure 1 shows the average number of hit batsmen per game from 1901-2008 in the American League and the National League.

[2] This ignores the fact that the batter could "charge the mound" and retaliate physically against the pitcher.

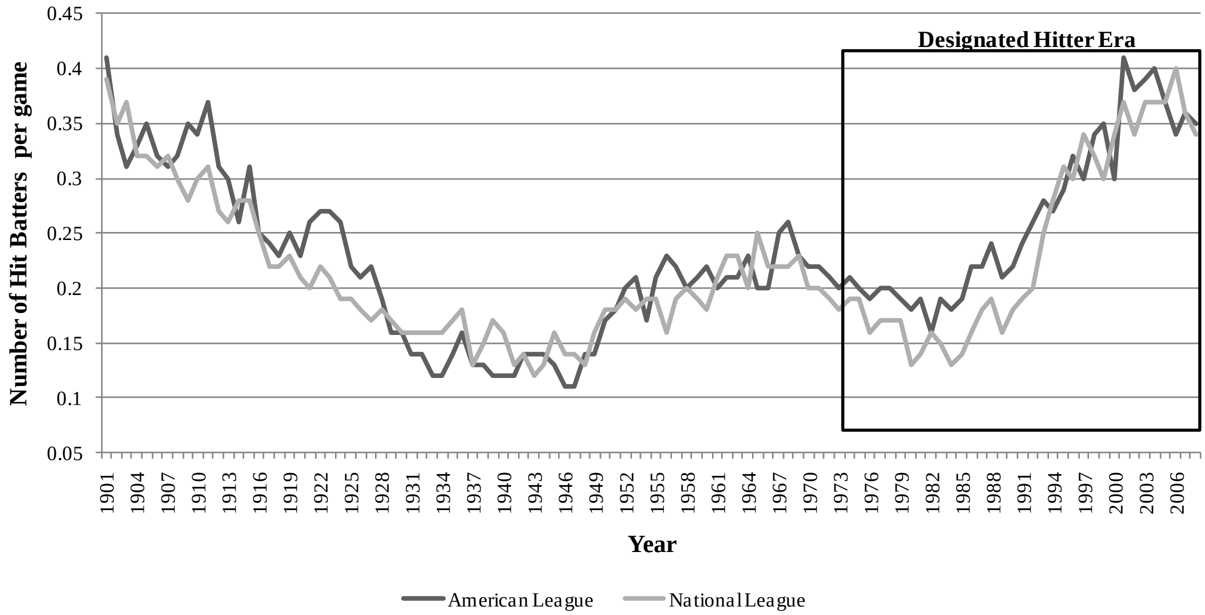

Figure 1. Average Hit Batsmen per Game

The moral hazard hypothesis in baseball was originated by Goff, Shughart, and Tollison (1997). Goff, et al. use annual data on hit batsmen from 1901 to 1990 in each league and a dummy variable to represent the years in which the designated hitter rule was present. After controlling for the differences in at-bats, they find that the designated hitter coefficient has a significant and positive effect on the number of hit batsmen. This result supports the moral hazard hypothesis that the designated hitter increased the number of hit batsmen in the American League. After controlling for additional situational game variables, they find that the designated hitter has an even stronger effect on the number of hit batsmen. Goff, et al. also find that the only other variables that are significantly associated with hit batsmen were saves and the financial rewards to winning. These findings support their assumption that aggregate data tends to cancel out the on-field variables because over the course of a 162 game season each pitcher would have likely faced similar situations.

In a response to Goff, et al., Levitt (1998) uses data from 1993-1996 and argues against moral hazard being the reason for the difference in hit batsmen between the American League and the National League. In order for it to be moral hazard, Levitt argues that pitchers must actually be retaliated against (i.e. hit by the opposing team's pitcher). Levitt claims that pitchers are hit at an extremely low rate, and even if every pitcher being hit was attributed to retribution, a pitcher was only retaliated against one out of every fifty times he hit someone. Levitt also finds evidence suggesting pitchers who hit batters more often than others are actually less likely to be hit back.[3] These findings show evidence against the moral hazard hypothesis.

In another comment on Goff, et al., Trandel, White, and Klein (1998) doubt the validity of the moral hazard hypothesis. They state that pitchers generally do not reach base, so it would be more costly to award them with a free base by hitting them. Instead, Trandel, White, and Klein argue that "star" players are hit more often because they are better batters. Using additional data from 1990-1997, Trandel, White, and Klein find no significant correlation between the designated hitter rule and the number of hit batsmen. This finding contradicts the original Goff, et al. results and suggests that the difference in hit batsmen between the American League and National League is due to something other than moral hazard.

Goff, Shughart, and Tollison (1998) respond to this criticism by claiming that something changed in the 1990's to reduce the moral hazard situation in the American League. They suggest that the Major League Baseball expansion in 1993 diluted the talent level of pitchers in the National League and this expansion led to more hit batsmen. Also, another possible reason given by Goff, Shughart, and Tollison for the reduced moral hazard situation is the creation of the double warning rule.

Stephenson (2004) proposes a new way to test for the moral hazard hypothesis. Stephenson looks at a sample of 206 starting pitchers and relief pitchers who switched from the National League to the American League, and vice versa, and compares the differences in hit

[3] Levitt's number of observations for pitchers being hit is very small.

batsmen for starting pitchers and relief pitchers. Stephenson hypothesizes that the starting pitchers' behavior should change, but the relief pitchers' should not. The reasoning for this is that relief pitchers rarely bat and therefore have a very low probability of being retaliated against. Using an equality of median change test, Stephenson cannot reject the null hypothesis that the median change in the starter's hit batsmen rate is equal to the reliever's hit batsmen rate. This evidence does not support the moral hazard hypothesis.

Using data from 1960-2002, Trandel (2004) looks at a team's hit by pitch count and compares it to the league average from that year in order to detect retaliation by pitchers. Trandel hypothesizes that if retaliation does exist, then the two would be correlated. Trandel finds no statistically significant correlation to exist, but suggests that one cannot determine from this study that retaliation does not exist, since it is widely believed that there is such a thing from those who play the game. He suggests seasonal data may be too aggregated to detect retaliation and feels future research should attempt to find a way to identify it.

Bradbury and Drinen (2006) use game-level data from 1973-2003 to test the moral hazard hypothesis in Major League Baseball. Since hit batsmen are rare events, Bradbury and Drinen feel that aggregated statistics cannot correctly control for certain factors that may affect hit batsmen. They control for the designated hitter rule by using a dummy variable for games in which the designated hitter is used. They also control for batter quality, pitcher quality, game situations, and retaliation. Similar to Trandel (2004), Bradbury and Drinen control for retaliation by looking at the number of batters hit on the pitching team in the game of analysis. After controlling for all of these variables, Bradbury and Drinen find that the designated hitter coefficient is positive and significant, which lends support to the moral hazard hypothesis. Another variable of interest for Bradbury and Drinen is the retaliation variable. They hypothesize if the pitching team's hit batsmen are correlated with the batting team's hit batsmen, then some evidence of retaliation does exist. They find that retaliation is a real concern in Major League Baseball. However, they are unable to identify if the pitcher is retaliated against.

Bradbury and Drinen also test interleague games with the same model. An interleague game is one in which National League teams play against American League teams. In such games, the rules that are used depends on which team is the home team. According to the moral hazard hypothesis, National League and American League pitchers should change their behaviors depending on the rules of the game (designated hitter or no designated hitter). In interleague games, the designated hitter and retaliation variable of batters hit are positively correlated with hit batsmen. Once again, this finding shows evidence in favor of the moral hazard hypothesis.

Bradbury and Drinen (2007) use play-by-play data in order to take the moral hazard in baseball hypothesis one step further. Bradbury and Drinen find compelling evidence of retaliation in this dataset. If a pitcher hits an opposing player in the previous half inning, then that pitcher is about four times as likely to be hit the next half inning, suggesting that pitchers are retaliated against and giving further evidence of the designated hitter rule creating a moral hazard. However, they also find that pitchers are still hit less frequently than other players, which supports Trandel, et al. (1998) and Levitt (1998).

Kawuara and Croix (2007) use team panel data from a Japanese Baseball League between 1975 and 2004 to test the moral hazard in baseball hypothesis. Like Major League Baseball, the Japanese League has two different leagues, one that uses the designated hitter and one that does not. Kawuara and Croix use two different designated hitter dummy variables, one for the years before the dangerous ball rule and one for after. As expected, the designated hitter coefficient for the years preceding the dangerous ball rule is positively correlated with hit batsmen. This result finds evidence in favor of the moral hazard hypothesis. The coefficient on their second designated hitter variable illustrates no significant affect on hit batsmen, suggesting that the inclusion of the dangerous ball rule has decreased the difference between hit batsmen in the two leagues.

