Explaining More Passing as a Rational Response to Decreased Risk

By

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Abstract

This paper demonstrates that increased passing in the NFL can be viewed as a rational response to rules changes in the late 1970s that markedly lowered the volatility of passing, even while yards per rush and pass attempt remained roughly constant. Simple charts (from data in two Excel workbooks available at *academic.depauw.edu/hbarreto_web/working*) illustrate how offenses in the NFL underwent a massive change from predominantly running to predominantly passing. The data exactly pinpoint, in 1978, the switch from the Classic to today's Modern Era of pro football. By splitting team passing data into sacks, incomplete, and complete passes, sensitivity analysis shows that the estimate of the SD of passing in 1975 ranges from 10.34 to 13.20.

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1. Introduction

Many fans today are aware that the NFL game is much more pass-oriented than it used to be (especially after the end of the 2011 regular season that saw a variety of passing records shattered), but they do not know when or why this happened. This paper utilizes team data from the NFL-AFL merger in 1970 to pinpoint exactly when the game changed. The Classic Era was before 1978 and, after a brief transitional period, the current Modern Era began in 1981. It was not a change in yards per rush or pass, but a shift in play calling that transformed the game. A simple explanation for the change, assisted by the logic of of optimal portfolio theory, is presented. Remarkably, it was not an increase in passing yards per attempt or a decrease in rushing yards per attempt—both of these core statistics have remained essentially unchanged throughout the period under study—but a decrease in passing volatility (driven by new rules that favored receivers and pass blockers) that explains the substantial change in how NFL teams try to score in the Modern Era.

2. Classic versus Modern Eras

The Excel workbook, NFLTeamData19702009.xls, freely available for download at *academic.depauw.edu/hbarreto_web/working*, has team data on rushing, passing, and other offensive variables. After adjusting for the numbers of games played each season, the data were used to create Figure 1, which plots the average number of yards passing (including losses due to sacks) and rushing in each game from 1970 to 2009. Figure 1 clearly shows that a tremendous change in how offenses advanced the ball occurred in the late 1970s.

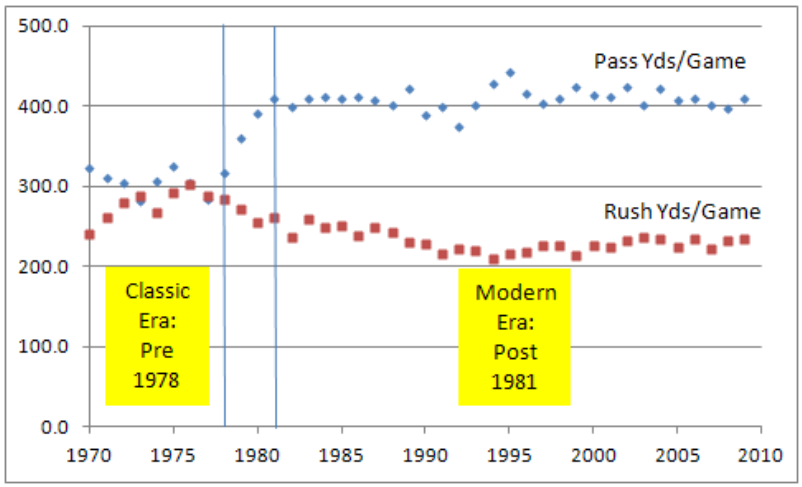


Figure 1: Identifying the Classic and Modern Eras in the NFL.

When the pass-happy AFL merged with the run-oriented NFL in 1970, it was unclear which direction the game would take, but it became obvious pretty quickly that running the ball was taking over the game. Figure 1 illustrates that the passing yards roughly equaled rushing yards in the mid 1970s. Then something happened and the two rapidly diverged during a transitional period between 1978 and 1981, after which they settled down to about 225 yards rushing and 400 yards passing per game, on average.

The average passing and rushing yards per game depicted in Figure 1 exactly pinpoints that the old, run-oriented game that typifies the Classic Era of the early years of the merged NFL-AFL gave way to the modern game with much more passing in the late 1970s, but why did the change occur? Two key rule changes in 1978 are largely responsible for the rise of passing and fall of rushing: 1) the Blount Rule and 2) allowing linemen to use their hands while blocking. Rules changes are made every year, but these two had a tremendous impact on the game.

