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ABSTRACT

Running the Risk of an Injury in the NFL: Short-Run and Career Consequences*

Similar to other workers in industrial settings NFL running backs can choose to provide additional work effort with possible negative health consequences. We find that the most informative measure for running backs is yards gained after contact, which not only increases total rushing yards but also increases injuries that can cause subsequent lost income due to future games missed. We econometrically examine the decisions running backs reveal in trading off injury risk against total yards gained and salary in the short run and how the tradeoff appears in the longer run where career length considerations come into play. Our estimates reveal subtle nonlinearities and interpersonal heterogeneity in risky effort and the associated short and long run injury risk and economic payoffs.

JEL Classification: Z21, Z22, C23

Keywords: non-fatal injuries, NFL, running backs, risky effort, rate-of-return, career length, Poisson regression, Arellano-Bond model, panel data, fixed effects

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"So I told the guy (special teams coach Jeff Fisher) the first guy that hits me, I'm going down. Ain't gonna be no yards after contact," Chris Carter commenting on having to return kickoffs as a rookie.

1. Introduction

We often view professional sports players as totally different than workers in other industries such as manufacturing where there is also a job-related risk of bodily harm. But is there really much of an economic difference where workplace safety is concerned? Both manufacturing workers and NFL players increase the risk of greater non-fatal injuries by working harder. In addition to lost wages in the short-run following the injuries due to missed work, non-fatal injuries can have downstream consequences of possible lower productivity and a lower pay rate, as well as reduced career length, which further lowers earnings in the long run. Viscusi (2004) is a comprehensive examination of the short-run labor market consequences of non-fatal injuries for industrial workers. Much less is known empirically about the longer-run consequences of non-fatal industrial injuries. Here we study NFL running backs, who have an endogenous component of their injuries due to risky effort they may take and its importance to their careers and earnings.

2. Risky Effort and Injuries Among Running Backs in the NFL

We begin with some results from the literature and then build on them with original econometric modeling to set up our approach to the ultimate research objective of how risky effort among NFL running backs affects their immediate and longer-run career success. We are particularly interested in how short-run and longer-run career success and length trade off against each other.

2.1 Risky Effort and Its Economic Consequences in the Short-Run

We begin with results from Simmons and Berri (2009) who found that running backs are compensated based on rushing yards (*Yds*), rather than attempts or yards per attempt. We supplement the pay-rushing yards link with additional research results from Keefer (2019) and Simmons and Berri (2009), which leads us to begin with the following equation that estimates the compensation of running backs

$$\ln(w_{it}) = \gamma_i + 0.00069 \times Yds_{it-1} + \mathbf{x}'_{it}\boldsymbol{\lambda} + \epsilon_{it} \quad (1)$$

where **x** controls for other personal and team characteristics. The estimated average rate of return to rushing yards is 0.069%, or an additional 100 rushing yards during the course of a season increases compensation in the subsequent year by 6.9% (Keefer 2019).[1] Because we are interested in how changes in risky effort affect compensation, we turn to how changes in risky effort affects rushing yards.

Now consider how rushing yards is a function of the amount of risk (*Risk*) taken by player *i*, the number of games missed from injury (*Inj*), and other factors (**k**).

$$Yds_{it} = f(Risk_{it}, Inj_{it}, \mathbf{k}_{it}) \quad (2)$$

The change in rushing yards from a change in risk is

$$dYds_{it} = \frac{\partial Yds_{it}}{\partial Risk_{it}} dRisk_{it} + \frac{\partial Yds_{it}}{\partial Inj_{it}} \frac{\partial Inj_{it}}{\partial Risk_{it}} dRisk_{it} \quad (3)$$

so that

$$\frac{dYds_{it}}{dRisk_{it}} = \underbrace{\frac{\partial Yds_{it}}{\partial Risk_{it}}}_{\text{direct effect}} + \underbrace{\frac{\partial Yds_{it}}{\partial Inj_{it}} \frac{\partial Inj_{it}}{\partial Risk_{it}}}_{\text{indirect effect}} \quad (4)$$

Using (4), the rate of return to risk is then

$$\frac{\partial \ln(w_{it+1})}{\partial Risk_{it}} = 0.00069 \left(\frac{\partial Yds_{it}}{\partial Risk_{it}} + \frac{\partial Yds_{it}}{\partial Inj_{it}} \frac{\partial Inj_{it}}{\partial Risk_{it}} \right) \quad (5)$$

[1] Keefer (2019) estimated the rate of return to rushing yards using fixed-effects regression to eliminate omitted variable bias from individual heterogeneity, such as talent. The rate of return to an additional 100 rushing yards of 6.9% is extremely close to the rate of return estimated in Simmons and Berri (2009) using median regression of 6.6%.

Because the return to risk taking in (5), depends on the size of the injury risk effect on injury outcomes we need to determine if our measure of risky effort is actually a measure of risky behavior. We hypothesize that the number of yards after initial contact per rushing attempt (*YAC/Att*) is a measure of risky effort by runners, where

$$Risk_{it} \equiv \frac{YAC_{it}}{Att_{it}} \tag{6}$$

We use per-rush yards after contact because we are interested in player risk taking, not increased injury risk from increased use. So, we specify *Inj* as a function of *YAC/Att*

$$Inj_{it} = \alpha_i + \beta\left(\frac{YAC_{it}}{Att_{it}}\right) + \mathbf{z}'_{it}\boldsymbol{\delta} + e_{it} \tag{7}$$

so that

$$\frac{\partial Inj_{it}}{\partial Risk_{it}} \equiv \beta \tag{8}$$

where **z** is a vector of other variables affecting injury risk. We estimate β using a fixed effects estimator (the so-called within transformation), which allows us to control for all time-invariant determinants of injuries, such as physical size, strength, and durability. For comparison we also estimate β using conditional fixed effects Poisson regression, with an exponential conditional expectation because the number of games missed due to injury is a non-negative integer. Our measure of risky effort also avoids endogeneity here. Injuries will affect the number of yards after contact through reduced rushes; games missed due to injury do not affect per rush measures.

Next, we turn our attention to estimating $\frac{\partial Yds_{it}}{\partial Inj_{it}}$, the effect of games missed due to injury on rushing yards in a season. Here

$$Yds_{it} = \sigma_i + \pi Inj_{it} + \rho\left(\frac{YAC_{it}}{Att_{it}}\right) + \mathbf{k}'_{it}\boldsymbol{\theta} + \mu_{it}, \tag{9}$$

with

$$\frac{\partial Yds_{it}}{\partial Inj_{it}} = \pi, \tag{10}$$

where **k** is a vector of other variables affecting rushing yards in a given season. We again use fixed effects estimation to account for all time-invariant determinants of rushing yards, such as talent, size, speed, elusiveness. Because injuries are a function of *YAC/Att*, we include *YAC/Att* as a control variable. From equations (8) and (10) the cost, in terms of compensation, associated with additional risk taking is $0.00069(\pi\beta)$. Because the effect of missing a game due to injury may have a different impact on rushing yards depending on use, we also estimate the following equation

$$Yds_{it} = \sigma_i + \pi_1 Inj_{it} + \pi_2\left(Inj_{it} \times \frac{Att_{it}}{G_{it}}\right) + \pi_3\left(\frac{Att_{it}}{G_{it}}\right) + \rho\left(\frac{YAC_{it}}{Att_{it}}\right) + \mathbf{k}'_{it}\boldsymbol{\theta} + \mu_{it} \tag{11}$$

where *Att/G* is the number of rushing attempts per game. As a result, $\pi_1 + \pi_2\left(\frac{Att_{it}}{G_{it}}\right)$ is the effect of injuries on rushing yards in equation (11). Thus, the compensation cost of additional risk would be $0.00069\left[\pi_1 + \pi_2\left(\frac{Att_{it}}{G_{it}}\right)\right]$.