Bradbury and Drinen (2008) use play-by-play data from 1989 to 1992 to test for externalities in Major League Baseball. There is a widespread belief in Major League Baseball that the quality of the batter "on deck"[4] affects the current batter. If the batter on deck is a good hitter, the current batter should be more likely to reach base. Bradbury and Drinen find evidence that contradicts this belief, suggesting that the better a batter is on deck negatively affects the current batter's chances of reaching base. One possible reason for this is that pitchers may expend more effort attempting to get the current batter out. This effect possibly also has an impact on hit batsmen. If a pitcher is expending more effort (i.e. throwing harder or putting more movement on the ball) on the current batter, he may be more likely to hit that batter. Since, the American League replaces a poor hitting pitcher with a better hitter (the designated hitter), one would expect, under the "effort hypothesis," that the American League would have more hit batsmen.

III. Data

A. Game-Level Data

The game-level data used in this paper is from Retrosheet, Inc. and Sports Reference, LLC and consists of all regular season[5] Major League Baseball games from 1973 to 2008. The

[4] "On deck" means the batter following the current batter.
[5] No playoff or World Series games are included in the data set.

year 1973 is chosen as the starting point because it is the first year in which the designated hitter was utilized. The game-level data is simply the statistics from each game throughout the course of each season for most variables. For *SluggingPct* and *EarnedRunAvg* , the statistics are season averages. The data is organized such that the batting team is the team of observation. However, since each team bats in a game, every game represents two observations. Table 1 contains the variables, definitions, and sources for the game-level data. Table 2 displays summary statistics for these variables.

Table 1. Variable Definitions and Sources for Game-Level Data

Variable	Definition	Source
Hit Batsmen	The number of batters hit by a pitch on the batting team.	Retrosheet, Inc.
DesignatedHitter	Dummy variable equal to 1 if a designated hitter was used in place of the pitcher and 0 otherwise.	Retrosheet, Inc.
SluggingPct	The average slugging percentage for the batting team in the year of analysis.	Sports Reference LLC
EarnedRunAvg	The earned run average for the pitching team in the year of analysis.	Sports Reference LLC
WildPitch	The number of wild pitches by the pitching team.	Retrosheet, Inc.
RetaliationHBP	The number of batters hit by a pitch on the pitching team.	Retrosheet, Inc.
Homeruns	The number of homeruns hit by the batting team.	Retrosheet, Inc.
ScoreDiff	The difference between the batting team’s score and the pitching team’s score.	Retrosheet, Inc.
AbsValScoreDiff	The absolute value of the score differential.	Retrosheet, Inc.
ReliefPitchers	The number of relief pitchers used by the pitching team.	Retrosheet, Inc.
ALReliefPitchers	The number of relief pitchers used by the pitching team if a designated hitter was used and 0 otherwise.	Retrosheet, Inc.
GamesRemaining	The number of games remaining between the two teams facing each other.	Retrosheet, Inc.
ALGamesRemaining	The number of games remaining between the two teams facing each other if a designated hitter was used and 0 otherwise.	Retrosheet, Inc.
Year Dummies	Dummy variables for each year equal to 1 if the game takes place in the year of reference and 0 otherwise.	Retrosheet, Inc.

Table 2. Summary Statistics for Game-Level Data

Variable	Mean	Standard Deviation	Min	Max
Hit Batsmen	0.26	0.001	0	5
Designated Hitter	0.505	0.500	0.000	1.000
SluggingPct	0.403	0.032	0.000	0.491
EarnedRunAvg	4.118	0.576	0.000	6.380
WildPitch	0.303	0.580	0.000	6.000
RetaliationHBP	0.260	0.529	0.000	5.000
Homeruns	0.913	1.020	0.000	10.000
ScoreDiff	0.000	4.246	-27.000	27.000
AbsValScoreDiff	3.366	2.589	0.000	27.000
ReliefPitchers	2.125	1.360	0.000	10.000
ALReliefPitchers	1.130	1.501	0.000	10.000
GamesRemaining	6.878	4.351	0.000	20.000
ALGamesRemaining	3.508	4.797	0.000	19.000

B. Player-Level Data

The player-level data used in this paper is from Sports Reference, LLC and is obtained from all players on Major League rosters at the end of the 2009 season who have pitched at least 5 years in Major League Baseball and at least 2 years in each the American League and the National League. The data ranges from 1986-2009, but is heavily weighted toward more recent years. The player-level data is treated as an unbalanced panel dataset, comprised of 96 pitchers over multiple years. Thus, each observation corresponds to a particular pitcher's statistics in a particular year. Table 3 contains the variables, definitions, and sources for the player-level data. Table 4 displays summary statistics for these variables.

Table 3. Variable Definitions and Sources for Player-Level Data

Variable	Definition	Source
Hit Batsmen per Game	The number of batters hit by a pitch per game by the pitcher in each year.	Sports Reference LLC
Age	The age of the pitcher in each year.	Sports Reference LLC
Walks	The number of walks allowed per game by the pitcher in each	Sports Reference LLC
EarnedRunAvg	The earned run average for the pitcher in each year.	Sports Reference LLC
Homeruns	The number of homeruns given up by the pitcher per game in each year.	Sports Reference LLC
ALReliefPitcher	A dummy variable equal to 1 if the pitcher is an American League relief pitcher in each year and 0 otherwise.	Sports Reference LLC
ALStarter	A dummy variable equal to 1 if the pitcher is an American League starting pitcher in each year and 0 otherwise.	Sports Reference LLC
NLReliefPitcher	A dummy variable equal to 1 if the pitcher is a National League relief pitcher in each year and 0 otherwise.	Sports Reference LLC
Year Dummies	Dummy variables for each year equal to 1 if it is the year of reference and 0 otherwise.	Sports Reference LLC

Table 4. Summary Statistics for Player-Level Data

Variable	Mean	Standard Deviation	Min	Max
Hit Batsmen per Game	0.387	0.015	0.000	4.500
Age	29.274	4.621	21.000	45.000
Walks	3.707	1.756	0.000	13.500
EarnedRunAvg	4.519	2.990	0.000	43.200
Homeruns	1.088	0.865	0.000	11.600
ALReliefPitcher	0.269	0.444	0.000	1.000
ALStarter	0.236	0.425	0.000	1.000
NLReliefPitcher	0.288	0.453	0.000	1.000

IV. Methodology

A. Game-Level

Following Bradbury and Drinen (2006), a Poisson regression is used to model the number of hit batsmen for a team in each game. A Poisson regression is used whenever the dependent variable is a positive count outcome with generally low numbers.[6] Equation (1) represents the

[6] Appendices 2A and 2B elaborate on the details of the Poisson regression model.

Poisson regression used to model hit batsmen in a game. This equation is estimated by maximum likelihood estimation.

$$\begin{aligned}\ln(HitBatsmen_g) &= \alpha + \beta_1 DesignatedHitter_g + \beta_2 SluggingPct_g + \beta_3 EarnedRunAvg_g \\ &+ \beta_4 WildPitch_g + \beta_5 RetaliationHBP_g + \beta_6 Homeruns_g + \beta_7 ScoreDiff_g \\ &+ \beta_8 AbsValScoreDiff_g + \beta_9 ReliefPitchers_g + \beta_{10} ALReliefPitchers_g + \beta_{11} GamesRemaining_g \\ &+ \beta_{12} ALGamesRemaing_g + \Omega' YearDummies\end{aligned} \tag{1}$$

The dependent variable $HitBatsmen_g$ is the number of hit batters on the batting team in game *g*.

The variable $DesignatedHitter_g$ is a dummy variable equal to 1 whenever game *g* is played with the designated hitter rule. If the coefficient is positive, it shows support in favor of the moral hazard hypothesis. Bradbury and Drinen (2006) find this variable to be positively associated with the number of hit batsmen.

The variable $SluggingPct_g$ represents the batting team's slugging percentage for the year the game is played in and is used to control for the batting team's batting quality. Since hitting a batter automatically rewards him with a free base, it is more costly for a pitcher to hit a poor batter. Thus, a team with a lower slugging percentage would be expected to have a lesser number of hit batters. Bradbury and Drinen (2006) control for batter quality by using the average runs scored by the team in the season the game is played. While this could be a sufficient proxy for batter quality, it is not solely a function of batting. A team could score runs because of the walks they are awarded and the number of errors the opposing team commits. However, a team's slugging percentage is almost solely a function of how well the team hits the ball.

The variable $EarnedRunAvg_g$ represents the pitching team's earned run average for the year the game is played in and is used to control for the pitching team's pitching quality. Since the number of hit batters in a game is largely accidental, the quality of the pitcher in the game may determine whether there are more hit batters. A team whose pitchers are of lesser quality may have less control and therefore hit more batters. Earned run average is commonly used by baseball analysts to judge the quality of a pitcher. A pitcher with a low earned run average is thought to be better than a pitcher with a high earned run average. Thus, this variable should be positively correlated with the number of hit batsmen.

The variable $WildPitch_g$ represents the number of wild pitches thrown by the pitching team in game *g*. This variable controls for the "wildness" of a team's pitchers. As previously stated, a large number of hit batsmen probably occur accidentally and therefore controlling for whether a team has more wild pitchers is needed. While $EarnedRunAvg_g$ is used to control for the quality of a pitcher, it cannot control for pitchers who are of high quality but may be innately wild. Past research has used the number of walks allowed by a team as a control for the wildness of a pitcher. However, it is not a sole function of the pitcher. A high quality batter should be able to judge whether the thrown ball is a ball or a strike which would therefore affect the number of walks allowed by the pitching team. A wild pitch, on the other hand, is almost only a function of the pitcher.

