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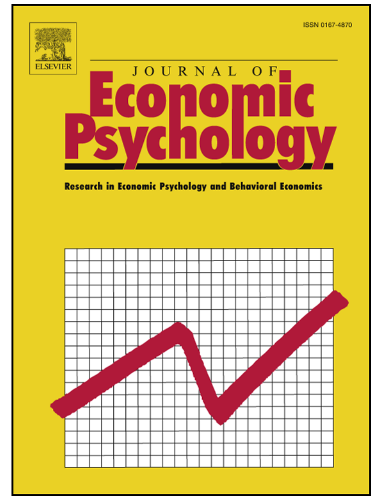

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There and Back Again:
Adaptation after Repeated Rule Changes of the Game

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Abstract: *Rule changes have offered a natural experimental setting in the sports environment and beyond for many years. However, an understanding of human behavioural adaptation processes after repeated rule changes is missing from the extant literature. The NBA offers a unique setting in which the three-point line was moved (shortened) for a period of three seasons (1994-95 to 1996-97) and then returned (lengthened) to its original position (pre 1994-95). We are therefore not only able to explore the behavioural changes after reducing distance restrictions but also how players re-adapt to the original, more difficult condition. Using a dataset of almost 700,000 player-game level observations we find that (on average) players instantaneously adjust to rule changes. Good scorers and younger players take particular advantage of the situation. On the other hand, older players decrease their 3-point attempt ratio and do not readjust after a return to the original distance. Positive feedback regarding 3-point efficiency encourages players to try more shots while efficiency gains in 2-point shots reduces this incentive, indicating that players may follow the heuristic of "win-stay". Finally, making 3-point shots easier for a couple of seasons has positive externalities on efficiency that last more than a decade after the re-adjustment of the distance.*

Keywords: Adaptation, Adjustment process, Natural experiment, Rule change

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1. Introduction

Economists frequently analyse sports settings as a "real world laboratory", attracted by the ability to test incentives operating in a controlled high-stake environment where rules are clearly specified and many factors can be observed and measured. This allows the use of highly reliable data with low variable errors or omitted variable biases (Goff and Tollison, 1990; Torgler, 2009). Labour economists, for example, have been a dominant force in sports economics, expressing fascination for the transparency and accessibility of the data: "There is no research setting other than sports where we know the name, face, and life history of every production worker and supervisor in the industry. Total compensation packages and performance statistics for each individual are widely available, and we have a complete data set of worker-employer matches over the career of each production workers and supervisor in the industry" (Kahn, 2000, p. 75).

In recent decades, sports data have been used to creatively explore various behavioural aspects with implications beyond just sports. For example, analyses have focused on strategic behaviour to empirically test game theoretical theorems or concepts such as minimax by looking at penalty kicks[1] (Palacios-Huerta, 2003, 2014)[2], corruption through investigation of non-linear incentive pay-off structures to identify match rigging among Sumo wrestlers (Duggan and Levitt, 2002), or favouritism for home teams by comparing extra time provided at the end of a soccer game (Garicano et al., 2005)[3]. Thus, sports data offers an opportunity to overcome the difficulties inherent in exploring strategic models of behaviour (Palacios-Huerta 2014)[4].

Based on these advantages, it follows that scholars in the area of decision science, behavioural economics, or economic psychology have made extensive use of sports data. A prominent example is Gilovich et al.'s (1985) "hot hand" paper attacking a common perception (held by basketball fan and experts) that a player has a better chance of making a shot after having made the last shot(s). Hotness and (strategic) momentum seemed intuitively appealing[5] and the paper sparked a long, heated debate with mixed or limited evidence exploring also settings such as golf, soccer, darts, tennis, or bowling trying to find solid

[1] For pressure factors in penalty kicks see Savage and Torgler (2012).
[2] See also Palacios-Huerta and Volij (2008) and Levitt et al. (2011).
[3] For a survey on referee bias see Dohmen and Sauermann (2016).
[4] Economists have also focused on game shows as a natural setting (see, e.g., List, 2008; Post et al., 2008; Belot et al., 2010; and Oberholzer-Gee et al., 2010).
[5] The overall appealing theme is whether success breed success, explored in other environments such as academia (see, e.g., Merton, 1968, 1973, 1988; Stephan, 2012; Azoulay et al., 2013; Wang, 2014, Chan et al., 2014a, 2014b) or the financial sector. The sociologist Merton (1973) calls it the "Matthew Effect" based on the Gospel According to St. Matthew: "For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath" (p. 445).

identification strategies or less confounding factors (Bar-Eli et al., 2006; Koehler and Conley, 2003; Gauriot and Page, 2014; 2017). In tennis Page and Coates (2017) looked at the effect of winning the first set tie-break on the probability of winning the second set. The study found a momentum effect for males but not females, which supports other findings such as men and women react differently to competitive pressure (see e.g. Banko, Leeds and Leeds, 2016; Gneezy and Rustichini, 2004). These differences may prompt a closer look at the biological micro-foundation of gender differences (e.g., the importance of hormones).

Behavioural scholars have also explored game rule changes as a natural experiment; such empirical studies have substantially increased since the 1970s and 1980s. For example, McCormick and Tollison (1984)[6] explored an increase in the number of referees from two to three in basketball to see whether the increase in enforcement affects fouls committed. The study inspired follow-up investigations such as Levitt's (2002) paper, which analysed an experiment during the 1998-99 season of the National Hockey League (NHL) that randomly assigned either one or two referees to a match. Others have looked at a dimension of deterrence represented by a change in the severity of punishment in soccer (Witt, 2005)[7] or the institutional effect of referees in controlling identity based conflict in international football (soccer) tournaments (Caruso, Di Domizio and Savage, 2017).

Elias and Dunning's (1971) investigation into sports rule changes indicates that there are two basic reasons for altering the rules of any sport: firstly, to modify some behaviour occurring within the games; and secondly, to develop the dynamics of the game with the intention of improving the game, quite often to increase commercial or public interest (Steen-Johnsen, 2008). There was, for example, a major change to the game of beach volleyball after the 2000 Sydney Olympics, where the size of the court was changed from an 9x9 (foot) to the

[6] See also Hutchinson and Yates (2007) and McCormick and Tollison (2007).
[7] For an exploration of the benefits and costs of the second referees see Depken and Wilson (2004).

smaller 8x8 (foot), and the point scoring systems were changed. Consequently, the games were more exciting for the spectators to watch, as outcomes were closer and less predictable (Gaitsis, 2003; Gatsis and Tzetzis, 2003). However, changes in the rules of most sports can also create the unintended consequence of altering the behaviours or incentives of the players, resulting in players and teams adapting (adopting) differently. For example, in 1996, International Rugby Union moved from an amateur to a professional sport: this simple change had a systemic effect on the game, which resulted in a significant change in the playing style (Eaves et al., 2005). Similarly, the introduction of several rule changes in the UK Rugby League competition between 1992 and 2000 did not appear to affect the outcomes but did have a significant impact on how the game was played (Eaves et al., 2008). Alternatively, National Hockey League (NHL) attempted to reduce the number of tied games by implementing a rule change in overtime, and while successfully reducing ties from 71% down to 55% it generated an unexpected perverse incentive (Abrevaya, 2004). The new rules actually rewarded teams for reaching overtime play, incentivising players to finish the normal period of play on a tie, which slightly increased the number of games ending in overtime. Another major rule change that has been extensively explored empirically was the advent of free agency in MLB in 1976 for six-year veterans; according to Szymanski (2003) the change was not motivated by the desire to influence competitive balance.