Finally, we must determine $\frac{\partial Yds_{it}}{\partial Risk_{it}}$, the direct effect of risk taking on rushing yards. However, we cannot estimate the effect using the coefficient ρ. Because injuries are a function of risk taking, we cannot determine the effect of risk taking while holding injuries constant; this is the so-called bad control problem (Angrist and Pischke 2009, pp. 64-68). Instead, we use the fact that rushing yards has two components, yards after initial contact (*YAC*) and yards before initial contact (*YBC*)

$$Yds_{it} = YAC_{it} + YBC_{it} \tag{12}$$

which is

$$Yds_{it} = \left(\frac{YAC_{it}}{Att_{it}}\right)Att_{it} + YBC_{it}. \quad (13)$$

So, $\frac{\partial Yds_{it}}{\partial Risk_{it}} = Att_{it}$, and increasing the number of yards after contact per rush increases total rushing yards by the number of attempts. The benefit to additional risk in terms of compensation is then $0.00069 \times Att_{it}$.

2.1.1 Preview to estimating the return to risky effort. In sum, the short-run rate of return to risky effort for an individual NFL running back is

$$\frac{\partial \ln(w_{it+1})}{\partial Risk_{it}} = 0.00069(Att_{it} + \pi\beta), \quad (14)$$

and the average short-run rate of return to running backs' risk taking here is

$$\overline{\frac{\partial \ln(w_{t+1})}{\partial Risk_{t}}} = 0.00069\left(\overline{Att} + \pi\beta\right). \quad (15)$$

Allowing injuries to impact rushing yards depending on use the rate of return to additional risk is

$$\frac{\partial \ln(w_{it+1})}{\partial Risk_{it}} = 0.00069\left[Att_{it} + \left(\pi_1 + \pi_2\left(\frac{Att_{it}}{G_{it}}\right)\right)\beta\right]. \quad (16)$$

Our first research objective, then, is to fill out the details of equations (15) and (16) with econometric estimates, which reveals how the rate of return to risky effort among NFL running backs depends on the number of rushing attempts, the marginal effect of injuries on rushing yards, and the marginal effect of injury risk on injuries.

2.2 Career Consequences of Risky Effort

Having modeled the year-to-year economic consequences of risky effort and injuries among NFL running backs we now consider the longer-run effects of a change in risk taking. We now let the number of rushing yards in a given season depend on a player's career effort as manifested in total career rushing yards. Algebraically, this means that

$$Yds_{it} = \varrho_i + \phi CarYds_{it} + \mathbf{m}'_{it}\boldsymbol{\eta} + \vartheta_{it}, \tag{17}$$

or

$$Yds_{it} = \varrho_i + \phi \sum_{p_i=0}^{t-1} Yds_{ip_i} + \mathbf{m}'_{it}\boldsymbol{\eta} + \vartheta_{it}, \tag{18}$$

where **m** is the vector of other factors. Because fixed effects regression using deviations from the individual means requires strong exogeneity, it is inconsistent here as the error term is correlated with future regressors, $\mathrm{Cov}\left(CarYds_{it} - \overline{CarYds_i}, \vartheta_{it} - \overline{\vartheta_i}\right) \neq 0$; therefore, our estimates of the effect of career yards from our discussion of the short-run effect of risk are biased. We in turn use first differences to account for individual heterogeneity,

$$\Delta Yds_{it} = \phi \Delta CarYds_{it} + \Delta\mathbf{m}'_{it}\boldsymbol{\eta} + \Delta\vartheta_{it}. \tag{19}$$

Substituting the definition of career yards, we then have

$$\Delta Yds_{it} = \phi \left(\sum_{p_i=0}^{t-1} Yds_{ip_i} - \sum_{d_i=0}^{t-2} Yds_{id_i} \right) + \Delta\mathbf{m}'_{it}\boldsymbol{\eta} + \Delta\vartheta_{it}, \tag{20}$$

which simplifies to

$$\Delta Yds_{it} = \phi Yds_{it-1} + \Delta\mathbf{m}'_{it}\boldsymbol{\eta} + \Delta\vartheta_{it}. \tag{21}$$

OLS estimation of the first-differenced equation in (21) is inconsistent because $\mathrm{Cov}(Yds_{it-1}, \Delta\vartheta_{it}) \neq 0$ so we employ instrumental variables estimation. We use the Arellano and Bond (1991) GMM estimator using all available lags of career yards in a given time period as instruments. Because there are five years of data in our panel the maximum number of lagged values is four. So, for year 2010 observations we use year

2009 career yards as our instrument, for year 2011 observations we use years 2010 and 2009 career yards, and so on. Our instrument matrix, **Z**, is

$$\mathbf{Z} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \boldsymbol{z}_{2009} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \boldsymbol{z}_{2010} & \boldsymbol{z}_{2009} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \boldsymbol{z}_{2011} & \boldsymbol{z}_{2010} & \boldsymbol{z}_{2009} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \boldsymbol{z}_{2012} & \boldsymbol{z}_{2011} & \boldsymbol{z}_{2010} & \boldsymbol{z}_{2009} \end{bmatrix} \tag{22}$$

where $\boldsymbol{z}$ represents the vector of our instrument, career yards, for a given time period. We use the one-step GMM estimator, as our interest is conducting inference on the regression coefficient for career yards (See Kniesner and Leeth 2004 for another workplace safety application).

So, a one-time change in rushing yards in period 0 will generate a change in career rushing yards in period *t* of

$$\widetilde{Yds_0}(1+\phi)^{t-1}, \tag{23}$$

where $\widetilde{Yds_0}$ is the difference in rushing yards in period 0. Given this, the effect on rushing yards in period *t* of a one-time change in rushing yards in period 0 is

$$\phi\widetilde{Yds_0}(1+\phi)^{t-1}. \tag{24}$$

The effect of a one-time increase in risk in period 0 on career yards in period *t* is then

$$\frac{\partial CarYds_{it}}{\partial Risk_{i0}} = (Att_{it} + \pi_1\beta)(1+\phi)^{t-1}, \tag{25}$$

and the change in rushing yards in period *t* is

$$\frac{\partial Yds_{it}}{\partial Risk_{i0}} = \phi(Att_{it} + \pi_1\beta)(1+\phi)^{t-1}. \tag{26}$$

2.2.1 Career consequences. Rushing yards and career rushing yards may have another long-run impact; they may affect the probability of remaining in the NFL. We define the variable *Contract* to be a binary variable equal to one if the player has an active contract.