Like Bradbury and Drinen (2006), two retaliation variables are included, $RetaliationHBP_g$ and $Homeruns_g$. First, $RetaliationHBP_g$ is the number of batters hit on the pitching team in game *g*. If retaliation is real, one would expect the coefficient to be positively associated with the number of hit batsmen on the batting team in the same game. Bradbury and Drinen's (2006) results support this hypothesis. Next, $Homeruns_g$ represents the number of homeruns hit by the batting team in game *g*. The number of homeruns hit by the batting team may positively affect the number of hit batsmen. There is a conventional thought in baseball that after a homerun is hit, the opposing pitcher may, from time to time, hit the next batter or possibly hit the batter who hit the homerun in the future. Bradbury and Drinen's (2006) results contradict the hypothesis that homeruns would be positively correlated with hit batsmen. They find that when as the number of homeruns hit by the batting team increases, the number of batters hit by a pitch on that same team decreases.

The variables $ScoreDiff_g$ and $AbsValScoreDiff_g$ represent the final score difference and the absolute value of the final score difference between the batting team and the pitching team in game *g*. These variables are included to account for the effect of how "close" or "competitive" a game is. One of the costs of hitting a batter is that the batter is awarded first base which increases the batting team's probability of scoring a run. Consequently, the cost of hitting a batter is higher when the score differential between the batting team and the pitching team is very close.

The major difference in this paper compared to past literature is that it takes into account other possible moral hazard problems in Major League Baseball. First, past literature has failed to consider the increasing use of relief pitching in Major League Baseball. Over the years, starting pitchers have pitched fewer innings which has increased the number of relief pitchers used in a game. For some reason, possibly a "style" difference, as the number of relief pitchers used in a game increases, so does the number of hit batters. Furthermore, in the National League, there may be a moral hazard component to relief pitching. Relief pitchers tend to bat much less frequently than starting pitchers, and consequently face little to no threat of retaliation.[7] Going from a starter to a reliever in the American League can increase hit batsmen due to a "style" difference, but in the National League going from a starter to a reliever can increase hit batsmen due to a "style" difference *and* moral hazard. As a result, the number of relief pitchers used in American League games should have less of an effect on hit batsmen than relief pitchers used in National League games. Figure 2 represents the mean hit batsmen in games with different amounts of relief pitchers.

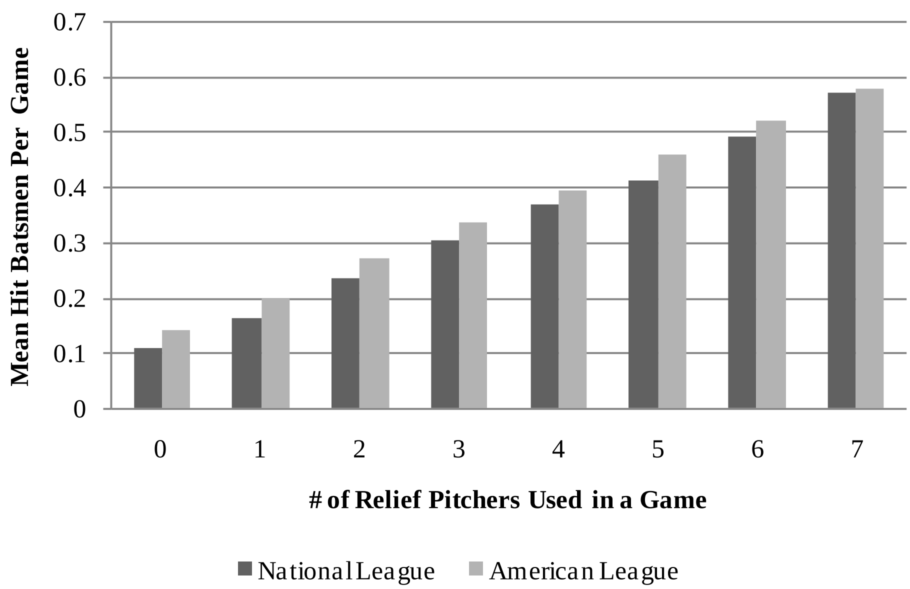

Figure 2. Mean Hit Batsmen per game and the Number of Relief Pitchers Used

In games with more relief pitchers, there is, on average, more hit batsmen. In addition, with the exception of 5 relief pitchers used in a game, the difference between the mean hit batsmen narrows between the American League and National League as more relief pitchers are used. As previously mentioned, this narrowing could be due to the possible moral hazard effect of one additional relief pitcher in National League. The variable $ReliefPitchers_g$ controls for the

[7] For example, Greg Maddux, a career National League starter, batted about 69 times per year and was hit 5 times. In contrast, Trevor Hoffman, a career National League reliever, has batted about 5 times per year and has been hit 0 times.

number of relief pitcher used in all games, and the variable $ALReliefPitchers_g$ controls for the number of relief pitchers used in American League games. Recall equation (1), but only focusing on the *ReliefPitchers* variables,

$$\ln(HBP_g) = \ldots + \beta_9 ReliefPitchers_g + \beta_{10} ALReliefPitchers_g + \ldots \quad (1)$$

For games in the National League, such that $AL = 0$, the coefficient on $ReliefPitchers_g$ is just β_9 as,

$$\ln(HBP_g) = \ldots + \beta_9 ReliefPitchers_g + \beta_{10}(0) ReliefPitchers_g + \ldots$$

or,

$$\ln(HBP_g) = \ldots + \beta_9 ReliefPitchers_g + \ldots$$

However, for games in the American League, such that $AL = 1$, the coefficient on $ReliefPitchers_g$ is $\beta_9 + \beta_{10}$, as,

$$\ln(HBP_g) = \ldots + \beta_9 ReliefPitchers_g + \beta_{10}(1) ReliefPitchers_g + \ldots$$

or,

$$\ln(HBP_g) = \ldots + (\beta_9 + \beta_{10}) ReliefPitchers_g + \ldots$$

Thus, since β_9 is the effect of an additional relief pitcher in a National League game, and $\beta_9 + \beta_{10}$ is the effect of an additional relief pitcher in an American League game, β_{10}, i.e. the coefficient on just $ALReliefPitchers_g$, represents the possible differing effect of an additional relief pitcher between the two leagues. So, if $\beta_{10} < 0$, then the effect of an additional pitcher in the American League is smaller than the effect of an additional pitcher in the National League, which would be consistent with the moral hazard hypothesis. Recall, the moral hazard hypothesis predicts the effect of an additional relief pitcher in the American League will be smaller than the effect of an additional relief pitcher in the National League.

The variables $GamesRemaining_g$ and $ALGamesRemaining_g$ apply the same logic, such that the effect of an additional game remaining in the American League is $\beta_{11} + \beta_{12}$, while the effect of an additional game remaining in the National League is just β_{11}. If $\beta_{12} > 0$, then the effect of an additional game remaining in the American League is larger than the effect of an additional game remaining in the National League, which would be consistent with the moral hazard hypothesis. The moral hazard hypothesis predicts that the effect of a game remaining in the American League would be bigger than the National League because National League pitchers are concerned about the threat of retaliation in a future game. Since American League batters still do not bat in future games, this threat is non-existent in the American League.

Lastly, $YearDummies$ is a series of dummy variables for each year that a game has taken place in order to control for specific factors that may affect hit batsmen in a given year.

B. Player-Level

An alternative way to test the moral hazard in baseball hypothesis is to compare players who have pitched in both the American League and National League. According to the moral hazard theory, a pitcher would hit more batters when he pitches in the American League. For the player-level data, several panel data regression models (including both player-fixed effects and random effects and with and without year dummies) are used to model the number of batters hit per game by a pitcher. Equation (2) represents the model used to analyze the player-level data.

$$\begin{aligned} HitBatsmenperGame_{it} &= \alpha + \beta_1 Age_{it} + \beta_2 Walks_{it} + \beta_3 EarnedRunAvg_{it} + \beta_4 Homeruns_{it} \\ &+ \beta_5 NLReliever_{it} + \beta_6 ALStarter_{it} + \beta_7 ALReliever_{it} + \varepsilon_{it} \end{aligned} \tag{2}$$

The dependent variable $HitBatsmenperGame_{it}$ represents the number of batters hit per game by pitcher *i* in year *t*.

The variable Age_{it} is a variable that controls for the age of pitcher *i* in year *t*. It is unknown whether a pitcher's age positively or negatively influences the number of hit batsmen in a year. Nevertheless, it is a factor that should be controlled for.

Similar to equation (1), a pitcher's wildness should be taken into account by including the variable $Walks_{it}$, which represents the number of walks per game issued by pitcher *i* in year *t*. It is commonly thought that the higher number of walks thrown by a pitcher, the "wilder" a pitcher is. Therefore, the number of walks should be positively correlated with the number of hit batsmen.

The variable $EarnedRunAvg_{it}$ represents the earned run average of pitcher *i* in year *t* and is used to control for the quality of the pitcher. The same logic that applies in equation (1) applies in equation (2).