For this special issue, we investigate an interesting rule change situation in NBA basketball. For the season 1994-95, the three-point line was shortened to a uniform 22 feet around the basket (previously 22 feet (6.7m) in the corners, and extended to 23 feet, nine inches at the top of the key (7.24m)). Three years later (season 1997-98) the three-point[8] was

[8] When the 3-point rule was introduced in the 1979-80 season, it was viewed as being little more than a gimmick, a way of artificially raising interest in the game and was not expected to last.

lengthened to its original distance of 23 feet, nine inches with the exception of the corners where the distance remained 22 feet[9].

This is not the first study to analyse the NBA rule change. Romanowich et al. (2007) looked at 57 players between the regular seasons 1991-1992 to 1999-2000 to explore whether moving the line closer leads to more three-point shooting reinforcement[10]. Their goal was to explore biases toward three-point shooting by looking at a simple matching equation to quantify systematic deviations from matching[11]. The equation of:

$$log\left(\frac{number\ of\ three-point\ shots\ attempted}{number\ of\ two-points\ attempted}\right) = s\ log\left(\frac{number\ of\ three-point\ shots\ scored}{number\ of\ two-points\ scored}\right) + logb$$

explored the bias (*b*) for a preference for or against three-point shots (intercept) and the slope (*s*), looking at the sensitivity to relative reinforcement rate in terms of overmatching ($s>1$) or under-matching ($s<1$), applied independently to three time periods (1991-1994, 1994-1997, 1997-2000). They find under-matching in all three time periods and a small increase in bias toward a three-point shot (change in the y intercept from 0.01 to 0.046) while the bias was maintained after the line was moved back to the original distance (b=0.047). An increase in three-point shots was a function of moving the three-point line closer to the basket but moving the three-point line back did not reverse the relative rate of three-point shots made. We will substantially extend that study by implementing a large sample, adding control factors using a panel analysis, exploring the dynamics in more detail, and focusing on an understanding of how individual player characteristics and performance changes are affected by rule change and the subsequent readjustment. To better understand the dynamics and the adjustment processes we created a large game-by-game level panel dataset. Our aim is to

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9 See http://www.nba.com/analysis/rules_history.html

10 For a discussion on reinforcement see Herrnstein (1970).

11 Other studies have used a similar approach of matching with basketball data but without looking at rule changes (Vollmer and Bourret, 2000, Alferink et al., 2009). For an early theoretical discussion of the matching law see Baum (1974).

identify who makes use of the rule change and who is or is not readjusting. For example, are older players adjusting and readjusting slower than the younger players? How do good shooters behave relative to other players? What are the implications of the rule changes of shooting efficiency? These questions (and more) are investigated in the empirical analysis.

2. Data

Our empirical analysis is based on player-game level National Basketball Association (NBA) data obtained from Basketball-Reference.com, which covers regular and playoffs game records from 1985-86 through to 2014-15 seasons. We have detailed information on players' performance, such as statistics on points, minutes played, and number of field goals made or attempts, as well as players' personal information, e.g. date of birth, heights, and position. The initial data covers about 740,000 player-game level observations from a total of 2,373 active players in the sample period. Subsequently, we consider a shorter time period and smaller player sample for a more robust analysis due to the timing of the interventions. Specifically, since the three-point line was shortened for 3 seasons (i.e. 1994-95 to 1996-97), we restrict the time period to 3 seasons before the initial change (1991-92 to 1993-94) and 3 seasons after the line was moved back (1997-98 to 1999-2000). We also restrict the player sample to those who have participated in at least one game in the first two periods (N=389), the last two periods (N=403), or all three periods (N=265). *Table 1* reports descriptive statistics for all the variables used in the empirical analysis. While most of the box score measures used in this study are intuitive (e.g., 3-point attempts or field goal (made) percentage), some warrant further explanation. One of our main dependent variables is *proportion of 3-points attempted (P3FGA)*, which is defined as number of 3-point attempts per all field goal attempted. Another one is *true shooting percentage (TS%)*, which is a measure of the shooting efficiency of a player developed by *APBRmetrics* (Association for

Professional Basketball Research Metrics) that includes field goals, 3-point field goals, and free throws. Finally, true shooting percentage is defined as: $Points/(2 * (Field\ Goal\ Attempt + (0.44 * Free\ Throw\ Attempt)) * 100$.

Table 1: Descriptive Statistics

	Pre 1994-95 seasons		1994-95 to 1996-97 seasons		Post 1996-97 seasons	
Variables	Mean	SD	Mean	SD	Mean	SD
3pt attempt / all field goal attempts (P3FGA)	0.057	0.102	0.133	0.150	0.140	0.152
3pt field goal %	0.280	0.357	0.326	0.325	0.320	0.320
2pt field goal %	0.470	0.242	0.468	0.264	0.458	0.265
Free throw %	0.747	0.275	0.726	0.286	0.740	0.286
Field goal %	0.457	0.233	0.444	0.240	0.433	0.238
True shooting %	0.512	0.230	0.517	0.247	0.506	0.248
3pt% / 2pt%	0.643	0.950	0.759	0.901	0.757	0.910
Minutes played	23.740	12.067	24.063	12.487	23.728	11.864
Age	27.422	3.491	28.062	3.921	27.535	4.309
Experience	5.390	3.553	5.965	3.847	6.112	4.006
New to team	0.338	0.473	0.385	0.487	0.382	0.486
Home game	0.500	0.500	0.500	0.500	0.500	0.500
Attendance	14950	4222	17240	5457	17397	2973
Playoffs	0.063	0.242	0.057	0.232	0.063	0.244
Observations	204255		74318		460696	

3. Empirical Results

3.1 Descriptive results

We begin with a descriptive analysis to obtain some intuition about the dynamic implications of the rule changes. Using year-by-year level data indicates that the proportion of 3-points attempted (*P3FGA*) substantially increased from 10% to around 15% as a consequence of reducing the shot distance (Fig. 1). While moving the line back reduced the proportion of shots again, it did not return to the pre-change conditions. Throughout the entire observation period, play-off games report a higher proportion of 3-point attempted shots.