Before 1978, defenders could hit and knock down receivers anywhere on the field, as long as the ball was not in the air. Today, once the receiver is five yards or more downfield, he cannot be touched and, if he is, the penalty is severe—five yards and an automatic first down. When first enacted, this was known as the Blount Rule.

Mel Blount was a cornerback for the Pittsburgh Steelers who was 6 feet 3 inches tall and weighed 205 pounds, quite large and fast for his position in his day. He was not only a perennial all-star, he was named Most Valuable Defensive Player of the Year in 1975 (a feat accomplished by only a handful of other cornerbacks). Blount simply manhandled opposing receivers and made it impossible for them to stay on their feet as they attempted to run a route. His Hall of Fame plaque (the full citation is available at *www.profootballhof.com/hof/member.jsp?player_id=30#*) reads, “Known for his rugged but clean style of play, his specialty was the ‘bump-and-run’ pass defense. Because of his size and speed, he literally overpowered pass receivers. Midway through his career, however, the rules were changed making such harassment of a receiver illegal.”

In addition to letting receivers run free downfield, pass blocking was given a huge boost by a rule change that allowed linemen to place their hands on defensive players trying to sack the quarterback. NFL rules on pass blocking (see *www.nfl.com/rulebook/useofhands*) include this explanatory note: “Pass blocking: Hand(s) thrust forward that slip outside the body of the defender will be legal if blocker immediately worked to bring them back inside. Hand(s) or arm(s) that encircle a defender—i.e., hook an opponent—are to be considered illegal and officials are to call a foul for holding.” Before 1978, a lineman could not

use his hands at all. The blocker kept his hands (rolled into fists) near his chest, with his elbows extended. Lewis (2006, p. 33) describes the ideal left tackle as extremely large and unusually quick, of course, but his arms and hands are also critical: “He had long arms: pass rushers tried to get in tight to the blocker’s body, then spin off it, and long arms helped to keep them at bay. He had giant hands, so that when he grabbed ahold of you, it meant something.” To be clear, holding calls are made in every game today because hooking is illegal, but linemen can legally thrust their hands forward and this confers a tremendous advantage for someone trying to prevent a sack.

The tandem of rules changes in 1978 that allowed receivers to run unimpeded once downfield and linemen to block using their hands greatly improved the performance of the passing game. Coaches quickly adapted to the new rules and spread formations with no running backs became common. One could argue that innovation was underway before the rules changes and cite such famous examples as Don Coryell and Bill Walsh, but there is no doubt that the rules changes gave these passing offenses a tremendous advantage. As a result, a sport that was increasingly dull and dominated by rushing in the mid 1970s, which had equal rushing and passing yards per game, changed dramatically in just three years. Figure 1 makes clear that by 1981 the transition to the Modern Era, where games routinely produced over 400 passing yards, was complete. It is no coincidence that as passing and scoring soared, so did the popularity of the NFL.

3. Explaining the Increase in Passing Yards per Game

While it may seem obvious how rule changes boosted passing yards per game, this paper offers an explanation that focuses on the return and risk of running and passing. Previous work, for example, Alamar (2006, p. 3), adjusts passing yards for passing touchdowns and interceptions to produce a measure of passing yards that shows a marked increase in returns to passing after the rules changes. Data adjustment leads to the simple explanation that teams pass more because the adjusted returns are higher. The *PTAdj* sheet in NFLTeamData19702009.xls has a chart of adjusted passing yards per attempt.

This paper offers an alternative framework. No adjustment is made to passing yards; instead, the variability in passing yards across individual plays is used to explain the increased attractiveness of passing. Not only is there no need to massage the data, the application of risk-reward theory offers a new perspective on observed run or pass play calling.

Once again, using team data from the NFLTeamData19702009.xls Excel file, we can track average rushing and passing yards per attempt, as shown in Figure 2. Remarkably, the typical pass play in the

NFL has netted roughly six yards before and after the 1978 rules changes, while running plays usually produce four yards per attempt. Alamar (2006) calls the net difference the *passing premium* and argues there is a puzzle in that teams should be passing more often. This may be true, but Figure 2 raises a different question: if the return on passing and running stayed roughly the same after the rules changes, why have we seen such an increase in passing yards per game?