We estimate the effects of rushing yards and career rushing yards on the probability of having an active contract the following season using logistic regression

$$\ln\left[\frac{p_{it+1}}{1-p_{it+1}}\right] = \varphi + \tau Yds_{it} + \xi CarYds_{it} + \mathbf{h}'_{it}\boldsymbol{\psi}, \tag{27}$$

where $p_{it+1} = \Pr(Contract_{it+1} = 1)$. We then use the estimates from (27) to determine the effects of additional risk on the probability of career survival in subsequent years, $\widehat{p^*_{it+1}} - \widehat{p_{it+1}}$, where p^*_{it+1} is the probability of having an active contract for player *i* if he had taken additional risk in period *t* = 0. Thus,

$$\widehat{p_{it+1}} = \frac{\exp\left(\hat{\varphi} + \hat{\tau} Yds_{it} + \hat{\xi} CarYds_{it} + \mathbf{h}'_{it}\widehat{\boldsymbol{\psi}}\right)}{1 + \exp\left(\hat{\varphi} + \hat{\tau} Yds_{it} + \hat{\xi} CarYds_{it} + \mathbf{h}'_{it}\widehat{\boldsymbol{\psi}}\right)}, \tag{27}$$

and

$$\widehat{p^*_{it+1}} = \frac{\exp\left[\hat{\varphi} + \hat{\tau}\left(Yds_{it} + \frac{\partial Yds_{it}}{\partial Risk_{i0}}\right) + \hat{\xi}\left(CarYds_{it} + \frac{\partial CarYds_{it}}{\partial Risk_{i0}}\right) + \mathbf{h}'_{it}\widehat{\boldsymbol{\psi}}\right]}{1 + \exp\left[\hat{\varphi} + \hat{\tau}\left(Yds_{it} + \frac{\partial Yds_{it}}{\partial Risk_{i0}}\right) + \hat{\xi}\left(CarYds_{it} + \frac{\partial CarYds_{it}}{\partial Risk_{i0}}\right) + \mathbf{h}'_{it}\widehat{\boldsymbol{\psi}}\right]}, \tag{28}$$

with $\frac{\partial CarYds_{it}}{\partial Risk_{i0}}$ and $\frac{\partial Yds_{it}}{\partial Risk_{i0}}$ defined in (25) and (26).

3. Data

Injury data we use are from Pro Football Reference, who maintains a database beginning in the 2009 season, of team injury reports including games missed by players. Pro Football Reference yielded career rushing attempts and career rushing yards. Yards gained after initial contact, our measure of risk, *YAC/Att*, came from Pro Football Focus for the 2009 through 2013 seasons. Finally, we collected the cumulative experience of a running back's team's five starting offensive linemen from the NFL. Thus, our final data set represents five years of running backs, which we limit to players with a positive number of rushing attempts in a given season resulting in 254 players and 628 player-years.

Table 1 presents summary statistics for our regression variables. The average number of games missed due to injury in a season is two, suggesting a high degree of injury risk faced by running backs in the NFL. The average number of rushing yards in a season is 400, on an average of about 94 rushing attempts. The average number of yards after initial contact per rush is about 2.4, compared to about 1.6 yards before initial contact per rush. The average years of experience is just under three years, with an average number of career rushing attempts of 355 and an average of 1,554 career rushing yards.

4. Econometric Results

We begin with our short-run econometric results followed by long-run economic consequences estimates. Remember that the main difference is that career effort accumulates and affects outcomes in the long-run so that there are both short-run and long-run tradeoffs of effort and pay that will differ.

4.1 Short-Run Econometric Results

Table 2 presents estimation results for regressions of games missed due to injury on our measure of risky effort, *YAC/Att*. Columns 1 and 2 present fixed effects regressions. The effect of *YAC/Att* on games missed due to injury ranges from about 0.68 in our full specification to about 0.71, both of which are statistically significant at the 5% level. The estimated elasticity of injuries with respect to *YAC/Att* is about 0.8; a 10% increase in *YAC/Att* yields an increase in games missed due to injury of 8%. The results support our hypothesis that *YAC/Att* is a measure of endogenous risk taking. Poisson regressions, presented in Columns 3, 4, and 5, generate similar results. Both Poisson regression with player dummy variables and conditional fixed effects Poisson regression yield a coefficient for *YAC/Att* of 0.36, both of which are significant at the 5% level. Thus, a one yard increase in *YAC/Att* changes games missed due to injury by 36%, which is similar to the semi-elasticities calculated from fixed effects regressions, 0.34 to 0.35.[2] The estimates also show that players who have been more active in previous seasons are exposed to greater injury risk, and the number of career rushing attempts has a positive impact on the number of games missed due to injury.

Table 3 presents robustness checks using *YAC/Game* as our measure of endogenous risk. Fixed effects, Poisson dummy variable, and conditional fixed effects Poisson results are all significant to the 1% level and economically meaningful. A 10-yard increase in *YAC/Game* results in almost two additional games missed due to injury. From the Poisson estimations, every additional yard after contact per game increases games missed due to injury by about eight percent, which confirms that our initial conclusions are econometrically robust.

Table 4 presents results for regressions of rushing yards on games missed due to injury. The effect is highly significant and robust to the inclusion of *YAC/Att* as a control variable (Columns 2 and 4). The effect is estimated to be -32.8 to -33.1 yards; for each game a running back misses due to injury his season total rushing yards falls by about 33 yards on average. Columns 3 and 4 present results including the number of rushing attempts per game played and the interaction of games missed due to injury and rushing attempts per game played. The binary variable for injuries is both small and statistically

[2] Regression results using ln(*YAC/Att*) as the measure of risk, yield similar results. The coefficient for fixed effects, Poisson dummy variable, and conditional fixed effects Poisson regressions are all significant to the 5%, and economically meaningful. Full results are available from the authors.

insignificant, which is to be expected because missing a game due to injury when the player does not rush the ball cannot change his season rushing yards. The interaction term is negative and highly significant in both regressions as missing a game has a larger impact for players who receive more rushing attempts when healthy. Figure 1 displays the effect of injuries on rushing yards for various levels of rushing attempts per game played, along with the 95% confidence interval, for our full specification. The effect is statistically significant for all values of attempts per game greater than or equal to 0.40. The effect ranges from about -22.6 for a player with an average of five rushing attempts per game, to -100.9 for players with an average of 23 carries per game played.

4.1.1 Short-run return to risky effort. We can now calculate the short-run rate of return to risky effort by NFL running backs. First, the average benefit of a one-yard increase in *YAC/Att* is an increase of 94.3 yards. The cost of the one-yard increase in *YAC/Att* is an expected loss of 22.4 yards from the associated increase in injuries. The average expected rate of return is 5.0%, as

$$\overline{\frac{\partial \ln(w_{t+1})}{\partial Risk_t}} = 0.00069(94.30 - 33.14 \times 0.677) = 0.050 \tag{29}$$

Using *YAC/Game* we also have

$$\frac{\partial \ln(w_{it+1})}{\partial Risk_{it}} = 0.00069(G_{it} + \pi_1 \beta) \tag{30}$$

For a 10-yard increase in *YAC/Game* the average expected rate of return, where the average number of games played is 13.99, is then 5.6%, as

$$\overline{\frac{\partial \ln(w_{t+1})}{\partial Risk_t}} = 0.00069(13.99 - 33.14 \times 0.179) \times 10 = 0.056 \tag{31}$$

However, because all the parameters used to calculate the rate of return to risky effort are themselves random variables, we simulate the rate of return to have a better understanding of the distribution. Because the parameters are all either regression coefficients or sample averages, all parameters can be simulated using normal distributions. We simulate the average rate of return 10,000 times based on the following distributions, where the parameters of the distribution for the effect of yards on compensation are taken from Keefer (2019).

$$\begin{gathered}\frac{\partial \ln(w_{it+1})}{\partial Yds_{it}} \sim \mathrm{N}(0.000690, 6.4 \times 10^{-8}) \\ \overline{Att} \sim \mathrm{N}(94.30, 13.37) \\ \pi \sim \mathrm{N}(-33.14, 22.05) \\ \beta \sim \mathrm{N}(0.677, 0.106)\end{gathered} \tag{32}$$

Table 5 presents the simulation results for each parameter, the benefit to additional risk, the cost to additional risk, and the average rate of return. The rate of return is positive in all but 30 of 10,000 simulations. Furthermore, the rate of return is between 4% and 6% in 50% of the simulations. Figure 2 displays a histogram of the simulation results for the average rate of return.