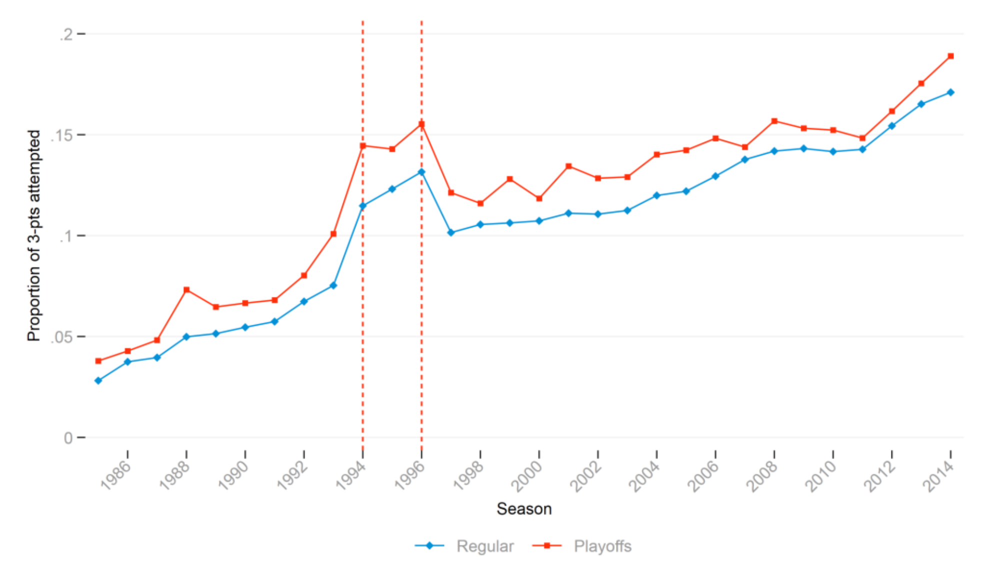

Fig. 1. Proportion of 3-point shot taken (relative to all field goal attempts).
Notes: The proportion of 3-points attempted measures the ratio between 3-points attempted to the total number of shots. The distance between the three-point line to the basket was shortened from 23’9” (22’ at the corners) to a uniform 22” during the 1994-95, 1995-96, and 1996-97 seasons (indicated by the red dashed lines). We took the individual-game average for each regular/playoffs season. Observations where the player did not attempt a field goal (either two or three points) were excluded from the calculation of season average.

The game-level data indicates that players on average immediately increase their P3FGA after the initial line change (Fig. 2). Similarly, we also find an immediate response after reverting the line back to the original length (Fig. 3). The results in Fig. 4 look at the number of weeks before (upper part) and after the change happened (lower part). Players who had not yet played in games after the rule changes may still have practiced under the new circumstances, thereby learning the new rules, which justifies exploring “real time”[12] behaviour and analysis of weekly performances. Again, we find instantaneous adjustments.

[12] In Fig. 2 and 3 we did not report “real time” data. For example, under +1 a player who played for the first time in game 3 after the rule change is aggregated with a player who played directly in game 1.

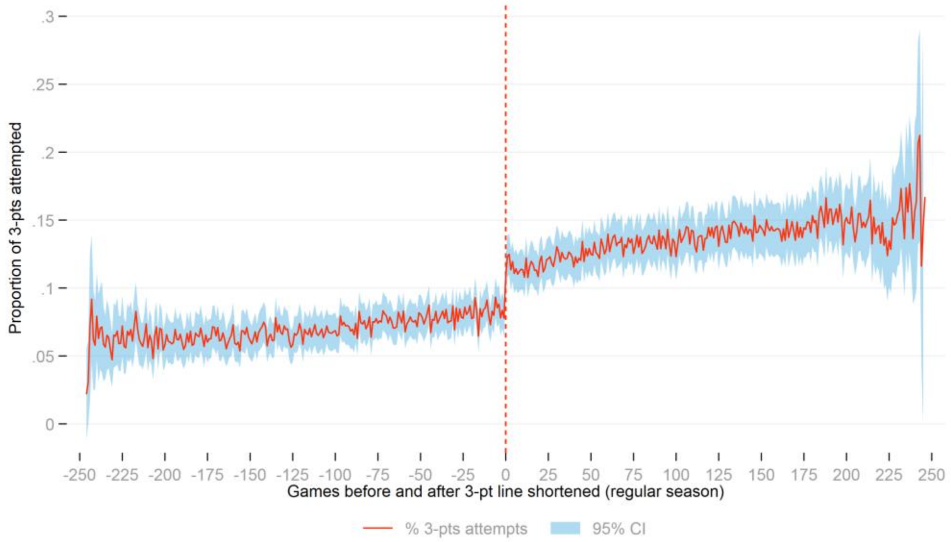

Fig. 2. P3FGA at the game level before and during the shortening of the line
Notes: Number of games before and after the first line change. Timeline = 0 indicates the first game each player played in the 1994-95 season (can vary between players). Only regular games are included here to avoid mixing the effects with the playoffs. Some players did not start to play until later in the season. This sample includes all players who played at least one regular game before and after the first line change, and only takes the observations 3 years before and after the initial line change (1991-02 to 1996-97 seasons). As reflected by the timeline there are 246 games before and after the rule change (total of 6 seasons of 492 regular games).

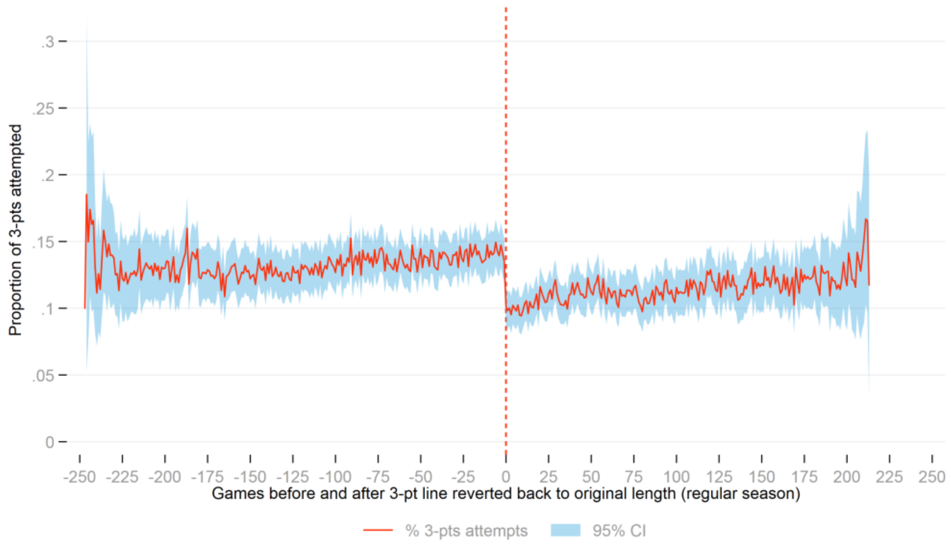

Fig. 3. *P3FGA* during the shortening of the line and the period after the reverting the line back to the original length
Notes: 1998-99 season is shorter due to the lockout. It was the third lockout in the history of NBA. It was started by the owners after the collective bargaining agreement with National Basketball Players Association failed[13].

[13] For a detailed discussion see https://en.wikipedia.org/wiki/1998%E2%80%9399_NBA_lockout.