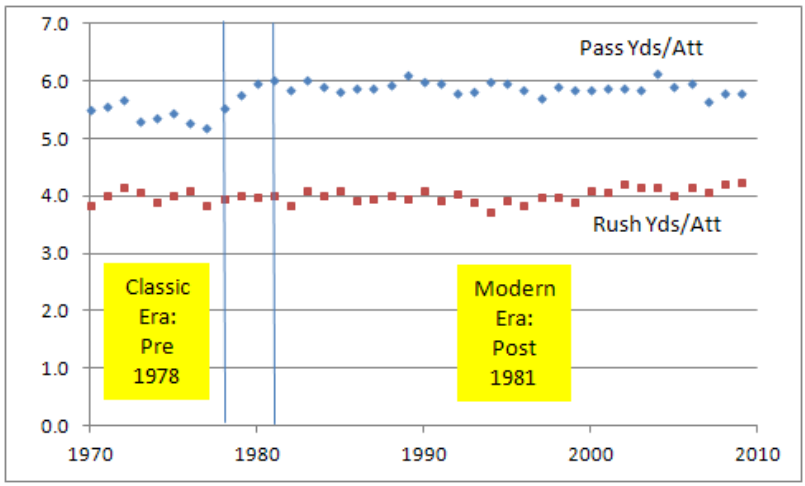


Figure 2: Average Yards per Pass and Rush have remained constant.

Passing and rushing yards per game can be split into two components:

$$\frac{Pass\ Yards}{Game} = \frac{Pass\ Yards}{Att} * \frac{Att}{Game}$$

$$\frac{Rush\ Yards}{Game} = \frac{Rush\ Yards}{Att} * \frac{Att}{Game}$$

We know Pass Yards/Att and Rush Yards/Att have remained roughly constant at 6 and 4 yards per attempt, respectively, so the answer must lie in the number of passes and runs attempted per game. Figure 3, based on data in the *PT* sheet of NFLTeamData19702009.xls, displays the average number of passes and rushes in each game from 1970 to 2009.

Figure 2 showed that the explanation for the marked change in passing and rushing yards per game that defines the Classic and Modern Eras is not to be found in changes in passing or rushing yards per attempt. It is the number passes and rushes in a game that drives the changes in total yards produced by air and ground, as Figure 3 clearly illustrates.

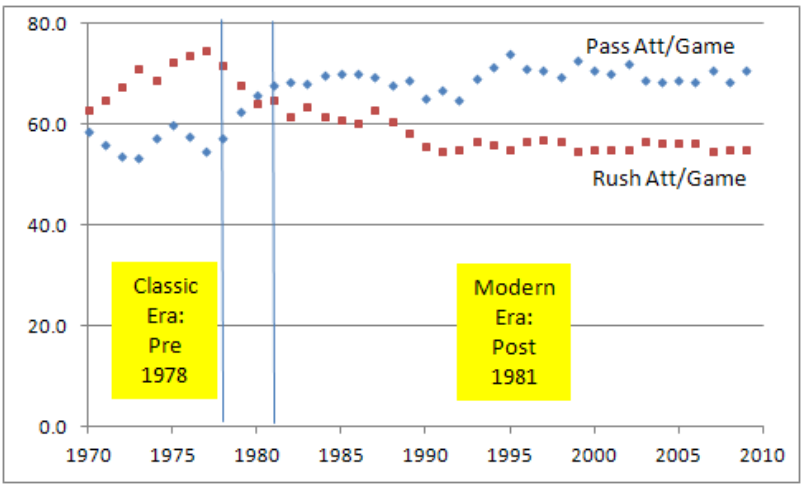


Figure 3: Passing is more common than running in the Modern Era.

In 1977, as shown by Figure 3 (and the *PT* sheet in the NFLTeamData19702009.xls Excel file), running plays were so common and passing attempts so low, that the gap between the two was at its maximum. Teams ran the ball 75 times and passed it 50 times, on average, in 1977. Then, in 1978, the Blount and liberalized blocking rules triggered a dramatic alteration in the run/pass mix. Not only did passing rise and running fall, by 1982, the number of passing plays exceeded the number of runs, a clear hallmark of the Modern Era game. In 2009, on average, offenses called about 55 rushes and 65 passes per game. In a nutshell, a typical Classic Era game would feature 60 percent run and 40 percent pass, while a Modern Era game flips these percentages. With roughly constant 6 and 4 yards per pass and rush attempt, it is throwing more passes and running less that produced the substantial shift in passing and rushing yards per game shown in Figure 1.