Allowing the effect of injuries on rushing yards to vary based on use we have the short-run rate of return is

$$\frac{\partial \ln(w_{it+1})}{\partial Risk_{it}} = 0.00069\left[Att_{it} + \left(-0.871 - 4.351\left(\frac{Att_{it}}{G_{it}}\right)\right)0.677\right]. \tag{33}$$

Using the average number of rushing attempts and the average number of rushing attempts per game, the average rate of return is 5.1%, as

$$\frac{\partial \ln(w_{it+1})}{\partial Risk_{it}} = 0.00069[94.30 + (-0.871 - 4.351 \times 6.822)0.677] = 0.051. \tag{34}$$

However, because the effect of injuries on rushing yards depends on use the rate of return is also a function of use,

$$\frac{\partial \ln(w_{it+1})}{\partial Risk_{it}} = 0.00069\left[\left(\frac{Att_{it}}{G_{it}}\right)G_{it} + \left(-0.871 - 4.351\left(\frac{Att_{it}}{G_{it}}\right)\right)0.677\right]. \quad (35)$$

Given the average number of games played, 14, for a player with only two attempts per game the rate of return is a mere 1.5%. For a player with 10 attempts per game the rate of return is 7.6%. Figures 3-6 display graphs of the rate of return, benefit and cost versus utilization for various numbers of games. The rate of return is negative for players with two or fewer games and is basically zero for three games.

4.2 Long-Run Econometric Results

To determine the long-run effect of risk taking we must estimate the effect of contemporaneously gained rushing yards on future performance. Table 6 presents our first-difference regressions of rushing yards on career rushing yards. First differencing the equation for rushing yards does not affect our estimate for the effect of games missed due to injuries on rushing yards; the first-differenced estimates range from -33.1 to -33.9 yards. The effect of career yards on current rushing yards is about -0.28 in the first-differenced OLS model. For our Arellano and Bond (1991) estimations the effect ranges from -0.20 to -0.22; all estimates are significant at the 1% level. For all estimations the Arellano and Bond (1991) test of serial correlation is satisfied, we reject the null hypothesis of no first-order serial correlation and fail to reject the null hypothesis of no second-order serial correlation in the first-differenced errors. The estimations also fail to reject the Hansen J-test of overidentification. The results imply that there is a cumulative negative effect on performance, similar to the increased injury risk from greater prior use. For each 100 rushing yards gained, a running back reduces future rushing yards by 20 to 22.

To illustrate the long-run effect of additional risky effort we present a comparison of two hypothetical running backs in Table 7. For each player we assume a baseline potential for rushing yards in a given season of 400 (the sample average). We then calculate the number of rushing yards in each time period as well as the career yards. The key is that in each period the full 400 yards is not realized due to the cumulative effect of career rushing yards. The only difference between the two players is that Player B rushes for an additional 72 yards in the initial period, the effect of increasing risky effort. Thus, Table 6 displays the effects of a one-time increase in risk in period 0 on rushing yards and career rushing yards in various time periods. Due to the initial advantage in rushing yards, Player B always has more career rushing yards; however, he simultaneously has fewer rushing yards in every season. By period $t = 4$ the initial advantage of 72 yards has diminished to a difference of only about 40 career rushing yards. The takeaway is that Player B experiences a 5.0% salary premium in $t = 1$, since his $t = 0$ rushing yards are greater due to the additional risk taken. However, Player A experiences a greater salary in all subsequent periods, ranging from 0.3% to 1% annually.

Table 8 contains our estimation results for the probability of having an active contract the following season. Both logistic and probit regressions are reported for robustness. It is clear that rushing yards have a positive and highly significant effect on the probability of remaining in the NFL, while career rushing yards have a negative and highly significant effect. The average marginal effect of rushing yards in our full logistic specification, Column 2, is 0.00059 or an additional 10 yards rushing increases the probability of having an active contract by 0.59 percentage points. The average marginal effect of career rushing yards is -0.000040, or an additional 100 career rushing yards decreases the probability of having an active contract by 0.40 percentage points. To determine the effect of additional risk taking on the probability of having an active contract, we use the same hypothetical comparison as above, players A and B. Using the results from our full logistic specification, Column 2, we calculate the average probability of having an active contract the following season for each player in each time period,

$$\widehat{p_{A1}} = \frac{1}{n}\sum_{i=1}^{n}\frac{\exp\left(\hat{\varphi} + \hat{\tau}400 + \mathbf{h}_{it}'\widehat{\boldsymbol{\psi}}\right)}{1 + \exp\left(\hat{\varphi} + \hat{\tau}400 + \mathbf{h}_{it}'\widehat{\boldsymbol{\psi}}\right)}$$

$$\widehat{p_{A2}} = \frac{1}{n}\sum_{i=1}^{n}\frac{\exp\left(\hat{\varphi} + \hat{\tau}320 + \hat{\xi}400 + \mathbf{h}_{it}'\widehat{\boldsymbol{\psi}}\right)}{1 + \exp\left(\hat{\varphi} + \hat{\tau}320 + \hat{\xi}400 + \mathbf{h}_{it}'\widehat{\boldsymbol{\psi}}\right)} \tag{36}$$

and

$$\widehat{p_{B1}} = \frac{1}{n}\sum_{i=1}^{n}\frac{\exp\left(\hat{\varphi} + \hat{\tau}472 + \mathbf{h}_{it}'\widehat{\boldsymbol{\psi}}\right)}{1 + \exp\left(\hat{\varphi} + \hat{\tau}472 + \mathbf{h}_{it}'\widehat{\boldsymbol{\psi}}\right)}$$

$$\widehat{p_{B2}} = \frac{1}{n}\sum_{i=1}^{n}\frac{\exp\left(\hat{\varphi} + \hat{\tau}305.6 + \hat{\xi}472 + \mathbf{h}_{it}'\widehat{\boldsymbol{\psi}}\right)}{1 + \exp\left(\hat{\varphi} + \hat{\tau}305.6 + \hat{\xi}472 + \mathbf{h}_{it}'\widehat{\boldsymbol{\psi}}\right)}. \tag{37}$$

The results are contained in Table 9. Due to the initial increase in rushing yards for Player B he has a significantly higher probability of having an active contract in period one. However, Player B has a significantly lower probability of continuing in every period beyond the initial period because he has fewer rushing yards and more career rushing yards in all subsequent periods.

5. Conclusion

Our research goal has been to summarize quantitatively what are the potential costs and benefits to NFL running backs from additional risky effort both in the short and longer runs. The key issues addressed econometrically include the effects of risky effort on injuries, salary and career length. Our research is the most complete empirical work to date on the avenues for how a running back trades off risky additional effort against salary in the short and long runs.

We find that the most informative measure of risk taking is yards after contact and that the elasticity of injuries with respect to risky effort is 0.8. We find a net financial gain of five percent for a 50 percent increase in risky effort with considerable individual heterogeneity in the return. Current risk taking also affect future performance. Again the marginal effects show substantial heterogeneity across players with the general result that current rushing success increases the likelihood of a runner getting a new contract but that past use (yards) reduces career length at the margin.