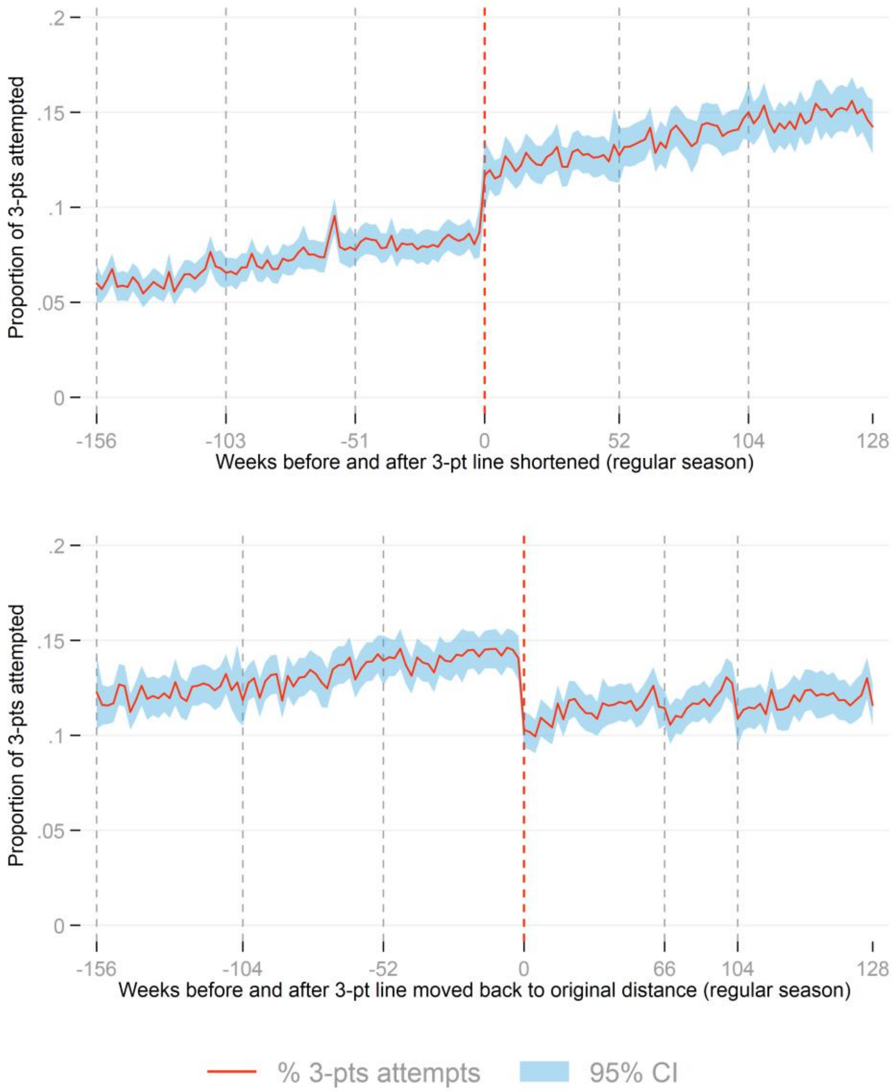

Fig. 4. Game weeks before, during, and after the rule change.
Notes: The x-axis reflects the actual number of weeks before and after the rule change, e.g. the first week of regular games in the 1991-92 season is 156 weeks (3 years) before the 1994-95 season (play-off excluded). 1998-99 season is shorter due to the lockout. Timeline is adjusted such that playoffs and off-seasons were not shown.

An increase or reduction of *P3FGA* is interesting from a psychological point of view but the economic perspective necessitates the question of whether it actually affects efficiency. We measure efficiency by looking at the ratio between three points made (successful) and three points attempted. The regular season results demonstrate a ratio increase – which conforms to our expectations – while the playoff shows a surprising decrease in three-point efficiency between seasons 1995-96 to 1998-99 (Fig. 5). Overall, for the regular season, the efficiency level remained higher in the second post-rule change period compared with the first pre-rule change period. Results also indicate that the increased *P3FGA* do not pay-off with respect to efficiency. For most of the post-rule period the regular season indicates higher efficiency values than during the playoffs. Interestingly, the relative shot precision of three pointers remained high when the line was returned to the original pre-1994/95 season. This is after observing an increase in relative three-point efficiency in the regular season due to the first rule change (Fig. 6). For both figures we also observe a positive trend a long time before 1994. Mather (2016) discusses the evolution and perception of the 3-point shot. In its debut in the 1979-80 NBA season the shot was called a "gimmick". The Phoenix Suns Coach John MacLeod, for example, told *The New York Times* in a pre-season 1979-80 interview that he is "not going to set up plays for guys to bomb from 23 feet. I think that's very boring basketball". In the 1980s the three-point shots gradually increased in popularity carving also a niche for 3-point specialists. Mather stresses that the 3-point shot emerged over time from a gimmick to a vital part of a team's offense strategy which could explain the positive trends that we observe in both figures.

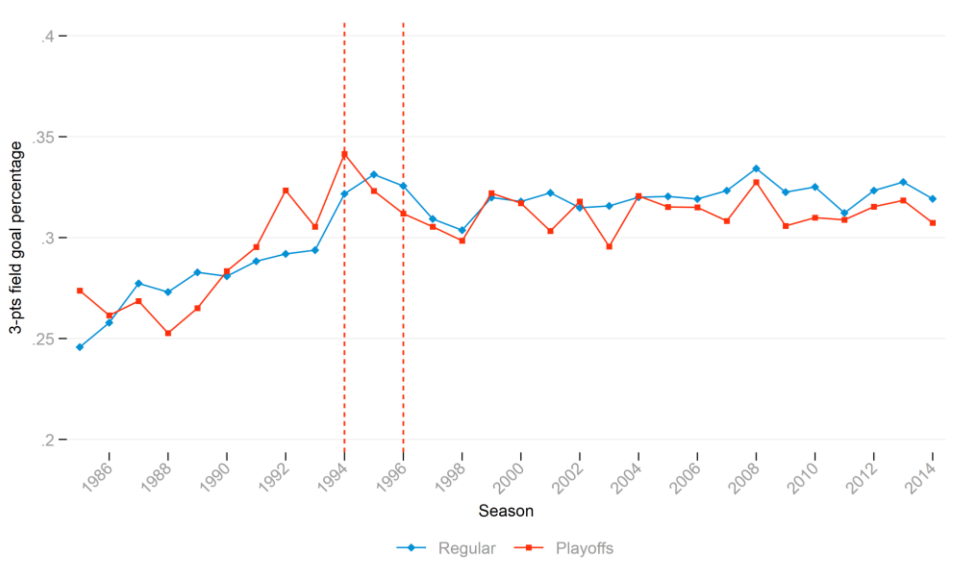

Fig. 5. Three-points shooting percentage (3-points made / 3-points attempts)