4. Why Pass More?

The change in play calling begs a final question: why are teams passing so much more than they used to? We know that the obvious answer, rules changes and new offenses produced more yards per pass attempt, is not correct. Teams get 6 and 4 yards per pass and rush, on average, and they have been earning these returns before and after the rules changes. If these returns did not change, then why did teams start passing more and running less?

The usual answer, as mentioned above, relies on modifying the data. Rockerbie (2008, p.4) not only adjusts passing yards to reflect the increased touchdowns generated via the pass and decreased number of interceptions, he also adjusts rushing plays for fumbles and adjusts all plays for penalty yardage “if

the penalty was a direct result of the play." This paper adopts a different approach, using raw passing and rushing outcomes along with optimal portfolio theory to explain the increase in the pass/rush ratio. Thus, Rockerbie's (2008) variability of passing (in Table 1 on p. 6) is much higher than the methodology used in this paper would have produced for the 2006 season.

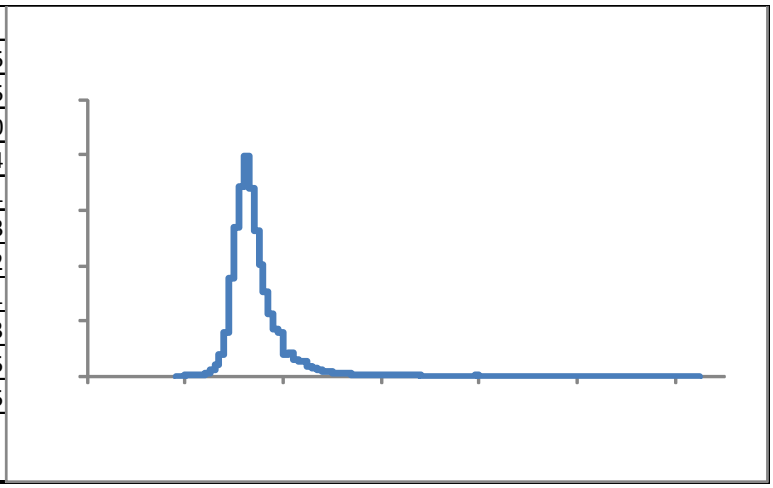
Faced with a choice of how to allocate funds between two competing investments, a low return, stable option (e.g., a Treasury bill) and a risky, high return option (e.g., the S&P 500), an investor solves a constrained utility maximization problem (see Barreto (2009, p. 197) for a detailed explanation of this optimization problem). Risk is measured by the standard deviation (SD) of returns, and plays an important role in determining the optimal allocation. There is an inverse relationship between risk, ceteris paribus, and the optimal amount invested: the higher (lower) the SD, the less (more) attractive the asset.

Although the objective of the offense, to maximize points scored, differs from that of an investor so optimal portfolio theory cannot be directly applied, we can utilize the idea that variability in returns is an important factor in determining the optimal strategy. When calling a play, it is obvious that the average return matters, but so does the variance in returns. The offense has two options, run or pass. The former is relatively safer, but yields fewer yards, on average, than the latter. We know the average yards per pass and rush attempt, 6 and 4, respectively, but what is the SD of each option?

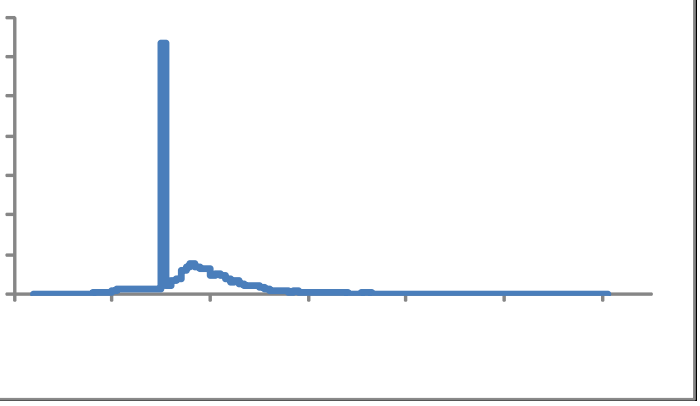
The Excel workbook, NFLPlayData2005.xls (available at *academic.depauw.edu/hbarreto_web/working*), has data on the yards gained (or lost) on every running and passing play that did not result in an interception from the 2005 season. Intercepted passes do not have a value for yards gained or lost. It is misleading to count them as zero yards because interceptions are not simply incomplete passes. The distribution of yardage outcomes for the 17,140 passing and 14,375 rushing plays is captured by the histograms in Figure 4. Frequency tables for each yard are included in the Excel file in the *Pass* and *Rush* sheets.