References

Arellano, Manuel and Stephen Bond (1991). "Some Tests for Panel Data: Monte Carlo Evidence and an Application to Employment Equations," *Review of Economic Studies* 58, 277-297.

Keefer, Quinn A.W. (2019). "Do Sunk Costs Affect Expert Decision Making? Evidence from the Within-Game Usage of NFL Running Backs," *Empirical Economics* 56 1769-1796.

Kniesner, Thomas J. and John D. Leeth (2004). "Data Mining Mining Data: MSHA Enforcement Efforts, Underground Coal Mine Safety, and New Health Policy Implications," *Journal of Risk and Uncertainty* 29(2), 83-111.

Simmons, Rob and David J. Berri (2009). "Gains from Specialization and Free Agency: The Story from the Gridiron," *Review of Industrial Organization* 34(1), 81-98.

Viscusi, W. Kip (2004). "The Value of Life: Estimates with Risks by Occupation and Industry," *Economic Inquiry* 42(1), 29-48.

Table 1. Descriptive Statistics

VARIABLES		
Injuries	2.011 (3.287)	The number of games missed due to injury.
Yards	400.0 (412.2)	Total rushing yards for the season.
YAC/Attempt	2.436 (0.828)	Yards gained after initial contact per rushing attempt.
YBC/Attempt	1.552 (1.477)	Yards gained before initial contact per rushing attempt.
YAC/Game	17.25 (16.72)	Yards gained after initial contact per game played.
YBC/Game	11.60 (15.53)	Yards gained before initial contact per game played.
Attempts	94.30 (91.64)	Total number of rushing attempts.
Attempts/Game	6.822 (6.363)	Rushing attempts per game played.
Snaps/Game	19.6 (16.52)	Total number of plays per game played.
Career Attempts	354.5 (525.9)	Total number of career rushing attempts through the end of the previous season.
Career Yards	1,554 (2,289)	Total number of career rushing yards through the end of the previous season.
Missed Tackles	11.27 (12.99)	Total missed attempted tackles.
Long	29.92 (20.97)	Longest run of the season.
TDs	2.648 (3.432)	Total number of rushing touchdowns.
Fumbles	0.962 (1.326)	Total number of fumbles
Experience	2.852 (2.677)	Years of experience.
Cumulative OL Experience	319.6 (95.87)	Total games started for the five starting offensive linemen through the end of the previous season.
Change Team	0.197	Binary variable for players on a new team.
Observations	628	
Number of Players	254	

Note: Means reported for continuous variables with standard deviations in parentheses. Proportions reported for binary variables.

Table 2. Injury Regression Results

Dependent Variable = Injuries					
			Poisson	Poisson DV	CFE Poisson
VARIABLES	(1)	(2)	(3)	(4)	(5)
YAC/Attempt	0.708**	0.677**	0.174*	0.360**	0.360**
	(0.336)	(0.325)	(0.0896)	(0.151)	(0.150)
Elasticity	[0.857]	[0.820]	[0.424]	[0.878]	
Semi-elasticity	{0.352}	{0.336}			
YBC/Attempt		0.175	0.0575	0.0421	0.0421
		(0.175)	(0.0410)	(0.0602)	(0.0601)
Snaps/Game	0.137***	0.136***	0.0449***	0.0523***	0.0523***
	(0.0223)	(0.0221)	(0.00526)	(0.0115)	(0.0115)
Career Attempts	0.00244*	0.00259*	0.000489**	0.00145*	0.00145*
	(0.00144)	(0.00142)	(0.000195)	(0.000779)	(0.000778)
Missed Tackles	-0.139***	-0.134***	-0.0454***	-0.0787***	-0.0787***
	(0.0284)	(0.0281)	(0.00905)	(0.0152)	(0.0151)
Long	-0.0382***	-0.0426***	-0.0108***	-0.0178***	-0.0178***
	(0.0116)	(0.0120)	(0.00399)	(0.00568)	(0.00567)
TDs	-0.214***	-0.217***	-0.159***	-0.115***	-0.115***
	(0.0597)	(0.0599)	(0.0304)	(0.0356)	(0.0356)
Fumbles	-0.119	-0.120	0.0276	0.0446	0.0446
	(0.108)	(0.108)	(0.0633)	(0.0888)	(0.0886)
Experience	-0.500	-0.598	0.0227	-0.600	-0.600
	(0.874)	(0.863)	(0.0739)	(0.460)	(0.459)
Experience-squared	-0.0471	-0.0440	-0.00965	-0.0241	-0.0241
	(0.0367)	(0.0368)	(0.00875)	(0.0236)	(0.0236)
Change Team	-0.0393	-0.0341	-0.256	-0.0325	-0.0325
	(0.330)	(0.328)	(0.164)	(0.252)	(0.252)
Fixed Effects	Year, Team & Player	Year, Team & Player	Year & Team	Year, Team & Player	Year, Team & Player

Constant	-3.853	-3.843	0.267	-2.640	
	(2.683)	(2.694)	(0.464)	(1.885)	
R-squared	0.624	0.626			
Observations	628	628	628	628	461
Number of Players	254	254	254	254	137

Note: Robust standard errors adjusted for clustering on players in parentheses. Conditional fixed effects Poisson standard errors based on Wooldridge's (1999) quasi-maximum likelihood approach. Elasticities in square brackets and semi-elasticities in curly brackets, calculated at the means of the independent variables. Poisson DV indicates the Poisson regression using player dummy variables to control for fixed effects. Conditional fixed effects Poisson sample size is smaller due to omitting players with only one year of data, 83 observations, and those players who never missed a game in the time period, 34 players and 84 observations.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 3. Yards After Contact Per Game Results

Dependent Variable = Injuries			
		Poisson DV	CFE Poisson
VARIABLES	(1)	(2)	(3)
YAC/Game	0.179***	0.0780***	0.0780***
	(0.0468)	(0.0192)	(0.0192)
Elasticity	[1.538]	[1.345]	
Semi-elasticity	{0.0892}		
YBC/Game	0.0488	0.000740	0.000742
	(0.0445)	(0.0172)	(0.0172)
Snaps/Game	0.00498	-0.000894	-0.000895
	(0.0281)	(0.0147)	(0.0146)
Career Attempts	0.00371**	0.00218***	0.00218***
	(0.00153)	(0.000820)	(0.000818)
Missed Tackles	-0.191***	-0.0925***	-0.0925***
	(0.0272)	(0.0145)	(0.0144)
Long	-0.0460***	-0.0187***	-0.0187***
	(0.0123)	(0.00632)	(0.00631)
TDs	-0.279***	-0.133***	-0.133***
	(0.0609)	(0.0392)	(0.0391)
Fumbles	-0.188*	0.00482	0.00481
	(0.104)	(0.0873)	(0.0871)
Experience	-1.010	-1.072**	-1.072**
	(0.883)	(0.432)	(0.431)
Experience-squared	-0.0280	-0.0156	-0.0156
	(0.0326)	(0.0185)	(0.0185)
Change Team	-0.269	-0.0598	-0.0598
	(0.314)	(0.214)	(0.213)
Fixed Effects	Year, Team & Player	Year, Team & Player	Year, Team & Player
Constant	0.545	-0.0870	
	(2.288)	(1.839)	
R-squared	0.577		
Observations	628	628	461
Number of Players	254	254	137