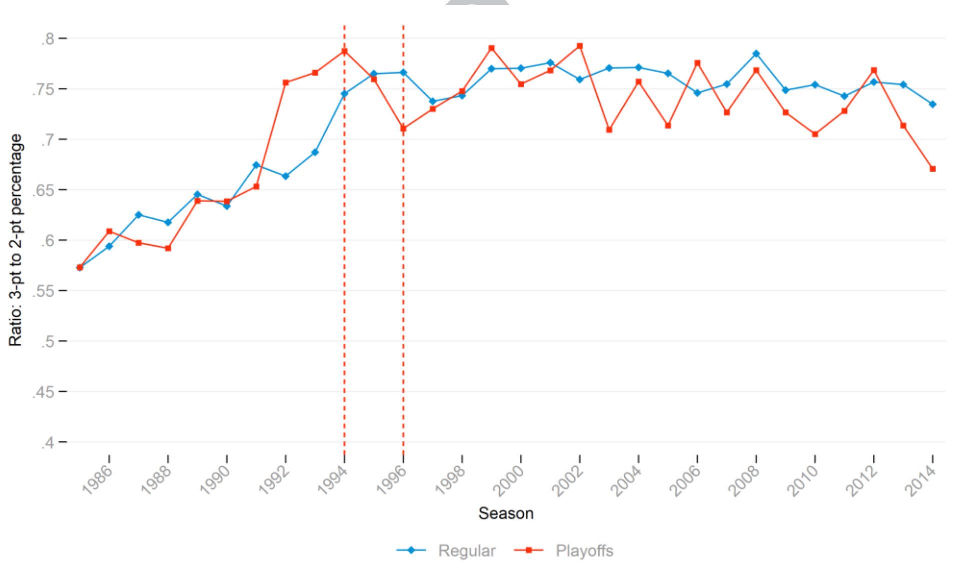

Fig. 6. Relative shot precision: Ratio between 3-pt to 2-pt field goal percentage (3-pt percentage / 2-pt percentage)

3.2 Determinant of behavioral change

Next, we use the game-level panel data to report results using fixed effects to control for unobserved player characteristics (see Table 2). We first take the full sample (seasons

1985-86 to 2014-15), retaining all the players who have attempted at least 1 field shot during the seasons (specification (1)). We subsequently restrict the sample to 3 years before the initial change and 3 years after the reversion (specification (2)), i.e., 1991-92 to 1999-2000 seasons (inclusive, 9 seasons). In specification (3) we report results restricting the sample to those who played at least one game before the initial change and one after the initial change, focusing the analysis just on the first change. In specification (4) we look at those who played at least one game before and after the reversion. In specification (5) we focus on those who played at least one game in all three periods (before, between the rule changes, and afterwards). In the final two specifications in Table 2 we look at the first line change (specification (6)) and the second one (specification (7)), in both cases restricting the time period to 3 seasons before and after the initial line change or the reversion. Our key variable is *short 3pt line* which is a dummy equal to 1 for the period in which the line was closer to the basket and 0 otherwise. We control for factors such as players' *age* (in years) or *experience* (number of NBA career games played), a dummy for *playoffs*, *minutes played* on the court during a game, a dummy for *home game*, the number of spectators in a game (*attendance*), a dummy indicating whether a player is new to the team (started in the new season or joined during the season). We also add a linear time trend (at the yearly level) to the model as suggested by the upward trend observed in the descriptive results. Overall the results are very robust throughout the specifications.

Table 2: Determinants of *P3FGA*

Sample Period	(1) 1985-2014	(2) 1991-1999	(3) 1991-1999	(4) 1991-1999	(5) 1991-1999	(6) 1991-1996	(7) 1994-1999
Short 3pt line	0.042***	0.040***	0.041***	0.040***	0.040***	0.035***	0.036***
	(15.62)	(17.33)	(15.90)	(15.73)	(14.43)	(10.02)	(11.36)
Minutes Played	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
	(13.31)	(7.89)	(5.94)	(6.94)	(5.70)	(6.45)	(7.20)
Age	0.015***	0.024***	0.028***	0.025***	0.029***	0.026***	0.024***
	(8.79)	(8.08)	(7.73)	(7.26)	(7.46)	(6.84)	(6.01)
Playoffs	0.007***	0.009***	0.009***	0.008***	0.007**	0.010***	0.008***
	(6.61)	(4.79)	(3.99)	(3.94)	(3.32)	(4.61)	(3.69)
New to team	-0.001	-0.003	-0.004	-0.002	-0.003	-0.005*	-0.003

	(-1.33)	(-1.53)	(-1.73)	(-1.13)	(-1.19)	(-2.15)	(-1.25)
Home Game	0.001**	0.001	0.0044	0.001	0.00045	0.001	0. 00036
	(3.07)	(1.12)	(0.65)	(0.91)	(0.59)	(1.33)	(0.48)
Attendance	1.1e-07	5.5e-08	1.5e-08	2.8e-08	1.9e-09	3.7e-08	1.1e-07
	(1.52)	(0.75)	(0.18)	(0.34)	(0.02)	(0.45)	(1.39)
Time trend	YES	YES	YES	YES	YES	YES	YES
Observations	697252	202387	147410	156542	125871	113387	112733
Players	2359	955	389	403	265	389	403
R^2 (within)	0.055	0.064	0.083	0.070	0.084	0.105	0.017
R^2 (between)	0.081	0.004	0.009	0.000	0.017	0.009	0.001
Prob. > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes: Dependent variable: *P3FGA*. Robust OLS with player fixed effects. *t*-statistics in parentheses. The symbols *, **, *** represent statistical significance at the 5%, 1% and 0.1% levels, respectively.

The coefficient for *short 3pt line* is always statistically significant at the 0.1% level. During that period, on average, a player increased ceteris paribus their *P3FGA* by around 4 percentage points. As seen beforehand in the descriptive analysis, playoffs are correlated with higher *P3FGA*. A greater number of minutes played encourages players to attempt more 3-points in relative terms while newcomers tend to be less likely to take risks and go for 3-points, although the coefficient is mostly not statistically significant. Home games encourage an increase in the *P3FGA* but the coefficient is only statistically significant in specification (1). The coefficients of attendance are positive but not statistically significant, suggesting that attendance has no effect on *P3FGA*. Since age and experience are highly correlated (ρ is around 0.88), in Table 3 we substitute age for NBA experience (number of games participated in the NBA); once again we find that an increase in experience leads to more *P3FGA*. However, contrary to the results on age, the coefficient is not always statistically significant. This suggests that age is a more powerful factor for understanding *P3FGA* behaviour.

Table 3: Determinants of *P3FGA* controlling for NBA experience

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sample Period	1985-2014	1991-1999	1991-1999	1991-1999	1991-1999	1991-1996	1994-1999
Short 3pt line	0.041***	0.040***	0.040***	0.039***	0.039***	0.035***	0.036***
	(15.62)	(17.26)	(15.80)	(15.72)	(14.35)	(10.00)	(11.26)
Minutes Played	6.3e-04***	5.8e-04***	5.4e-04***	6.1e-04***	5.8e-04***	5.7e-04***	6.1e-04***
	(13.08)	(7.80)	(5.80)	(6.88)	(5.59)	(6.37)	(7.22)