The average yards per rush and pass are roughly 4 and 6 (as revealed by the team data yards per attempt), but Figure 4 also contains a measure of dispersion. The SD of rushing is a little over 6 yards per attempt, smaller than the SD of passing, which is almost 10 yards per attempt. Just like in financial markets, the higher return of the passing game must be paid for by greater variability in returns.

Variable	Rush
Number Obs	14375
Number Non-missing	14375
Number Missing	0
Number of Unique values	84
Mean	4.01
SD	6.13
Min	-12
25th Percentile	1
Median	3
75th Percentile	5
Max	95



Variable	Pass
Number Obs	17140
Number Non-missing	17140
Number Missing	0
Number of Unique values	102
Mean	6.07
SD	9.87
Min	-26
25th Percentile	0
Median	3
75th Percentile	10
Max	91



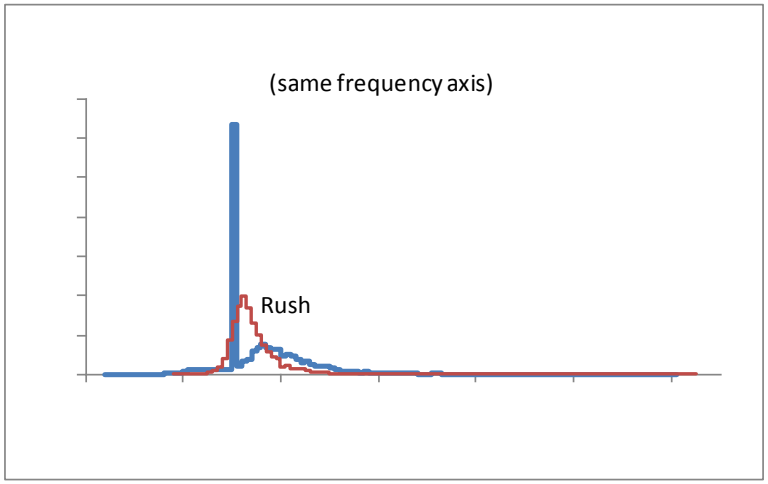


Figure 4: The distribution of rushing and passing plays for the 2005 season.

While a case could be made that the rushing data are approximately normally distributed (notwithstanding the long right hand tail and lack of symmetry), the passing histogram is clearly not normally distributed. The tall spike, of course, represents the many (6,348, to be exact) plays that resulted in zero yards. There were 122 completed passes for no gain, 58 sacks of zero yards, and the remaining 6,168 plays were incomplete passes.

Unfortunately, there is no similar individual play data for games during the Classic Era. According to the author's personal correspondence with STATS, LLC (a leading sports information and statistics provider), play-by-play data are unavailable for games until the late 1990s. Thus, the perfect test—comparing the SD of passing for Classic versus Modern Era games—cannot be run. However, as a second best alternative, team data can be used to estimate the SD of passing plays. The year 1975 will serve as the example to be compared to 2005.

Table 1 shows the actual passing results from the team data set in the first two rows. The much greater number of pass attempts (including sacks) is due to more games being played in 2005 and more pass-oriented offenses in the Modern Era. The fewer interceptions in 2005 (on almost double the pass attempts) reflect the greatly improved performance of the passing game in 2005, as does the number of completions. Notice, however, that the yards per attempt are roughly similar, while sacks are less costly in 2005. The last column shows that yards per completed pass were higher in 1975—this is due to the absence of a short, controlled passing game which is the hallmark of a modern offense.

Year	Pass Att	Int	Pass Att - Int	Pass Yds	Comp	Sacks	Sack Yds	Incomp	Yds/Att	Yds/Sack	Yds/Comp
1975	10880	533	10347	59256	5231	907	7339	4209	5.73	8.09	12.73
2005	17647	507	17140	104174	9791	1182	7547	6167	6.08	6.38	11.41
	1975 Passes Adjustment:		1.656518798								
1975 Adj			17140	98159	8665	1502	12157	6972	5.73	8.09	12.73
	Years Compared:		1975 Adj - 2005 Actual								
	Difference		0	-6015	-1126	320	4610	805	-0.35	1.71	1.32
	% Difference		0.0%	-5.8%	-11.5%	27.1%	61.1%	13.1%	-5.8%	26.8%	11.6%

Table 1: Team passing data from 1975 and 2005.
Note: 1975 Adj is scaled up so pass attempts (net of interceptions) equal 2005.