Note: Robust standard errors adjusted for clustering on players in parentheses. Conditional fixed effects Poisson standard errors based on Wooldridge's (1999) quasi-maximum likelihood approach. Elasticities in square brackets and semi-elasticities in curly brackets, calculated at the means of the independent variables. Poisson DV indicates the Poisson regression using player dummy variables to control for fixed effects. Conditional fixed effects Poisson sample size is smaller due to omitting players with only one year of data, 83 observations, and those players who never missed a game in the time period, 34 players and 84 observations.
*** p < 0.01, ** p < 0.05, * p < 0.1

Table 4. Rushing Yards Fixed Effects Results

Dependent Variable = Rushing Yards				
VARIABLES	(1)	(2)	(3)	(4)
Injuries	-32.76***	-33.14***	0.104	-0.871
	(4.671)	(4.696)	(1.678)	(1.784)
Injuries×(Attempts/Game)			-4.454***	-4.351***
			(0.240)	(0.231)
Attempts/Game			68.68***	67.81***
			(1.741)	(1.631)
YAC/Attempt		71.50***		39.90***
		(22.21)		(11.53)
Career Yards	-0.0810**	-0.0739**	-0.0364**	-0.0333**
	(0.0317)	(0.0307)	(0.0159)	(0.0151)
Cumulative OL Experience	0.0657	0.0783	0.0570	0.0643
	(0.190)	(0.189)	(0.0672)	(0.0664)
Experience	78.50	88.18	35.05	41.24*
	(80.24)	(81.83)	(27.07)	(22.91)
Experience-squared	-9.653***	-10.20***	-0.350	-0.745
	(2.923)	(2.927)	(0.988)	(0.906)
Change Team	8.636	-3.080	26.09***	19.30**
	(30.79)	(31.14)	(9.809)	(9.371)
Fixed Effects	Year, Team & Player	Year, Team & Player	Year, Team & Player	Year, Team & Player
Constant	258.7*	-21.38	13.66	-138.5**
	(144.0)	(164.2)	(56.36)	(63.47)
R-squared	0.824	0.832	0.978	0.980
Observations	628	628	628	628
Number of Players	254	254	254	254

Note: Robust standard errors adjusted for clustering on players in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 5. Short-Run Average Rate of Return Simulation Results

VARIABLES	Mean	Stand. Dev.	Minimum	Maximum
$\frac{\partial \ln(w_{it+1})}{\partial Yds_{it}}$	0.000690	0.000255	-0.000215	0.00160
$\overline{Att}$	94.30	3.688	81.21	107.45
π_1	-33.14	4.736	-49.94	-16.26
β	0.677	0.328	-0.486	1.845
Benefit	0.0660	0.0267	-0.0175	0.172
Cost	-0.0164	0.00997	-0.0480	0.000379
Rate of Return	0.0497	0.0168	-0.0227	0.124

Note: Based on 10,000 simulations. Average rate of return is for a one-yard increase in *YAC/Att*.

Table 6. Rushing Yards First Difference Results

Dependent Variable = Rushing Yards				
	FD	Arellano-Bond		
VARIABLES	(1)	(2)	(3)	(4)
Career Yards	-0.277***	-0.217***	-0.212***	-0.198***
	(0.0331)	(0.0521)	(0.0532)	(0.0518)
Injuries	-33.13***	-33.46***	-33.56***	-33.85***
	(5.215)	(5.050)	(5.143)	(5.180)
YAC/Attempt	70.00***	69.13***	68.40***	70.24***
	(24.55)	(23.74)	(23.70)	(24.46)
Cumulative OL Experience	0.128	0.124	0.114	0.108
	(0.194)	(0.183)	(0.183)	(0.182)
Change Team	25.54	27.16	28.99	19.74
	(32.67)	(31.45)	(31.31)	(32.25)
Fixed Effects	Year, Team & Player	Year, Team & Player	Year, Team & Player	Year, Team & Player
Instrument Lags		2	3	4
Hansen J		[0.095]	[0.249]	[0.150]
1st Order Serial Correlation		[0.042]	[0.041]	[0.026]
2nd Order Serial Correlation		[0.107]	[0.139]	[0.154]
R-squared	0.445			
Observations	359	359	359	359
Number of Players	165	165	165	165

Note: Robust standard errors adjusted for clustering on players in parentheses. Player fixed effects accounted for using first differences. Lagged values of career yards used as instruments. P-values listed in square brackets for the Hansen J statistic testing the overidentifying restrictions, and for the Arellano and Bond (1991) tests of first and second order serial correlation.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 7. Long-Run Comparison

	Player A			Player B			Difference		
t	Baseline	Rushing Yards	Career Yards	Baseline	Rushing Yards	Career Yards	Rushing Yards	Career Yards	Salary
0	400.00	400.00		400.00	472.00		72.00		
1	400.00	320.00	400.00	400.00	305.60	472.00	-14.40	72.00	5.0%
2	400.00	256.00	720.00	400.00	244.48	777.60	-11.52	57.60	-1.0%
3	400.00	204.80	976.00	400.00	195.58	1022.08	-9.22	46.08	-0.8%
4	400.00	163.84	1180.80	400.00	156.47	1217.66	-7.37	36.86	-0.6%
5	400.00	131.07	1344.64	400.00	125.17	1374.13	-5.90	29.49	-0.5%
6	400.00	104.86	1475.71	400.00	100.14	1499.30	-4.72	23.59	-0.4%
7	400.00	83.89	1580.57	400.00	80.11	1599.44	-3.77	18.87	-0.3%
8	400.00	67.11	1664.46	400.00	64.09	1679.56	-3.02	15.10	-0.3%

Note: Based on an effect of career yards on current rushing yards of -0.20. Difference is defined as the measure for Player B minus the measure for Player A.

Table 8. Probability of Having an Active Contract Results

Dependent Variable = Contract				
	Logistic		Probit	
VARIABLES	(1)	(2)	(3)	(4)
Rushing Yards	0.00391***	0.00458***	0.00219***	0.00257***
	(0.00144)	(0.00151)	(0.000768)	(0.000823)
Career Yards	-0.000305***	-0.000314***	-0.000168***	-0.000173***
	(5.47e-05)	(5.58e-05)	(2.84e-05)	(2.89e-05)
Injuries		0.0430		0.0248
		(0.0372)		(0.0212)
Snaps/Game	0.0294	0.0178	0.0146	0.00822
	(0.0219)	(0.0237)	(0.0108)	(0.0119)
Missed Tackles	-0.00756	-0.00800	-0.00456	-0.00503
	(0.0368)	(0.0371)	(0.0175)	(0.0177)
Long	0.00980	0.00911	0.00594	0.00560
	(0.0120)	(0.0122)	(0.00622)	(0.00631)
TDs	0.0163	0.0181	-0.00191	-0.00196
	(0.0951)	(0.0967)	(0.0499)	(0.0505)
Fumbles	-0.0283	-0.0386	-0.0188	-0.0255
	(0.150)	(0.152)	(0.0819)	(0.0827)
Change Team	-0.756***	-0.735***	-0.441***	-0.429***
	(0.274)	(0.277)	(0.157)	(0.158)
Fixed Effects	Year & Team	Year & Team	Year & Team	Year & Team
Constant	-0.491	-0.524	-0.235	-0.259
	(0.865)	(0.893)	(0.448)	(0.458)
Observations	628	628	628	628
Number of Players	254	254	254	254

Note: Robust standard errors adjusted for clustering on players in parentheses. *Contract* is equal to one if the player has an active contract the following season and zero otherwise.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 9. Probability of Having an Active Contract Comparison

	Player A			Player B			Difference
t	Rushing Yards	Career Yards	Probability	Rushing Yards	Career Yards	Probability	Probability
0	400.00		0.900	472.00		0.925	0.0246***
1	320.00	400.00	0.851	305.60	472.00	0.841	-0.0104***
2	256.00	720.00	0.801	244.48	777.60	0.791	-0.0102***
3	204.80	976.00	0.753	195.58	1022.08	0.744	-0.00927***
4	163.84	1180.80	0.711	156.47	1217.66	0.703	-0.00805**
5	131.07	1344.64	0.674	125.17	1374.13	0.667	-0.00680**
6	104.86	1475.71	0.643	100.14	1499.30	0.638	-0.00562**
7	83.89	1580.57	0.618	80.11	1599.44	0.614	-0.00460***
8	67.11	1664.46	0.598	64.09	1679.56	0.594	-0.00373***

Note: Probability refers to the average probability of having an active contract the following season. Difference is defined as the measure for Player B minus the measure for Player A.