NBA	4.2e-05*	6.5e-05*	6.5e-05	5.4e-05	5.7e-05	7.0e-05	7.1e-05*
Experience	(2.30)	(2.11)	(1.86)	(1.59)	(1.50)	(1.76)	(2.43)
Playoffs	0.009***	0.013***	0.014***	0.013***	0.013***	0.015***	0.012***
	(8.03)	(6.55)	(5.96)	(5.84)	(5.45)	(5.96)	(5.48)
New to team	-0.001	-0.002	-0.003	-0.002	-0.002	-0.005	-0.002
	(-1.07)	(-1.28)	(-1.48)	(-0.91)	(-0.98)	(-1.93)	(-1.09)
Home Game	9.8e-04**	6.3e-04	4.4e-04	6.0e-04	4.4e-04	9.7e-04	3.6e-04
	(3.06)	(1.11)	(0.65)	(0.91)	(0.59)	(1.31)	(0.48)
Attendance	1.3e-07	8.6e-08	5.3e-08	6.3e-08	4.4e-08	7.2e-08	1.4e-07
	(1.83)	(1.15)	(0.62)	(0.74)	(0.46)	(0.88)	(1.75)
Time trend	0.004**	0.003	0.003	0.004	0.004	0.005	0.002
	(2.90)	(1.77)	(1.49)	(1.80)	(1.49)	(1.62)	(0.87)
Observations	697252	202387	147410	156542	125871	113387	112733
Players	2359	955	389	403	265	389	403
R^2 (within)	0.055	0.063	0.083	0.069	0.083	0.105	0.017
R^2 (between)	0.135	0.012	0.000	0.001	0.000	0.000	0.001
Prob. > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes: Dependent variable: *P3FGA*. Sample period: 1991-92 to 1999-2000 season. Robust OLS with player fixed effects. *t*-statistics in parentheses. The symbols *, **, *** represent statistical significance at the 5%, 1% and 0.1% levels, respectively.

The coefficient for *short 3pt line* remains highly statistically significant for all the different player positions (see Table 4). Not surprisingly, point guards[14] and shooting guards[15] take most advantage of the shorter 3-point line distance, increasing the *P3FGA* by around 6 percentage points.

Table 4: How the rule change affected the behaviour of players based on their position

	(1) Centre	(2) Point Guard	(3) Power Forward	(4) Shooting Guard	(5) Small Forward
Short 3pt line	0.013***	0.065***	0.024***	0.061***	0.047***
	(3.53)	(13.64)	(5.09)	(13.84)	(9.51)
Minutes Played	0.0001	0.001***	0.00023	0.001***	0.001***
	(0.90)	(4.33)	(1.56)	(3.79)	(4.12)
Age	0.010*	0.032***	0.021***	0.045***	0.041***
	(2.58)	(3.63)	(4.43)	(5.83)	(5.85)
Playoffs	0.003	0.013**	0.009*	0.003	0.013**
	(1.53)	(2.88)	(2.33)	(0.69)	(2.97)
New to team	-0.003	-0.003	-0.003	-0.002	0.001
	(-1.56)	(-0.62)	(-1.17)	(-0.38)	(0.28)
Home Game	0.001	-0.001	0.001	-0.001	0.001
	(0.99)	(-0.33)	(0.89)	(-0.80)	(0.71)
Attendance	8.4e-08	-3.5e-08	1.2e-07	1.2e-08	-5.9e-08

[14] Famous point guards are, e.g., Earvin “Magic” Johnson or John Stockton. They are usually the shortest players among the starting five and are good at passing and shooting (for a good discussion on the fundamentals of basketball see Phelps, 2000).

[15] Good examples were Michael Jordan and Kobe Bryant. They are usually the best perimeter shooters aiming at freeing themselves to go for the shoot. They strongly profited from the introduction of the three-point line (Phelps, 2000)

	(0.90)	(-0.19)	(0.97)	(0.07)	(-0.35)
Time trend	YES	YES	YES	YES	YES
Observations	43009	31985	45011	38254	41694
Players	91	67	93	81	82
R^2 (within)	0.022	0.120	0.049	0.128	0.118
R^2 (between)	0.004	0.007	0.008	0.003	0.003
Prob. > F	0.009	0.000	0.001	0.000	0.000

Notes: Dependent variable: *P3FGA*. Sample period: 1991-92 to 1999-2000 season. Robust OLS with player fixed effects, t-statistics in parentheses. Model based on specification (5), Table 2 (players who played at least one game in each of the 3 periods). The symbols *, **, *** represent statistical significance at the 5%, 1% and 0.1% levels, respectively.

We now take a closer look how age and experience are connected to rule changes (Table 5). First, we analyse the initial rule change based on players who had at least one game before or after the change (specification (1)). Older players appear to be less likely to take advantage of the 3-point line change, where an increase in age results in players reducing the *P3FGA* due to the change. On the other hand, after the reversion re-adjustment processes are not observed (specification (2)). Results looking at all three periods (specification 3) confirm the findings of specification (1). Age is negatively correlated with *P3FGA* during the shortening of the 3-point line. Results reported in specification (4) support the finding that older players do not readjust after the line is returned to its original distance. The results do not change when we replace *age* with *NBA experience* (see specifications (5) to (8)). Likewise, we obtain robust results when controlling for *experience* (or *age*) in the two sets of models (results not reported but are available upon request).

Table 5: Age and experience effects

DV: Shot choice	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sample	1991-96	1994-99	1991-99	1991-99	1991-96	1994-99	1991-99	1991-99
Short 3pt line	0.120***	0.047**	0.121***		0.050***	0.037***	0.052***	
	(4.24)	(2.79)	(5.23)		(8.01)	(8.05)	(9.73)	
Pre 1994-95 seasons				-0.155***				-0.056***
				(-4.77)				(-8.45)
Post 1996-97 seasons				-0.083**				-0.044***
				(-2.76)				(-5.42)
Age	0.027***	0.025***	0.030***	0.027***				
	(7.16)	(6.01)	(7.62)	(7.04)				
Short 3pt line # Age	-0.003**	-3.6e-04	-0.003***					
	(-3.08)	(-0.62)	(-3.59)					
Pre 1994-95 seasons # Age				0.004***				
				(3.63)				
Post 1996-97 seasons #				0.001				

Age				(1.52)				
NBA Experience					1.1e-04**	7.1e-05*	6.7e-05	6.1e-05
					(2.77)	(2.43)	(1.77)	(1.68)
Short 3pt line # NBA Experience					-3.5e-05**	-2.7e-06	-2.7e-05**	
					(-3.15)	(-0.34)	(-3.05)	
Pre 1994-95 seasons # NBA Experience								4.4e-05**
								(3.30)
Post 1996-97 seasons # NBA Experience								1.1e-05
								(0.99)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	113387	112733	125871	125871	113387	112733	125871	125871
Players	389	403	265	265	389	403	265	265
R^2 (within)	0.108	0.017	0.086	0.087	0.107	0.017	0.084	0.085
R^2 (between)	0.010	0.001	0.017	0.018	0.001	0.001	0.000	0.002
Prob. > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes: Robust OLS with player fixed effects. *t*-statistics in parentheses. The symbols *, **, *** represent statistical significance at the 5%, 1% and 0.1% levels, respectively. Reference group for specification (4) and (8): 1994-96 to 1996-97 seasons.