The 1975 Passes Adjustment value in Table 1 is found by dividing the number of passes (net of interceptions) in 2005 by its corresponding value in 1975: 1.6565 = 17140/10347. Multiplying the 1975 values by this factor sets the frequency of passes in the two years equal to each other, which enables a

better comparison of the 1975 and 2005 seasons. The final two rows of Table 1 show that after scaling up the 1975 team passing statistics, 1975 saw slightly fewer passing yards (6,015) from many fewer completions (1,126) along with many more sacks (320), lost yards due to sacks (4,610), and incomplete passes (805).

To use the information in the aggregated, team data for 1975 to estimate the SD of the individual play passing distribution, we take advantage of the fact that the distribution of all passing plays can be broken down into three separate parts: sacks, incomplete passes, and complete passes. Figure 5 shows how the individual passing play data for 2005 are actually composed of three separate histograms. The sacks distribution has an average of -6.39 yards/sack and an SD of 3.62 yards/sack. The histogram of incomplete passes is not shown because it is simply a vertical line at zero. Finally, the completed passes histogram has a mean of 11.41 yards/completion and an SD of 9.92 yards/completion. When combined, the three distributions produce the All Plays column and histogram in Figure 5.

Breaking down the outcomes of all passing plays into three parts, one of which—the distribution of incomplete passes—we know exactly, enables estimation of the SD of all passing plays by using the fact that the average and SD of the entire distribution depends on the three underlying distributions according to these formulas:

$$Avg_{All} = \frac{Sacks}{AllPlays} Avg_{Sack} + \frac{Incomp}{AllPlays} Avg_{Incomp} + \frac{Comp}{AllPlays} Avg_{Comp}$$

$$SD_{All} = \sqrt{\frac{Sacks\left(SD_{Sack}^2 + Avg_{Sack}^2\right) + Incomp\left(SD_{Incomp}^2 + Avg_{Incomp}^2\right) + Comp\left(SD_{Comp}^2 + Avg_{Comp}^2\right)}{AllPlays} - Avg_{All}^2}$$

The terms for incomplete passes drop out because we know the average and SD for incompletes is zero. So, for example, from the 2005 team data, we would compute the average and SD of all of the plays by substituting in the appropriate values in the two formulas above, like this:

$$Avg_{All} = \frac{1182}{17140}(-6.39) + \frac{9790}{17140}11.41 = 6.07$$

$$SD_{All} = \sqrt{\frac{1182\left(3.62^2 + (-6.39)^2\right) + 9790\left(9.92^2 + 11.41^2\right)}{17140} - 6.07^2} = 9.87$$

Avg	6.07	-6.39	0.00	11.41
SD	9.87	3.62	0.00	9.92
Total Plays	17140	1182	6168	9790
Yards	All Plays	Sacks	Incomp	Comp
-26	1	1	0	0
-25	0	0	0	0
-24	0	0	0	0
-23	0	0	0	0
-22	0	0	0	0
-21	0	0	0	0
-20	0	0	0	0
-19	3	3	0	0
-18	3	3	0	0
-17	4	4	0	0
-16	7	7	0	0
-15	7	7	0	0
-14	14	12	0	2
-13	19	19	0	0
-12	26	26	0	0
-11	46	46	0	0
-10	72	72	0	0
-9	114	113	0	1
-8	141	141	0	0
-7	138	133	0	5
-6	121	116	0	5
-5	134	113	0	21
-4	128	106	0	22
-3	104	77	0	27
-2	104	61	0	43
-1	135	64	0	71
0	6348	58	6168	122
1	225	0	0	225
2	318	0	0	318
3	399	0	0	399
4	579	0	0	579
5	685	0	0	685
6	763	0	0	763
7	672	0	0	672
8	632	0	0	632
9	646	0	0	646
10	444	0	0	444
11	521	0	0	521
12	453	0	0	453