Figure 1. Marginal Effect and 95% Confidence Interval of Injuries On Rushing Yards As A Function of Attempts per Game

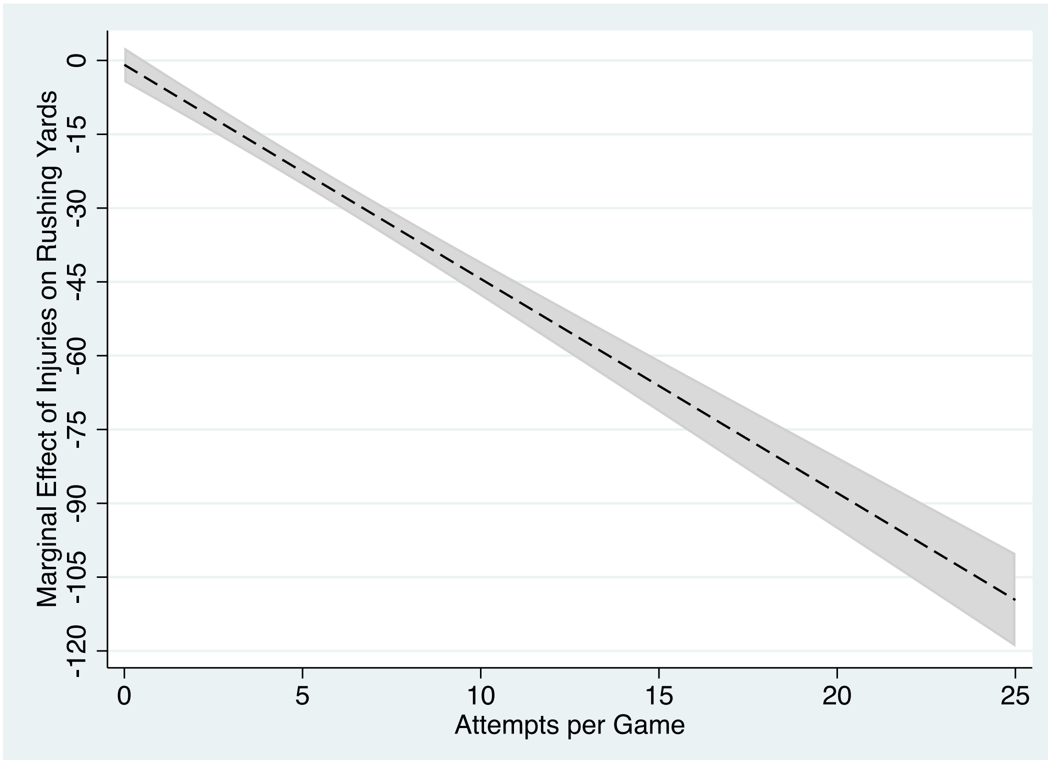

Figure 2. Histogram of Short-Run Average Rate of Return Simulation Results

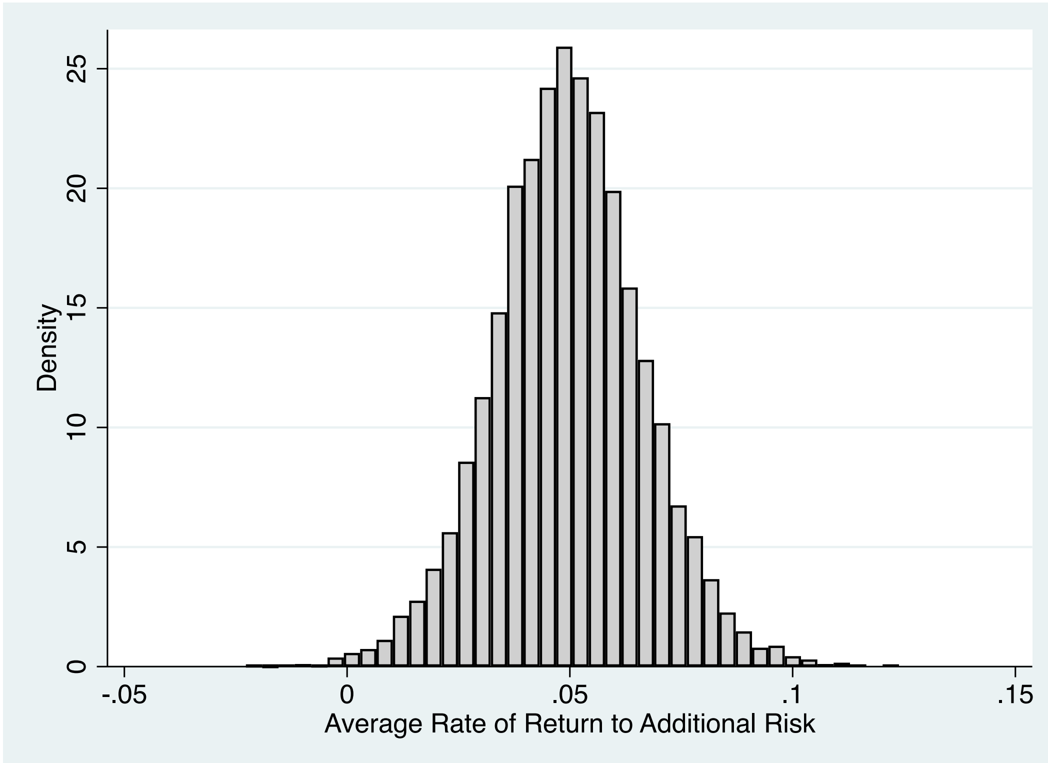

Figure 3. Short-Run Rate of Return, Benefit, and Cost by Utilization