One possible explanation for this result could be that changes in motor skills affect the capacity to adjust and re-adjust to such changes. Motor skills are the fundamental way in which we measure human performance, especially in relation to athletes where coaches need to understand player development and their abilities and limitations. Of particular importance is the physiological aspects of motor development and function, e.g. fine coordination, endurance and the continuous age-related process of movement changes. Motor learning encompasses the acquisition of new unknown skills as well as relearning and improvement of motor skills acquired in the past (Voelcker-Rehage, 2008, p. 6). Rule changes like the movement of the three-point line effectively change the physical distance a player has between the hoop and the shot limit; players need to adapt and relearn the motor skill related to that particular shot as the mechanics would have changed. Unfortunately, the majority of research addressing the effect of age on motor learning has focused on the extremes, the young (approximately 20-30) and the old (50+), and only a few studies have explored the effects over time and at all ages. Voelcker-Rehage and Willimczik (2006) life span study of motor skills demonstrates that younger adults learnt much faster than older adults, with peak learning in the late teens and early twenties. This peak slowly declines as the individual approaches the mid-thirties after which it remains fairly consistent until the late sixties or early seventies. This indicates that younger players would be able to (on average) adapt faster than the slightly older players.

3.3 Influence of skills and specialization

We now explore whether those with increased shot quality, i.e., players with higher accuracy of specific shots, take advantage of the rule change. We develop a variable called cumulative shooting percentage which measures the historical performance of specific shots (e.g., 2-points, 3-points, or free throws), normalised by attempts. Historical performance includes shots taken by a player during his NBA career excluding the present game. We differentiate between overall career history (specifications (1), (3), (5), (7), (9), and (11)) and the previous ten games' performance (specifications (2), (4), (6), (8), (10), and (12)). We again apply specification (5) from Table 2 adding only the new variable and additionally exploring its interaction with the variable *short 3pt line* (Table 6). Specifications (1) and (2) indicate that during the shorter 3-point line period, improvements in 3-point efficiency encouraged players to attempt more three-point shots in relative terms. An increase in free throws percentage also has a positive impact on *P3FGA* that is statistically significant at the 0.1% level. A player experienced a 10% increase in 3-point (free throw) efficiency is 1.6 (1.8) percentage point more likely to attempt 3-point relative to all shots (specification 1 and 5). On the other hand, those experienced increased in 2-point efficiency reduce the likelihood of *P3FGA* (a 10% increase reduced *P3FGA* by 3 percentage points, see specification (3)). Such results provide support for specialization or the psychological heuristic of "win-stay": "if it is working don't change strategy". Not surprisingly, we find similar results when looking at the overall field goal efficiency (specification (7) and (8)) or the true shooting percentage (specifications (9 and (10)). Moreover, players who improved their 3pt shots relative to 2pt shots increased their *P3FGA*.

Table 6: Influence of shot quality on shot choice

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Efficiency of shots	3pt% OCH[1]	3pt% LTG[2]	2pt% OCH	2pt% LTG	FT% OCH	FT% LTG	FG% OCH	FG% LTG	TS% OCH	TS% LTG	3pt%/2pt% OCH	3pt%/2pt% LTG
Short 3pt line	0.003	0.039***	0.184***	0.061***	-0.092***	-0.003	0.225***	0.083***	0.162***	0.048***	0.005	0.042***
	(0.70)	(12.70)	(6.36)	(8.05)	(-4.37)	(-0.33)	(9.13)	(10.00)	(4.81)	(5.13)	(1.21)	(12.82)
Shooting efficiency	-0.018	0.040***	0.152**	0.017	-0.018	-0.027***	-0.022	0.011	0.267***	0.071***	0.019	0.010***
	(-0.49)	(7.05)	(2.92)	(1.90)	(-0.59)	(-4.51)	(-0.40)	(1.16)	(4.26)	(6.06)	(1.81)	(5.38)
Short 3pt line *	0.161***	0.032***	-0.303***	-0.045**	0.180***	0.058***	-0.402***	-0.096***	-0.234***	-0.017	0.067***	0.011***
Shooting efficiency	(7.30)	(4.52)	(-5.12)	(-3.02)	(6.33)	(5.63)	(-7.84)	(-5.72)	(-3.70)	(-1.00)	(8.93)	(4.04)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	120924	95136	125763	125766	125565	124712	125766	125766	125768	125768	119996	93856
Players	262	261	265	265	264	265	265	265	265	265	259	259
R^2 (within)	0.098	0.113	0.088	0.084	0.089	0.087	0.092	0.086	0.088	0.086	0.099	0.111
R^2 (between)	0.015	0.009	0.019	0.017	0.009	0.015	0.008	0.016	0.021	0.017	0.004	0.008
Prob. > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes: Dependent variable: *P3FGA*. Robust OLS with player fixed effects. t-statistics in parentheses. The symbols *, **, *** represent statistical significance at the 5%, 1% and 0.1% levels, respectively. 3pt% = three-point percentage; 2pt% = two-point percentage; FT% = free throw percentage; FG% = field goal percentage; TS% = true shooting percentage; 3pt%/2pt% = ratio between three-point percentage and two-point percentage.

[1] OCH: Overall Career History.

[2] LTG: Last Ten Games.

3.4 Effects on shooting efficiency

To further explore shooting efficiency, we again use the controls from specification (5) Table 2, building additional dummies for pre 1994-95 and post 1996-97 sessions (reference group is the period with the shorter distance), controlling for historical shooting efficiency (cumulative value since the beginning of a player's career) and *P3PGA* (see Table 6). 3pt shooting % increases after the line is shortened (an increase of 2.4 percentage points), but when the line is moved back to the original position, the decrease (1 percentage point) is not significant (specification (1)). Relative 3-point efficiency (specification (6)) also increases substantially due to the shortening of the line (5.4 percentage points). Again, the decrease in performance is not statistically significant, which indicates that making 3-points easier for a couple of seasons has a positive spill-over effect afterwards (for the next three seasons). The spill-over effect actually remains for a number of years (see Table 8). Such spill-over effects are also relevant for TS (specification (5), Table 8) while 2-point efficiency and field goal efficiency decrease in the post-period, indicating statistically significant coefficients. Table 8 also reports that an increase in the 3-point ratio attempts has a positive effect on 3 and 2-point efficiencies and on TS. Beyond that, such a rule adjustment helped players to increase their relative 3-point efficiency (see specification (6)).

Table 7: Shooting efficiency

	(1) 3pt%	(2) 2pt%	(3) FT%	(4) FG%	(5) TS%	(6) 3pt%/2pt%
Pre 1994-95 seasons	-0.024***	-0.005	-0.002	-0.007	-0.011**	-0.054**
	(-3.47)	(-1.41)	(-0.46)	(-1.93)	(-3.18)	(-2.74)
Post 1996-97 seasons	-0.010	-0.010*	0.006	-0.011**	-0.007	-0.021
	(-1.50)	(-2.55)	(1.20)	(-2.84)	(-1.89)	(-1.09)
P3FGA	0.354***	0.053***	-0.003	-0.139***	0.120***	0.637***
	(15.52)	(5.15)	(-0.21)	(-13.64)	(9.18)	(7.96)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes
Observations	61948	124022	86379	125766	125768	55596
Players	260	265	264	265	265	256
R^2 (within)	0.020	0.022	0.003	0.032	0.038	0.009

R^2 (between)	0.000	0.022	0.002	0.081	0.099	0.041
Prob. > F	0.000	0.000	0.000	0.000	0.000	0.000

Notes: Dependent variable: Shooting efficiency. Robust OLS with player fixed effects. *t*-statistics in parentheses. The symbols *, **, *** represent statistical significance at the 5%, 1% and 0.1% levels, respectively. Reference group: 1994-96 to 1996-97 seasons. 3pt% = three point percentage; 2pt% = two-point percentage; FT% = free throw percentage; FG% = field goal percentage; TS% = true shooting percentage; 3pt%/2pt% = ratio between three point percentage and two point percentage.