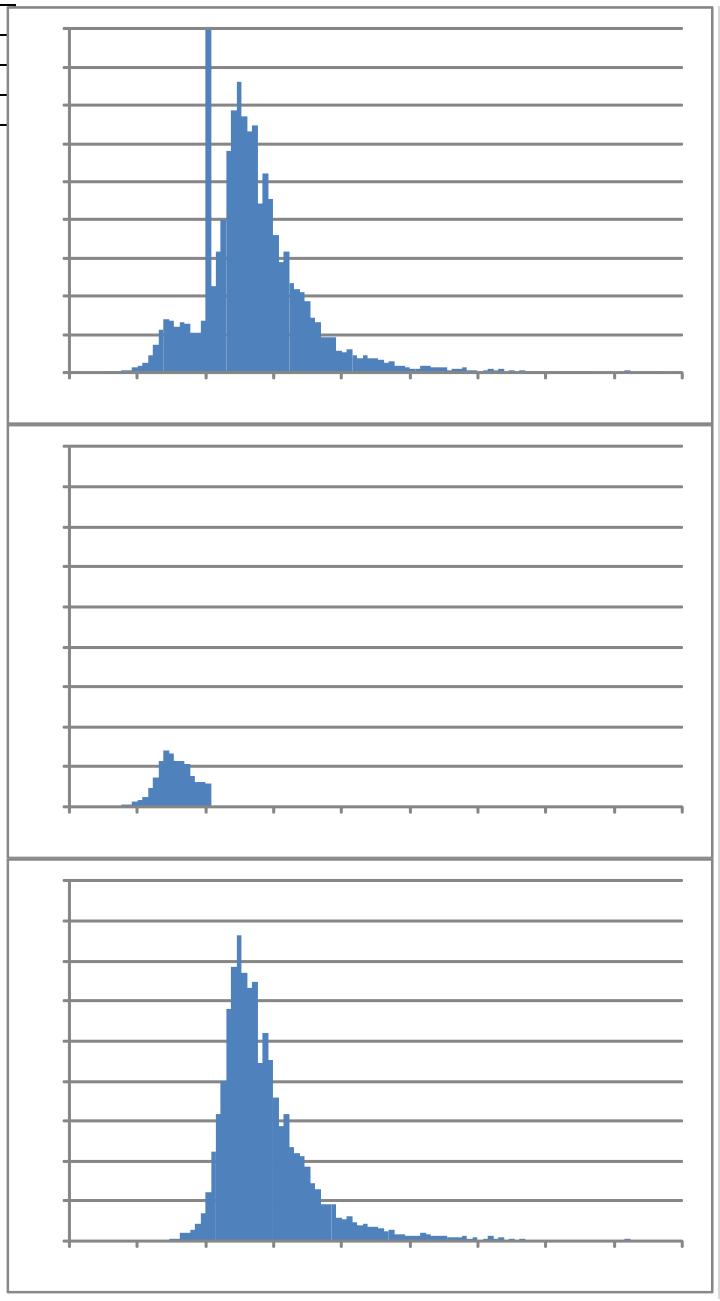


Figure 5: Passing plays by sacks, incomplete, and complete plays.

Note: See the *PassAnalysis* sheet in NFLPlayData2005.xls for the complete frequency table.

Note: The same frequency axis is used for ease of comparison; the vertical bar in the All Plays histogram is not fully displayed.

For 1975, the team data can be used in the formulas like this:

$$Avg_{All} = \frac{907}{10347}(-8.09) + \frac{5231}{10347}12.73 = 5.73$$

$$SD_{All} = \sqrt{\frac{907\left(SD_{Sacks}^2 + (-8.09)^2\right) + 5231\left(SD_{Comp}^2 + 12.73^2\right)}{10347} - 5.73^2}$$

The SD of passing depends upon the SD of sacks and SD of completed passes, two variables that are unknown because we do not have play-by-play data. We do know, however, how the game has changed and we can use this information to plug in values for the SD of sacks and SD of completed passes.

The SD of sacks was surely higher in 1975 because offenses used neither the shotgun nor quick, three- or five-step drops. Both of these developments help protect the quarterback and are reflected in the modern-day sack distribution that is massed closer to zero. Not only does a sack today lead to fewer yards lost, on average, but large losses are less likely.