The variable $Homeruns_{it}$ represents the number of homeruns given up per game by pitcher *i* in year *t*. It is included in the regression for the same reasons that it is included in equation (1).

The variables $NLReliever_{it}$, $ALStarter_{it}$, and $ALReliever_{it}$ represent variables that could possibly have moral hazard aspects to them. Both American League relief pitchers and American League starters do not bat and therefore face no threat of retaliation. Also, a National League relief pitcher bats very infrequently and therefore it is assumed that he faces little to no threat of retaliation. Since all three of these types of pitchers have no threat of retaliation, it is expected that they will hit significantly more batters than National League starters, such that the coefficient on each of these three variables is positive.

V. Game-Level Results[8]

The results from equation (1) are displayed in Table 5. Both coefficient estimates and the incident rate ratios are reported for several different specifications. Note that the form of the Poisson regression model complicates direct interpretation of the coefficient estimates. One concern with the Poisson regression model is overdispersion of the dependent variable, or that the expected mean is not equal to the variance. The deviance statistic listed in the results table indicates that the data are not overdispersed. To be safe, the results displayed in Table 5 are also displayed in Appendix 4 using the negative binomial regression instead of the Poisson regression. The negative binomial regression is similar to the Poisson regression, but it allows for overdispersion. The results between the two regressions are almost exactly the same.

[8] Since the dataset used here is similar to the dataset used by Bradbury and Drinen (2006), an attempted replication and extension of their results is presented in Appendices 3A and 3B.

Table 5. Game-Level Results

Dependent Variable: *Hit Batsmen*	(1)		(2)		(3)		(4)		(5)	
Variable	Coef.	IRR	Coef.	IRR	Coef.	IRR	Coef.	IRR	Coef.	IRR
Designated Hitter	0.123***	1.131	0.124***	1.131	0.108***	1.115	0.110***	1.117	0.163***	1.177
	(0.027)	(0.031)	(0.027)	(0.031)	(0.027)	(0.030)	(0.027)	(0.030)	(0.027)	(0.031)
Slugging Pct	0.348	1.416	0.371***	1.45	0.680***	1.973	0.712***	2.039	-	-
	(0.226)	(0.319)	(0.226)	(0.327)	(0.224)	(0.441)	(0.224)	(0.456)	-	-
Earned Run Avg	0.105***	1.111	0.107***	1.113	0.136***	1.146	0.140***	1.150	-	-
	(0.011)	(0.013)	(0.011)	(0.013)	(0.011)	(0.013)	(0.011)	(0.013)	-	-
Wild Pitch	0.047***	1.048	0.051***	1.052	0.079***	1.082	-	-	-	-
	(0.009)	(0.009)	(0.008)	(0.009)	(0.008)	(0.009)	-	-	-	-
Retaliation HBP	0.105***	1.111	0.108***	1.114	0.072***	1.075	-	-	-	-
	(0.009)	(0.010)	(0.009)	(0.010)	(0.009)	(0.009)	-	-	-	-
Homeruns	-0.051***	0.950	-0.046***	0.955	-	-	-	-	-	-
	(0.005)	(0.005)	(0.005)	(0.005)	-	-	-	-	-	-
Score Diff	0.039***	1.040	0.042***	1.043	-	-	-	-	-	-
	(0.002)	(0.001)	(0.001)	(0.001)	-		-	-	-	-
AbsVal ScoreDiff	0.016***	1.017	-	-	-	-	-	-	-	-
	(0.002)	(0.002)	-	-	-	-	-	-	-	-
Relief Pitchers	0.163***	1.180	0.160***	1.173	0.183***	1.200	0.189***	1.208	0.193***	1.213
	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)	(0.006)
ALRelief Pitchers	-0.026***	0.975	-0.025***	0.975	-0.022***	0.978	-0.022***	0.978	-0.024***	0.976
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Games Remaining	0.001	1.001	0.001	1.001	0.002	1.002	0.002	1.002	0.001	1.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
ALGames Remaining	0.005**	1.005	0.005**	1.005	0.005**	1.005	0.005**	1.005	0.006**	1.006
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Years Used	1973-2008		1973-2008		1973-2008		1973-2008		1973-2008	
Obs.	155,712		155,712		155,712		155,712		155,712	
Deviance Statistic	1.000***		1.000***		1.000***		1.000***		1.000***	

Results reported with robust standard errors. Constants and year dummies not reported.
*p-value<0.10, **p-value<.05, ***p-value<.01

The variables $RetaliationHBP_g$, $Homeruns_g$, $ScoreDiff_g$, and $AbsValScoreDiff_g$ all represent control variables used by Bradbury and Drinen (2006). The signs of the coefficients and their respective significance levels are equivalent to Bradbury and Drinen's. $SluggingPct_g$, $EarnedRunAvg_g$, and $WildPitch_g$ are control variables unique to this paper and represent player quality variables. The signs and significance levels of the coefficients are equivalent to the signs and significance levels of the coefficients associated with Bradbury and Drinen's similar control variables.

The coefficient on the designated hitter dummy variable is positive and significant which lends support to the moral hazard hypothesis and is consistent with Bradbury and Drinen (2006). The coefficient suggests that teams who play with a designated hitter hit about 5 more batters a year which means that the American League hits approximately 75 more batters a year.[9]

The number of games remaining against an opponent is insignificant. This result could be due to players hitting more batters earlier in the season. A game early in the season may not be as important as a game later in the season when teams are competing for a playoff spot. Therefore, pitchers may view games earlier in the season as "lower cost" games which results in more hit batsmen. Future research could possibly control for this problem by including a variable that interacts the competitiveness of a team and the number of games remaining.

While the number of games remaining against an opponent is insignificant, the number of games remaining against an opponent in the American League is significant and positively correlated with hit batsmen. Recall from equation (1), the effect of an additional game remaining in the American League is $\beta_{11} + \beta_{12}$ while the effect of an additional game remaining in the National League is just β_{11}. Therefore, since β_{12} is positively correlated with hit batsmen, this suggests that the effect of an additional game remaining in the American League is greater than an additional game remaining in the National League. This result is consistent with moral hazard theory and also suggests that past literature has underestimated the amount of moral hazard in Major League Baseball.

[9] For a description of how these numbers were calculated see Appendix 5.

The positive coefficient on the variable $ReliefPitchers_g$ matches what theory and Figure 2 would suggest. On average, games with more relief pitchers will have more hit batsmen than games with less relief pitchers. Since relief pitchers may have a different style than starting pitchers, the assumption cannot be made that the positive coefficient on the $ReliefPitchers_g$ variable suggests relief pitching has a moral hazard aspect to it. Nevertheless, it does imply that relief pitching has a positive effect on hit batsmen and should be controlled for in future research.

The negative coefficient on the variable $ALReliefPitchers_g$ can, however, suggest that there is some moral hazard to relief pitching. Recall equation (1) while only focusing on the relief pitching variables. The effect of a relief pitcher in the American League is $\beta_9 + \beta_{10}$ and the effect of a relief pitcher in the National League is just β_9. Since β_{10} is negative, it suggests that, on average, the effect of an additional relief pitcher in the American League is smaller than the effect of an additional relief pitcher in the National League. This finding is consistent with what moral hazard theory would suggest. If the only difference between relief pitching and starting pitching was "style", then there would be no difference in hit batsmen between the two leagues, but this result suggests that there is a difference between the two leagues and the most likely reason is moral hazard. Figure 3 shows the mean hit batsmen per game from the results assuming different levels of relief pitchers between the American League and the National League.

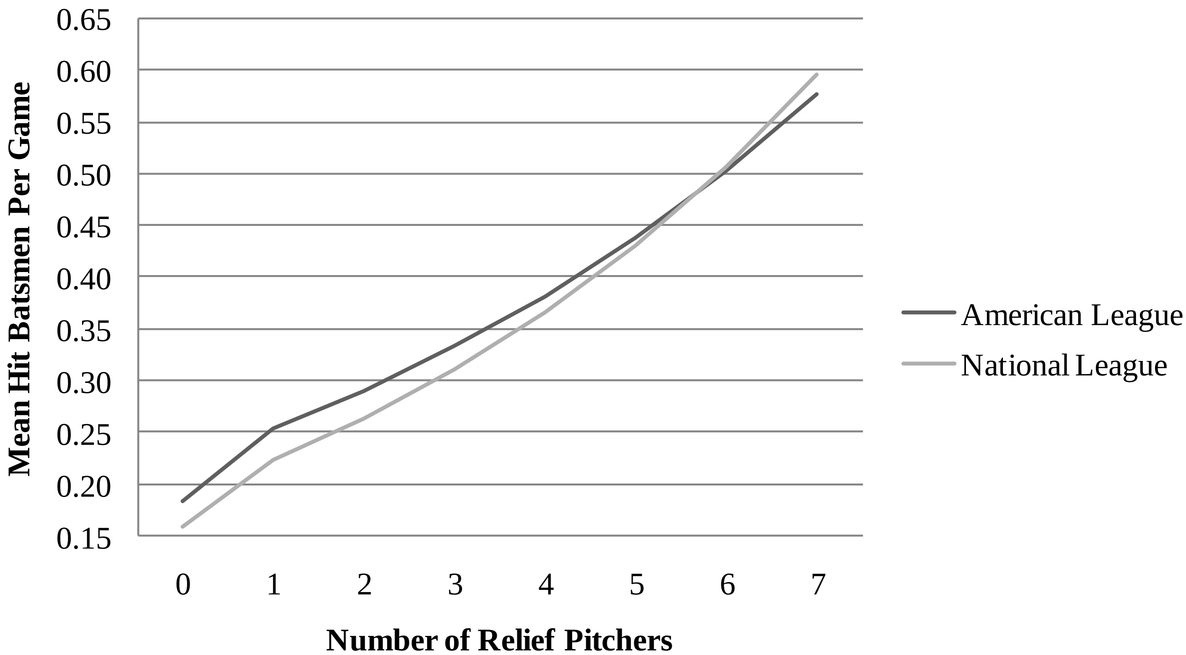

Figure 3. Moral Hazard in Relief Pitching and Hit Batsmen

As the number of relief pitchers used in a game increases, the difference in the mean hit batsmen per game decreases between the American League and National League.