Table 8: Spill-over effects

	(1) 3pt%	(2) 2pt%	(3) FT%	(4) FG%	(5) TS%	(6) 3pt%/2pt%
Before initial line change						
1991-92	-0.040**	-0.000	0.014	-0.005	-0.011	-0.111**
	(-3.04)	(-0.02)	(1.48)	(-0.74)	(-1.56)	(-2.82)
1992-93	-0.036***	0.001	0.010	-0.003	-0.007	-0.101***
	(-3.52)	(0.22)	(1.26)	(-0.54)	(-1.19)	(-3.36)
1993-94	-0.036***	-0.002	-0.005	-0.006	-0.012**	-0.091***
	(-4.88)	(-0.55)	(-0.88)	(-1.62)	(-3.19)	(-4.19)
After reversion						
1997-98	-0.007	-0.011*	-0.002	-0.010*	-0.007	-0.017
	(-1.01)	(-2.22)	(-0.32)	(-2.47)	(-1.69)	(-0.82)
1998-99	-0.006	-0.024***	-0.012	-0.020***	-0.016*	0.030
	(-0.60)	(-3.70)	(-1.27)	(-3.44)	(-2.50)	(0.91)
1999-00	0.022	-0.012	0.011	-0.006	-0.000	0.065
	(1.91)	(-1.60)	(1.13)	(-0.86)	(-0.01)	(1.73)
2000-01	0.020	-0.018	0.015	-0.011	-0.005	0.092
	(1.34)	(-1.91)	(1.21)	(-1.36)	(-0.60)	(1.97)
2001-02	0.025	-0.014	0.017	-0.006	-0.002	0.086
	(1.41)	(-1.20)	(1.21)	(-0.66)	(-0.18)	(1.55)
2002-03	0.023	-0.010	0.015	-0.003	0.004	0.094
	(1.13)	(-0.78)	(0.92)	(-0.28)	(0.32)	(1.47)
2003-04	0.027	-0.012	0.008	-0.004	0.002	0.090
	(1.13)	(-0.84)	(0.44)	(-0.33)	(0.15)	(1.28)
2004-05	0.032	-0.005	0.022	0.003	0.014	0.112
	(1.22)	(-0.31)	(1.01)	(0.20)	(0.93)	(1.38)
2005-06	0.035	0.006	-0.001	0.017	0.025	0.078
	(1.29)	(0.26)	(-0.05)	(0.88)	(1.30)	(0.91)
2006-07	0.023	0.025	-0.033	0.026	0.029	0.137
	(0.67)	(0.99)	(-1.09)	(1.12)	(1.28)	(1.24)
2007-08	0.016	0.008	0.002	0.016	0.025	0.159
	(0.40)	(0.27)	(0.09)	(0.54)	(0.80)	(1.38)
2008-09	0.028	0.059*	0.083**	0.056*	0.080**	-0.112
	(0.80)	(2.45)	(2.69)	(2.52)	(3.05)	(-1.04)
2009-10	-0.163**	0.024	0.022	0.021	0.038	-0.107
	(-3.27)	(0.76)	(0.71)	(0.47)	(0.68)	(-0.85)
Control	YES	YES	YES	YES	YES	YES
Observations	76569	153255	104007	155759	155761	67597
Players	260	265	264	265	265	256
R^2 (within)	0.020	0.024	0.005	0.035	0.042	0.008
R^2 (between)	0.004	0.062	0.341	0.245	0.213	0.005

Notes: Dependent variable: Shooting efficiency. Robust OLS with player fixed effects. *t*-statistics in parentheses. The symbols *, **, *** represent statistical significance at the 5%, 1% and 0.1% levels, respectively. Reference group: 1994-96 to 1996-97 seasons. 3pt% = three point percentage; 2pt% = two-point percentage; FT% = free throw percentage; FG% = field goal percentage; TS% = true shooting percentage; 3pt%/2pt% = ratio between three point percentage and two point percentage. All players in the sample retired from the NBA before 2010-11, Shaquille O'Neal was the only player from the sample retired in 2010-11 season.

4. Conclusions

The fields of economic psychology and behavioural economics have been able to harness the comparative advantage of using the sports environment as a real-world laboratory environment to test and explore fascinating questions to better understand human nature and human behaviour. The controlled environment with clearly specified rules, incentives, and observable factors with little statistical error enhances the attractiveness of sports data as an instrument or tool to explore a large amount of open questions and hypotheses beyond the sports environment. Regular changes in the rules of a game provide additional ways to explore behavioural implications of such changes that affect human incentives and constraints. These observations are made while maintaining high external validity of field data and noting behaviour in a high stakes environment or an actual economic setting where decisions have substantial financial implications.

In our analysis, we complement existing rule change studies by focusing not just on one rule change but the repeated change of a single rule that reduced players' restrictions, followed by a return to the original condition. This double change provides the unique opportunity to explore the adaption and re-adaption processes. We find that players tend to immediately adjust and respond to the new environment. Reducing the distance of the three-point line to the basket increases the proportion of 3-point field goals attempted (relative to the overall field goal attempts). Point guards and shooting guards take particular advantage of such rule changes, while older players or players with more NBA experience reduce their 3-point ratio after shortening the distance. In addition, older players do not readjust their ratio after the distance is returned to the original condition. Thus, such players seemed to struggle more with rule adjustments. Positive feedback such as efficiency improvements in players' shots due to the reduced distance encourages players to try more 3-shots while those who increased their 2pt efficiency actually reduced such attempts which may indicate that they follow the heuristic of “win-stay”. Making 3-points shots easier for a couple of seasons has positive externalities on relative 3-point efficiency as players’ efficiency gains achieved during the period of shorter distances do not readjust negatively after again increasing the distance. Such positive efficiency spill-overs remain evident for more than a decade afterwards.

We believe that some results can be fed back into a laboratory experimental setting or even a field experiment. The efficiency gains of the rule change and the observable slowness of re-adjustments among older players provide a good starting point. For example, experiments could check whether similar tendencies can be found using different contexts and tasks. Another interesting approach is to re-adjust the rule change in the opposite direction; for example, what happens if the task is harder first and then again easier? Laboratory experiments provide more flexibility to conduct comparative approaches designing the task around or closer to open questions. Thus, using sports and laboratory experimental data jointly provide valuable opportunities for future research.

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Highlights

- Players' shot choice are influenced by the distance between 3pt line and basket.
- Adaptation process depends on player's age, experience, and shooting skill levels.
- Reducing difficulty has a long-term positive externalities on shooting efficiency.