Like sacks, the SD of completed passes was surely greater in the Classic Era. In 1975, offenses did not utilize short passing plays to control the ball and the long pass was a major weapon. This is reflected in the higher yards per completed pass and would create a histogram that is more evenly distributed (with more mass above the average) than today's version.

While we have strong reasons to believe that both the SD of sacks and SD of completed passes in 1975 are higher than their 2005 counterparts, we do not know by how much. Table 2 shows how the SD of passing varies according to the value of the SD of sacks and SD of completed passes. For example, if the SD of sacks was 5 yards per sack and the SD of completed passes was 14 yards per completed pass, then the SD of passing for 1975 would have been 12.5 yards per pass attempt.

	SD of completed passes				
	11	12	13	14	15
4	10.84	11.36	11.91	12.47	13.04
5	10.87	11.40	11.94	12.50	13.07
6	10.92	11.44	11.98	12.54	13.11
7	10.97	11.49	12.03	12.58	13.15
8	11.03	11.55	12.08	12.63	13.20

Table 2: Sensitivity analysis of the effect of the SDs of sacks and completed passes on the SD of passing.

Without play-by-play data, the exact value of the SD of passing in 1975 remains unknown, but a strong case can be made that it was higher than today's SD of passing because we know the SD of sacks and SD of completed passes were higher in 1975. Knowing that the SD of passing has fallen, i.e., that passing is safer now than before 1978, supports the qualitative claim that the increase in passing attempts per game resulted from a decrease in risk that makes passing more attractive than it used to be.

5. Conclusion

Data compiled in the Excel workbook, NFLTeamData19702009.xls (freely available online at *academic.depauw.edu/hbarreto_web/working*), shows that passing yards in a typical NFL game jumped markedly after two critical rules changes in 1978. The explanation for the rise in passing yards that defines a Classic versus a Modern Era game is not, however, an increase in average yards per pass attempt—in fact, both yards per rush and pass attempt have stayed remarkably constant. Instead, it was an increase in the number of passes attempted that drove the rise in passing yards.

To explain the change in play calling, this paper used insights from optimal portfolio theory. While the match is not exact because the goals of investors and football teams are not the same, there are fundamental similarities. Using play-by-play data from 2005 (in an Excel file also freely available at the web site above), passing's higher return compared to rushing (6 versus 4 yards per attempt) can be interpreted as compensation for higher risk (SD of 10 yards per attempt for passing versus an SD of 6 yards per rush). Future work, perhaps utilizing simulation, exploring optimal strategies under varying return and variability conditions would be an important contribution to our understanding of decision-making in football.

Although we do not have a clear model of strategic behavior in football, the increase in passing attempts per game can be interpreted as a rational response to a decrease in passing risk. Unfortunately, this claim cannot be tested directly because play-by-play data for games before the mid-1990s are not available. An estimate of the SD of passing was teased out of team data by decomposing passing plays into three components (sacks, incomplete and complete passes). It seems obvious that sack and completed pass distributions had more dispersion pre-1978 and team data shows that the average of sacks and completed passes were farther from the overall average, therefore, the SD of passing was surely higher. A range of plausible values for the two unknowns, SD of sacks and SD of complete passes in 1975, yielded a range of estimates of the SD of passing from roughly 11 to 13 yards per attempt. These values are higher than the known SD of passing of 9.87 yards per attempt in 2005.

This analysis is certainly not precise. Not only are the play-by-play data for 1975 unavailable, but even for 2005, when we have each running and passing play, there are problems. First, football is a situational game and there is no one measure of risk and return for an entire season or a particular team or even for an individual game. The risk and return of a particular play depends on offensive and defensive characteristics of the teams and the down, distance, time remaining, and score. Second, the data do not reflect the fact that a run by a quarterback may have been a scramble and, thus, the play called was actually a pass. Finally, we have essentially ignored interceptions, which have fallen dramatically and belong in the conversation of how the risk of passing has decreased. These issues are important, but the idea that running and passing are roughly analogous to investing in safer or riskier assets, with higher returns viewed as compensation for greater volatility is a useful way to interpret observed mixes of runs and passes. Seen in this light, the increase in passes per game after the 1978 rules changes is a rational response to decreased risk, measured by a decrease in the SD of passing. The chain of lower SD of passing leading to more passing plays leading to more passing yards per game is a succinct way of describing how modern day NFL football has evolved from its run-oriented roots in the 1970s.

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