VI. Implications

Past research has debated the reason for the diminishing difference in hit batsmen between the American League and the National League. From 1973-1993 the American League teams hit more batters per game than the National League in every year, but from 1994-2009 the National League hit more batters per game in 5 of the years. In addition, the difference between the hit batsmen between the leagues seems to have lessened. Past research suggests that maybe the Major League Baseball expansion in 1993 and the double warning rule in 1994 has caused the difference in hit batsmen to decrease.[10] The double warning rule is really a moral hazard in itself for National League pitchers. The double warning rule states that if the umpire deems a pitch to be intentionally thrown at a batter then he can warn both teams that another pitch of the same kind will result in the ejection of the pitcher and the manager (Major league Baseball Official Rules).[11] In the National League, this rule gives a pitcher the incentive to be the first pitcher to intentionally throw at another player. If the umpire then warns both teams, the cost of retaliation for the opposing team increases. Therefore, the double warning rule creates a possible moral hazard.

In addition to those reasons, the results in this paper suggest another possible reason for the decrease in the difference of hit batsmen between leagues: the increased use of relief pitching. Over the course of the designated hitter era, the number of relief pitchers used in a game has increased. The increased use of relief pitching will most likely increase the number of hit batsmen in the American League and the National League due to their "style", but it will also increase hit batsmen in the National League due to moral hazard. Therefore, the increased use of relief pitching could be a reason for the decreasing difference in hit batsmen between the two leagues. Figure 4 represents the mean number of relief pitchers used in a game for the American League and the National League from 1973-2008.

[10] The expansion added two additional teams to the National League. Thus, past researches have suggested the expansion allowed for newer pitchers who were less talented to enter the National League.
[11] Official Rule 8.02 (d)

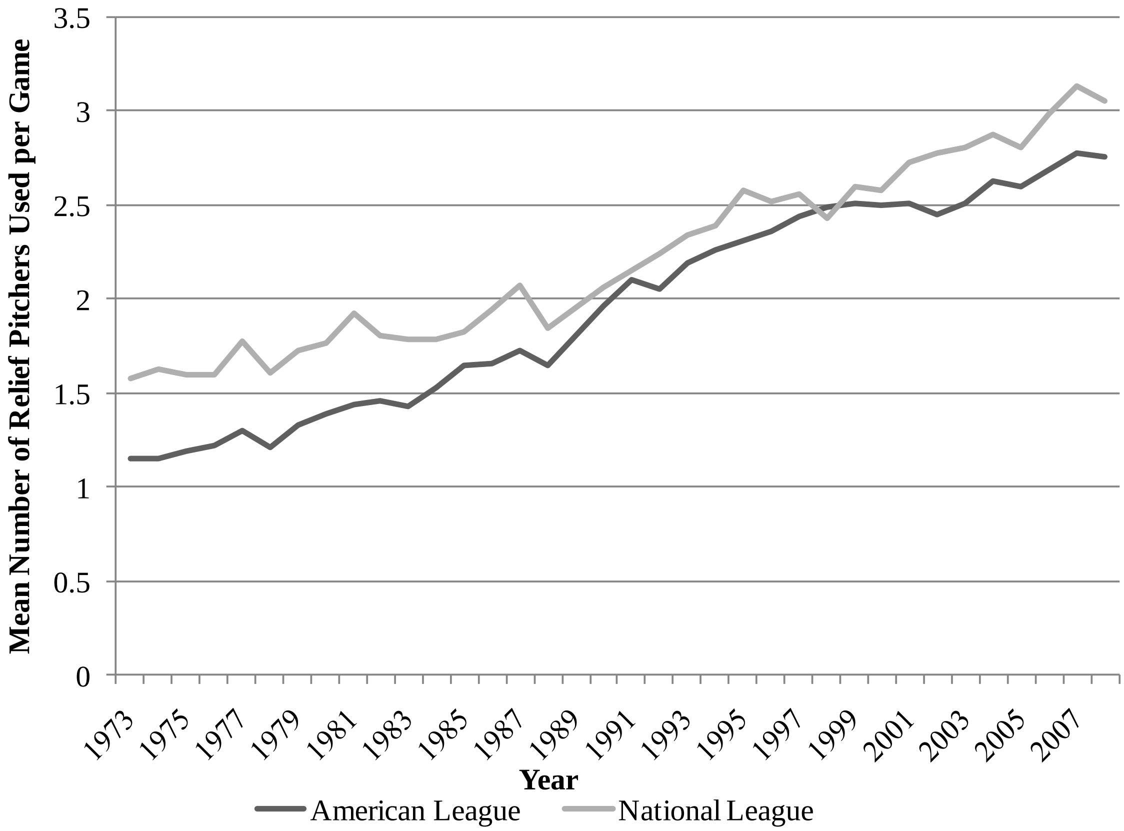

Figure 4. The Mean Number of Relief Pitchers Used per Game

Figure 4 shows the upward trend in the number of relief pitchers used per game. With the evidence of this paper, it is possible that the relief pitching moral hazard coupled with the double warning moral hazard has decreased the difference in the number of hit batsmen between the two leagues.

VII. Player-Level Results

The results for equation (2) are displayed in Table 6.

Table 6. Player-Level Results

Dependent Variable: *Hit Batsmen per Game*	(1)	2	3	4	5	6	7	8
Variable	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
Age	0.005	0.005	0.002	0.003	-	-	-	-
	(0.017)	(0.004)	(0.004)	(0.003)	-	-	-	-
Walks	0.022**	0.022**	0.031***	0.030***	-	-	-	-
	(0.011)	(0.011)	(0.010)	(0.010)	-	-	-	-
EarnedRunAvg	0.035***	0.037***	0.039***	0.041***	-	-	-	-
	(0.007)	(0.007)	(0.007)	(0.007)	-	-	-	-
Homeruns	-0.084***	-0.090***	-0.101***	-0.108***	-	-	-	-
	(0.023)	(0.022)	(0.021)	(0.021)	-	-	-	-
NLReliever	-0.015	0.013	0.019	0.025	0.013	0.015	0.060	0.064
	(0.066)	(0.067)	(0.046)	(0.045)	(0.067)	(0.065)	(0.048)	(0.047)
ALStarter	-0.002	0.008	0.014	-0.001	0.005	0.015	0.000	0.010
	(0.046)	(0.045)	(0.043)	(0.043)	(0.047)	(0.065)	(0.045)	(0.044)
ALReliever	0.003	0.002	-0.007	0.014	0.028	0.028	0.058	0.058
	(0.065)	(0.064)	(0.043)	(0.045)	(0.066)	(0.028)	(0.048)	(0.048)
Method	FE	FE	RE	RE	FE	FE	RE	RE
Year Dummies	Yes	No	Yes	No	Yes	No	Yes	No
Years Used	1986-2009	1986-2009	1986-2009	1986-2009	1986-2009	1986-2009	1986-2009	1986-2009
Observations	808	808	808	808	808	808	808	808

Constants and year dummies not reported. *p-value<0.10, **p-value<.05, ***p-value<.01 .
A Hausman test rejects the null hypothesis at a 1% level level of significance of not different coefficient estimates between fixed and random effects estimates. However, random effects estimates are presented to show the pitching dummy variables are insignificant regardless of the specification.

The results for $EarnedRunAvg_{it}$, $Walks_{it}$, and $Homeruns_{it}$ are all consistent with their hypotheses and with their counterparts from equation (1).

The results for the three possible moral hazard variables, $NLReliever_{it}$, $ALStarter_{it}$, and $ALReliever_{it}$ are not consistent with the moral hazard hypothesis or the results from the game-level data, but are consistent with the results of Stephenson (2004). Since these three of these types of pitchers do not face retaliation, it was expected that their coefficients would be positively correlated with $HitBatsmenperGame_{it}$. One possible reason for these contradictory results is the period from which this data was collected. All of the data comes from current players and during this time frame the number of batters hit between the American League and the National League has decreased. In order for the player-level data to truly test the robustness of the game-level results, a greater amount of data should have been collected from the past and present.