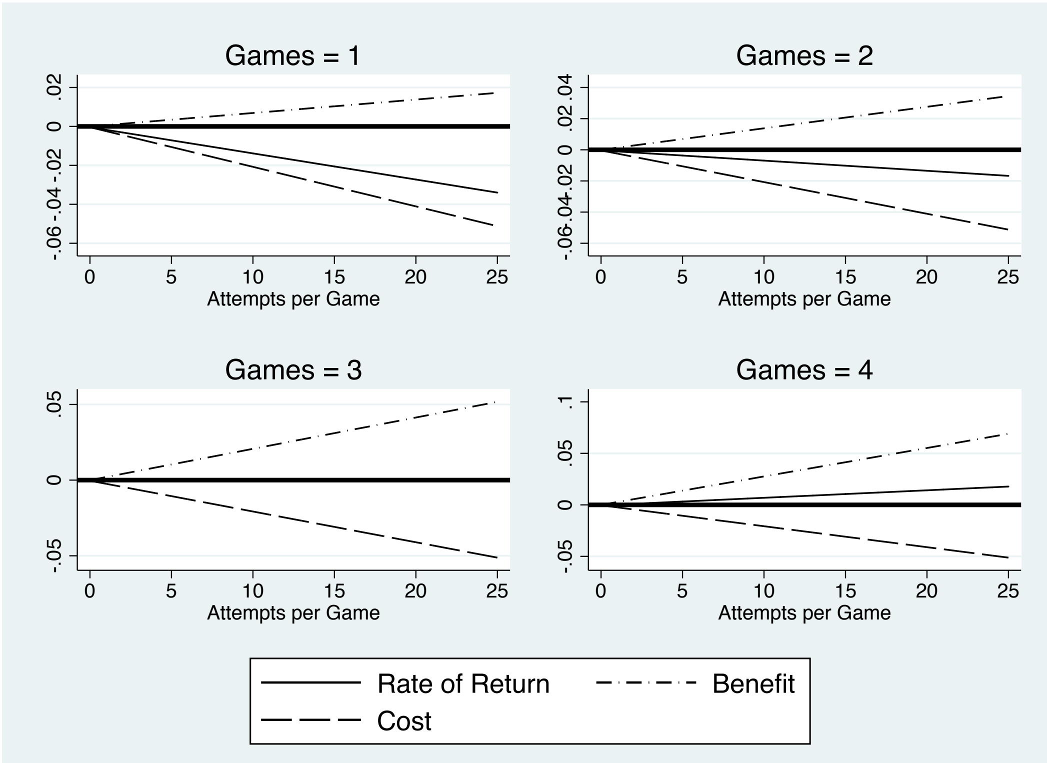

Figure 4. Short-Run Rate of Return, Benefit, and Cost by Utilization

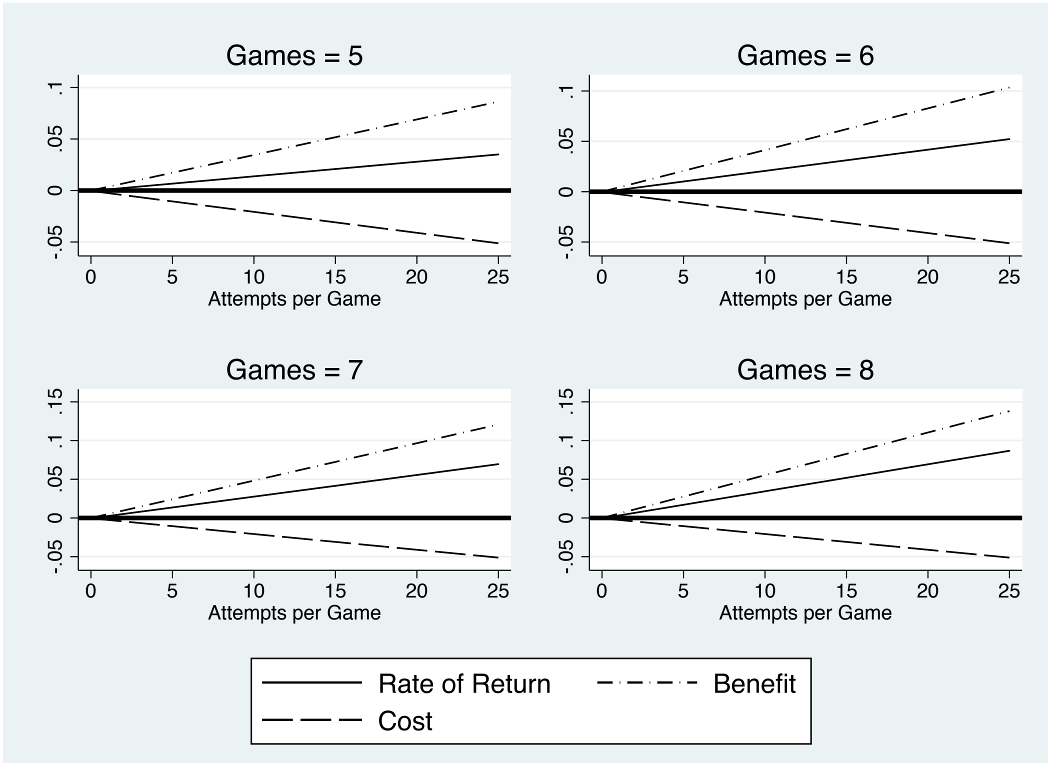

Figure 5. Short-Run Rate of Return, Benefit, and Cost by Utilization

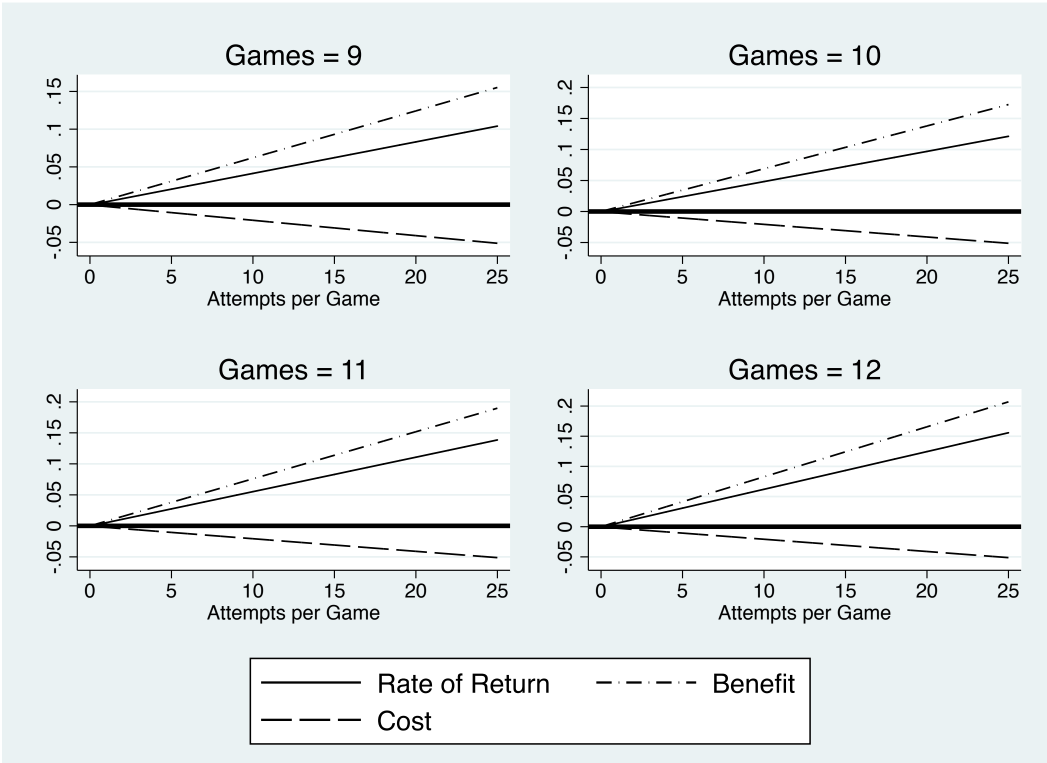

Figure 6. Short-Run Rate of Return, Benefit, and Cost by Utilization