The results from game-level data in more current years are consistent with the results in player-level data. From 1990-2008, game-level data suggests that American League teams do not hit significantly more batters than the National League teams.[12]

Lastly, the low number of observations for the player-level data could also be a problem. Since a hit batsman is such a rare event, it is likely that a greater number of observations are needed.

VIII. Conclusion

The purpose of this paper was to use game-level data to find other forms of moral hazard in Major League Baseball. Specifically, this paper looked at whether the number of relief pitchers used and the number of games remaining have a moral hazard aspect to them. The results for the relief pitching variables support the moral hazard hypothesis in that the effect of an additional relief pitcher in the American League is smaller than the effect than the effect of an additional relief pitcher in the National League. Also, an additional game remaining in the American League has more of an effect on hit batsmen than an additional game remaining in the National League. This result supports that moral hazard hypothesis since pitchers in the American League do not have to worry about retaliation in future games.

[12] A table of the 1991-2008 game-level results is displayed in Appendix 4.

This paper sheds new light on the debate about why the difference in hit batsmen between the American League and National League has decreased in more recent years. The results of this paper suggest it is possible, along with previous researcher's suggestions, that the increased use of relief pitching has been a driving force in decreasing the difference between the two leagues.

Future research should focus on testing the robustness of the game-level results pertaining to relief pitching. The use of player-level data was included in this paper in order to test the robustness of the game-level results. However, the results from player-level data do not support the moral hazard hypothesis. This paper only includes player-level data from current players where there seems to be diminishing evidence of the designated hitter creating a moral hazard. In hindsight, it would be more advantageous for future research to collect a larger sample of players from the past and present.

Also, this paper used game-level data to test the relief pitcher hypothesis. Another possible route for future research would be to test the relief pitcher hypothesis at the play-by-play level. Play-by-play data is the least aggregated data to date and allows for unique observations to be made.

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Appendix 1A: Baseball Terminology

Term	**Definition**
Designated Hitter	The player who bats in place of the pitcher.
Hit Batter	When the pitcher throws the ball and hits the opposing team's batter.
Wild Pitch	A ball thrown by the pitcher that is not catchable for the catcher.
American League	A league in Major League Baseball that is comprised of 14 teams and the designated hitter is allowed.
National League	A league in Major League Baseball that is comprised of 16 teams and the designated hitter is not allowed.
Digging in	A technique used by a batter in order to increase his power.
Charging the mound	When a batter charges the pitcher in order to enact some kind of physical harm.
Starting pitcher	A pitcher who starts the game, but does not necessarily finish the game.
Relief pitcher	A pitcher that comes into the game and replaces another pitcher.
Interleague game	A game in which teams from opposite leagues face each other (i.e. A team from the National League faces a team from the American League).
Single	When a batter hits the ball and runs first base.
Double	When the batter hits the ball and runs to second base.
Triple	When the batter hits the ball and runs to third base.
Homerun	When the batter hits the ball and runs to home base (he makes it around all of the bases).
Slugging Percentage	The number of total bases divided by the number of at-bats. This percentage is a good representation of batter quality. $\frac{(number\ of\ singles) + (2 \times number\ of\ doubles) + (3 \times number\ of\ triples) + (4\ \times number\ of\ homeruns)}{number\ of\ at\ bats}$
A run	When a player crosses home plate the team is awarded with a run. For example, if the score is 0 – 0 and a person scores a run, the score is now 1-0.
Error	When a player in the field misplays a ball and allows the batter to reach base when he otherwise would not have. An error is calculated in the opinion of the official score keeper.
Earned Run	Any run scored that is a sole function of pitching, and not scored because of an error.
Wild Pitcher	A pitcher who has very erratic throwing.
On Deck Batter	The batter who is set to bat after the current batter.

Appendix 1B: Baseball Rules

Designated Hitter Rule	When a player is allowed to bat in place of the pitcher. This rule is allowed in the American League, but it is not in the National League.
Hit-by-pitch	When a batter is hit by the pitcher, he is awarded first base
Walk	When a pitcher throws four balls that are not called strikes, the other team is awarded first base (like Hit-by-pitch).
Strike	When a pitcher throws the ball and the batter either: swings and misses or the ball is not swung at but is in the "strike zone". 3 strikes = 1 out and 3 outs means the inning is over.
Double Warning Rule	When an umpire deems a hit batsmen to be intentional and warns both teams that if another batter is hit intentionally, they will be thrown out of the game

Appendix 2A: Poisson Model[13]

Suppose there is a series of observed values of (X_i, y_i), for $i = 1, \ldots, n$, where X_i is a vector of independent variables and y_i is a dependent variable that is a discrete numerical variable between 0 and ∞. The Poisson model assumes that the observations of y_i are obtained from a process that approximately follows a Poisson distribution where the parameter λ_i depends on the observations of X_i, such that for $i = 1, \ldots, n$,

$$\Pr(Y = y_i | X_i) = \frac{e^{-\lambda_i} \cdot \lambda_i^{y_i}}{y_i!},$$

and λ_i takes the log-linear form,

$$\ln \lambda_i = \beta \cdot X_i \ ,$$

or by taking the exponential of both sides,

$$e^{\ln \lambda_i} = e^{\beta \cdot X_i} \Rightarrow \lambda_i = e^{\beta \cdot X_i}.$$

The likelihood function is thus,

$$L = \frac{e^{-\lambda_1} \cdot \lambda_1^{y_1}}{y_1!} \cdot \ldots \cdot \frac{e^{-\lambda_n} \cdot \lambda_n^{y_n}}{y_n!},$$

where $\lambda_i = e^{\beta \cdot X_i}$ for $i = 1, \ldots, n$.

The likelihood function is maximized with respect to the vector of coefficients β.

[13] The summary of the Poisson regression model provided here is based on Greene (2003).

Figure 5 displays the results of the actual percentage of hit batsmen and the expected number of hit batsmen.

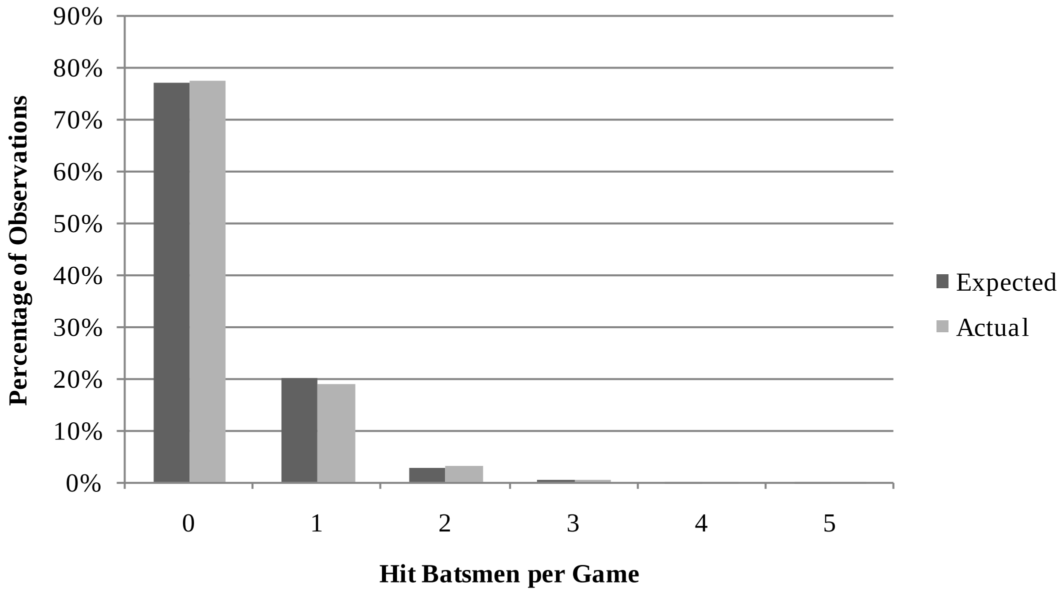

Figure 5. Overdispersion Graph

Figure 5 suggests that the data is not overdispersed, however see Appendix 4 for more assurance that the data is not overdispersed.

Appendix 2B: Poisson Coefficient and Incidence Rate Ratio

Starting at the basic Poisson model,

$$\Pr(Y = y_i | x_i) = \frac{e^{-\lambda_i} \cdot \lambda_i^{y_i}}{y_i!}$$

and,

$$\ln \lambda_i = \beta \cdot x_i \text{ or } \lambda_i = e^{\beta \cdot x_i} .$$

Ideally, we would again like to know the effect of a change in *x* on *y*, i.e. $\frac{\partial y}{\partial x}$. What if we instead consider $\frac{\partial \lambda}{\partial x}$? The interpretation of $\frac{\partial \lambda}{\partial x}$ is essentially the same as $\frac{\partial y}{\partial x}$, i.e. it will tell us the change in the expected number of occurrences of *y* for a given change in *x*.

What is $\frac{\partial \lambda}{\partial x}$? Remember $\lambda = e^{\beta \cdot x}$, so,

$$\frac{\partial \lambda}{\partial x} = \beta \cdot e^{\beta \cdot x} .$$

Notice, the change in the mean/expected number of occurrences for a given change in *x* depends on the "initial value" of *x*. In this paper the "initial value" of *x* is the mean.

Poisson – Incidence Rate Ratio (IRR)

Consider the following,

$$\ln \lambda_i - \ln \lambda_j$$

where λ_i and λ_j represent two different expected value of the number of occurrences of *y* given some observations of *x*.

Furthermore, note that,

$$\ln\lambda_i - \ln\lambda_j = \beta \cdot x_i - \beta \cdot x_j = \beta \cdot (x_i - x_j),$$

And let's assume that the difference between x_i and x_j is 1, i.e. $x_i - x_j = 1$, then,

$$\ln\lambda_i - \ln\lambda_j = \beta \cdot (1) = \beta .$$

or,

$$\ln\lambda_i - \ln\lambda_j = \ln\left(\frac{\lambda_i}{\lambda_j}\right) = \beta ,$$

and taking the exponential of both sides,

$$e^{\ln\left(\frac{\lambda_i}{\lambda_j}\right)} = e^{\beta} \Rightarrow \frac{\lambda_i}{\lambda_j} = e^{\beta} .$$

To put it more simply, the incidence rate ratio is e raised to the coefficient or, e^{β}

Appendix 3A: Bradbury and Drinen (2006) Replicating and Extending

Table 7 represents the results from replicating and extending Bradbury and Drinen's (2006) research.[14]

Most of the results in Table 7 are very similar to that of Bradbury and Drinen (2006). One trend, though, seems to be that as data from 2004-2008 is added the effect of the designated hitter decreases slightly.

[14] Note that the difference in observations in the replication section is due to Retrosheet, Inc.'s constant updating of their data as new data is released. Also, as new data is release Retrosheet, Inc. adds to past data.

Table 7. Bradbury and Drinen (2006) Replicating and Extending

Dep. Variable: *Hit Batsmen*	(1)			(2)			(3)			(4)			(5)		
Variable	B&D (2006)	Rep.	Ext.	B&D (2006)	Rep.	Ext.	B&D (2006)	Rep.	Ext.	B&D (2006)	Rep.	Ext.	B&D (2006)	Rep.	Ext.
Designated Hitter	1.077***	1.077***	1.057***	1.049***	1.049***	1.035***	1.05***	1.05***	1.034***	1.094***	1.094***	1.069***	1.122***	1.122***	1.095***
	(5.75)	(5.75)	(4.92)	(3.70)	(3.72)	(3.05)	(3.77)	(3.80)	(2.99)	(7.31)	(7.37)	(6.18)	(9.98)	(9.99)	(8.92)
Average Runs Scored	1.017	1.019	1.023**	1.059***	1.061***	1.063***	1.072***	1.074***	1.077***	1.085***	1.087***	1.089***	-	-	-
	(1.28)	(1.38)	(1.90)	(4.24)	(4.35)	(5.04)	(5.17)	(5.28)	(6.10)	(6.08)	(6.15)	(7.03)	-	-	-
Average Runs Allowed	1.077***	1.076***	1.083***	1.121***	1.12***	1.123***	1.132***	1.132***	1.136***	-	-		-	-	-
	(5.06)	(5.02)	(6.11)	(7.81)	(7.77)	(8.98)	(8.50)	(8.45)	(9.75)	-	-		-	-	-
Walks allowed	1.115***	1.116***	1.103***	1.126***	1.127***	1.115***	1.122***	1.123***	1.110***	-	-		-	-	-
	(6.21)	(13.28)	(6.38)	(6.72)	(6.77)	(7.05)	(6.52)	(6.58)	(6.80)	-	-		-	-	-
Batters Hit	1.148***	1.148***	1.136***	1.098***	1.098***	1.09***	-	-	-	-	-		-	-	-
	(13.29)	(13.28)	(14.38)	(8.95)	(8.94)	(9.67)	-	-	-	-	-		-	-	-
Home runs	0.973***	0.973***	0.971***	1.05***	1.05***	1.046***	-	-	-	-	-		-	-	-
	(4.59)	(4.62)	(5.82)	(8.90)	(8.87)	(9.31)	-	-	-	-	-		-	-	-
Score Differential	1.054***	1.054***	1.051***	-	-	-	-	-	-	-	-		-	-	-
	(35.45)	(35.44)	(38.76)	-	-	-	-	-	-	-	-		-	-	-
Absolute Score Differential	1.01***	1.01***	1.012***	-	-	-	-	-	-	-	-		-	-	-
	(4.45)	(4.45)	(5.95)	-	-	-	-	-	-	-	-		-	-	-
Observations	131342	131418	155712	131342	131418	155712	131342	131418	155712	131342	131418	155712	131342	131418	155712
Years Used	1973-2003	1973-2003	1973-2008	1973-2003	1973-2003	1973-2008	1973-2003	1973-2003	1973-2008	1973-2003	1973-2003	1973-2008	1973-2003	1973-2003	1973-2008

B&D (2006) = Bradbury and Drinen's (2006) reported results; Rep. = Attempted replication of Bradbury and Drinen's (2006) results; Ext. = Extension of Bradbury and Drinen's (2006) model using additional years. Incident rate ratios are reported with robust *z*-statistics. Constants and year dummies included in each regression, but not reported. *p-value<0.10; **p-value<0.05; ***p-value<0.01

Appendix 3B: Replicating and Extending Bradbury and Drinen (2006) – Interleague Play

Table 8. Bradbury and Drinen (2006) Replicating and Extending - Interleague Play

Dep. Variable: *Hit Batsmen*	All			Intraleague			Interleague		
Variable	B&D (2006)	Rep.	Ext.	B&D (2006)	Rep.	Ext.	B&D (2006)	Rep.	Ext.
Designated Hitter	1.044**	1.044**	1.017	1.037	1.036	1.010	1.113*	1.113*	1.096**
	(2.08)	(2.07)	(1.13)	(1.58)	(1.58)	(.62)	(1.83)	(1.83)	(2.08)
Average Runs Scored	0.989	0.988	0.974*	0.992	0.992	0.974*	0.986	0.983	0.996
	(.57)	(.58)	(1.79)	(.37)	(.36)	(1.65)	(.24)	(.30)	(.09)
Average Runs Allowed	1.037*	1.036*	1.066***	1.038	1.038	1.06***	1.051	1.05	1.144***
	(1.69)	(1.67)	(3.83)	(1.62)	(1.60)	(3.30)	(.81)	(.80)	(2.70)
Walks allowed	1.154***	1.154***	1.031	1.165***	1.165***	1.035	1.033	1.035	0.968
	(4.80)	(4.81)	(1.52)	(4.79)	(4.80)	(1.59)	(.37)	(.38)	(.52)
Batters Hit	1.123***	1.123***	1.121***	1.121***	1.12***	1.117***	1.141***	1.141***	1.16***
	(7.92)	(7.91)	(10.40)	(7.38)	(7.37)	(9.52)	(2.78)	(2.78)	(4.33)
Home runs	0.971***	0.971***	0.968***	0.972***	0.972***	0.967***	0.962	0.962	0.976
	(3.30)	(3.30)	(4.82)	(3.03)	(3.03)	(4.70)	(1.43)	(1.43)	(1.15)
Score Differential	1.048***	1.048***	1.047***	1.048***	1.048***	1.048***	1.052***	1.052***	1.041***
	(20.29)	(20.28)	(27.03)	(19.08)	(19.07)	(25.93)	(6.84)	(6.84)	(7.61)
Absolute Score Differential	1.01***	1.01***	1.013***	1.011***	1.011***	1.013***	1.001	1.001	1.014
	(2.90)	(2.91)	(5.03)	(3.00)	(3.01)	(4.69)	(.10)	(.11)	(1.71)
Years Used	1997-2003	1997-2003	1997-2008	1997-2003	1997-2003	1997-2008	1997-2003	1997-2003	1997-2008
Observations	33676	33680	57974	30284	30288	52062	3392	3392	5912

B&D (2006) = Bradbury and Drinen (2006) reported results; Rep. = Attempted replication of Bradbury and Drinen (2006) results; Ext. = Extension of Bradbury and Drinen (2006) model using additional years. Incident rate ratios are reported with robust z-statistics. Constants and year dummies not reported. *p-value<0.10, **p-value<.05, ***p-value<.01

The replication for Bradbury and Drinen's (2006) interleague play results are also very similar. In games where all the data is included, adding the 2004-2008 data makes the designated hitter variable insignificant, but in the Interleague play section it makes it more significant.

Appendix 4: Negative Binomial Regression Results

One assumption with the Poisson model is that the data are not overdispersed. While the results indicate that the data are not overdispersed, a negative binomial regression was used, as well, to be safe. Like the Poisson model, the negative binomial regression involves count outcomes, but it allows for overdispersion of the data. The results below are those of the negative binomial model. All of the results are very similar to the Poisson regression results.

Table 9. Negative Binomial Results

Dependent Variable: *Hit Batsmen*	(1)		(2)		(3)		(4)		(5)	
Variable	Coefficient	IRR	Coefficient	IRR	Coefficient	IRR	Coefficient	IRR	Coefficient	IRR
Designated Hitter	0.124***	1.131	0.124***	1.133	0.110***	1.116	0.112***	1.119	0.165***	1.180
	(0.027)	(0.031)	(0.027)	(0.031)	(0.027)	(0.030)	(0.027)	(0.030)	(0.027)	(0.031)
SluggingPct	0.353	1.423	0.377***	1.457	0.686***	1.986	0.719***	2.053	-	-
	(0.226)	(0.321)	(0.225)	(0.327)	(0.224)	(0.444)	(0.224)	(0.456)	-	-
EarnedRunAvg	0.106***	1.111	0.107***	1.113	0.137***	1.146	0.140***	1.151	-	-
	(0.011)	(0.013)	(0.011)	(0.013)	(0.011)	(0.013)	(0.011)	(0.013)	-	-
WildPitch	0.047***	1.048	0.051***	1.052	0.079***	1.082	-	-	-	-
	(0.008)	(0.009)	(0.008)	(0.009)	(0.008)	(0.009)	-	-	-	-
RetaliationHBP	0.106***	1.111	0.108***	1.114	0.072***	1.075	-	-	-	-
	(0.009)	(0.010)	(0.009)	(0.010)	(0.009)	(0.010)	-	-	-	-
Homeruns	-0.051***	0.950	-0.0461***	0.955	-	-	-	-	-	-
	(0.005)	(0.005)	(0.005)	(0.005)	-	-	-	-	-	-
ScoreDiff	0.039***	1.040	0.042***	1.043	-	-	-	-	-	-
	(0.001)	(0.001)	(0.001)	(0.001)	-		-	-	-	-
AbsValScoreDiff	0.016***	1.017	-	-	-	-	-	-	-	-
	(0.002)	(0.002)	-	-	-	-	-	-	-	-
ReleifPitchers	0.164***	1.178	0.160***	1.174	0.183***	1.201	0.190***	1.209	0.194***	1.214
	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)	(0.006)
ALReliefPitchers	-0.026***	0.974	-0.026***	0.975	-0.022***	0.978	-0.022***	0.978	-0.024***	0.976
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
GamesRemaining	0.001	1.001	0.001	1.001	0.002	1.001	0.002	1.002	0.001	1.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
ALGamesRemaining	.005**	1.005	0.005**	1.005	0.005**	1.005	0.005**	1.005	0.006**	1.006
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Years Used	1973-2008		1973-2008		1973-2008		1973-2008		1973-2008	
Observations	155,712		155,712		155,712		155,712		155,712	

Results reported with robust standard errors. Constants and year dummies not reported. *p-value<0.10, **p-value<.05, ***p-value<.01

Appendix 5: Designated Hitter Results Explanation

Using the mean as the starting point for each variable the results are as follows:

American League

Variable	Mean	Variable	Coefficient	(Mean x Coefficient) = Estimate	Estimate
Designated Hitter	1.000	*Designated Hitter*	0.123		0.123
SluggingPct	0.403	*SluggingPct*	0.348		0.140
EarnedRunAvg	4.119	*EarnedRunAvg*	0.105		0.434
WildPitch	0.303	*WildPitch*	0.047		0.014
RetaliationHBP	0.260	*RetaliationHBP*	0.105		0.027
Homeruns	0.913	*Homeruns*	-0.051		-0.047
ScoreDiff	0.000	*ScoreDiff*	0.039		0.000
AbsValScoreDiff	3.366	*AbsValScoreDiff*	0.016		0.055
ReliefPitchers	2.125	*ReliefPitchers*	0.163		0.347
ALReliefPitchers	0.995	*ALReliefPitchers*	-0.026		-0.026
GamesRemaining	6.879	*GamesRemaining*	0.001		0.010
ALGamesRemaining	3.370	*ALGamesRemaining*	0.005		0.018
1973	0.025	*1973*	-0.114		-0.003
1974	0.025	*1974*	-0.084		-0.002
...	…	...	…	…	…
2007	0.031	*2007*	0.178		0.006
2008	0.031	*2008*	0.159		0.005
Constant	1	*Constant*	-2.452		-2.452
				Sum of all the estimates =	-1.351
				Hit Batsmen = The exponential of the sum of all the estimates (e^-1.371)	**0.259**

The estimate is found by taking the mean multiplied by the coefficient.

National League

Variable	Mean	Variable	Coefficient	(Mean x Coefficient) = Estimate	Estimate
Designated Hitter	0.000	*Designated Hitter*	0.123		0.000
SluggingPct	0.403	*SluggingPct*	0.348		0.140
EarnedRunAvg	4.119	*EarnedRunAvg*	0.105		0.434
WildPitch	0.303	*WildPitch*	0.047		0.014
RetaliationHBP	0.260	*RetaliationHBP*	0.105		0.027
Homeruns	0.913	*Homeruns*	-0.051		-0.047
ScoreDiff	0.000	*ScoreDiff*	0.039		0.000
AbsValScoreDiff	3.366	*AbsValScoreDiff*	0.016		0.055
ReliefPitchers	2.125	*ReliefPitchers*	0.163		0.347
ALReliefPitchers	0.000	*ALReliefPitchers*	-0.026		0.000
GamesRemaining	6.879	*GamesRemaining*	0.001		0.010
ALGamesRemaining	0.000	*ALGamesRemaining*	0.005		0.000
1973	0.025	*1973*	-0.114		-0.003
1974	0.025	*1974*	-0.084		-0.002
...	…	...	…	…	…
2007	0.031	*2007*	0.178		0.006
2008	0.031	*2008*	0.159		0.005
Constant	1.000	*Constant*	-2.452		-2.452
				Sum of all the estimates =	-1.487
				Hit Batsmen = The exponential of the sum of all the estimates (e^-1.371)	**0.226**

Now, by taking mean hit batsmen in the American League case (0.259) minus the mean hit batsmen in the National League case (0.226), the difference between the leagues is 0.033. If you multiply 0.033 times the number of games in a season (162) this equals 5.346 or roughly 5 batters. To get how many batters the American League hits over the National League you simply take the 5.346 and multiply it by the number of teams in the American League (14).

Appendix 6: 1991-2008 Game-Level Results

Table 10. Game-Level Results 1991-2008

Dependent Variable: *Hit Batsmen*	(1)
Variable	Coef.
Designated Hitter	0.049 (0.035)
Slugging Pct	0.001 (0.270)
Earned Run Avg	0.089*** (0.013)
Wild Pitch	0.047*** (0.010)
Retaliation HBP	0.088*** (0.010)
Homeruns	-0.053*** (0.006)
Score Diff	0.038*** (0.002)
AbsVal ScoreDiff	0.019*** (0.002)
Relief Pitchers	0.147*** (0.005)
ALRelief Pitchers	-0.008 (0.009)
Games Remaining	0.002 (0.002)
ALGames Remaining	0.002 (0.003)
Years Used	1991-2008
Obs.	82,700
Deviance Statistic	1.00***

Results reported with robust standard errors. Constants and year dummies not reported.
*p-value<0.10, **p-value<.05, ***p-value<.01

Appendix 7A: Correlation Matrix for Game-Level Data

Correlation Matrix - Game-Level Data

	Designated Hitter	*Slugging Pct*	*Earned Run Avg*	*Wild Pitch*	*Retaliation HBP*	*Homeruns*	*Score Diff*	*Absolute Value of Score diff*	*Relief Pitchers*	*Games Remaining*	*AL Games Remaining*	*AL Relief Pitchers*
Designated Hitter	1.000											
Slugging Percentage	0.204	1.000										
Earned Run Average	0.233	**0.501**	1.000									
Wild Pitch	0.011	0.013	0.026	1.000								
Retaliation HBP	0.014	0.092	0.082	0.047	1.000							
Homeruns	0.040	0.219	0.169	0.013	0.020	1.000						
Score Diff	0.000	0.063	0.080	-0.125	-0.108	0.322	1.000					
Absolute Value of Score diff	0.044	0.076	0.072	0.052	0.043	0.130	0.000	1.000				
Relief Pitchers	-0.114	0.228	0.219	0.038	0.075	0.237	0.274	-0.023	1.000			
Games Remaining	-0.047	-0.116	-0.110	-0.009	-0.013	-0.022	0.000	-0.012	-0.055	1.000		
AL Games Remaining	**0.755**	0.127	0.151	0.004	0.012	0.028	0.000	0.030	-0.104	**0.402**	1.000	
AL Relief Pitchers	**0.726**	0.273	0.289	0.029	0.045	0.144	0.129	0.028	**0.390**	-0.052	0.530	1.000

Appendix 7B: Correlation Matrix for Player-Level Data

Correlation Matrix - Player-Level Data

	Age	*Earned Run Avg*	*Homeruns*	*Walks*	*NL Reliever*	*AL Starter*	*AL Reliever*
Age	1.000						
Earned Run Avg	-0.156	1.000					
Homeruns	-0.014	**0.502**	1.000				
Walks	-0.253	**0.394**	0.236	1.000			
NL Reliever	0.137	-0.038	-0.048	0.173	1.000		
AL Starter	-0.111	0.014	0.015	-0.319	-0.354	1.000	
AL Reliever	0.048	0.050	0.036	0.175	-0.386	-0.338	1.000