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Non-compete agreements, wages and efficiency: theory and evidence from Brazilian football

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Abstract
We propose a model to study non-compete agreements and evaluate their quantitative effects. We explore an exogenous policy change that removed non-compete clauses in the market for Brazilian footballers, the Pele Act of 1998. The Act raised players' lifetime income but changed the wage profile in a heterogeneous way, reducing young players' salaries. We structurally estimate the model's parameters by matching wages and turnover profiles in the post Act period. By changing a single parameter related to the non-compete friction, we can match the changes in the age-earnings profile. We then show that the bulk of income gains is due to distributional forces, with efficiency gains playing a minor role.

Key words: labor mobility, labor frictions, wage profile, labor turnover
JEL codes: J30; J41; J60; K31; Z22

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1 Introduction

Non-compete agreements forbid or make it costly for an employee to enter into or start a similar profession in competition against the current employer. Starr, Prescott and Bishara (2021) estimate that 18% of all US workers are currently bound by non-compete agreements. This figure rises to 39% for those with a professional degree, and 46% for those earning over USD 150 thousand a year. They also estimate that 38% of all US workers were bound by some non-compete covenant at some point in their career.

Given the large prevalence of non-competes, it is of paramount importance to understand their consequences to workers and firms. However, research on the topic is still at an early stage (U.S. Department of the Treasury, 2016). Despite some recent advances, key aspects of non-compete agreements still need to be better understood. How do non-compete agreements affect the relation between wages and age? Do they have large effects on workers' earnings? Do they cause significant income redistribution between workers and firms? Should we be concerned about large efficiency effects? Part of the problem in answering these questions is that it is difficult to isolate non-compete clauses from all other factors that affect wages. Usually, those clauses are endogenously determined and negotiated by employers and employees.

This paper builds a model to study this question and explores the end of non-compete agreements in Brazilian football in 1998 with the so-called Pele Act for quantitative analysis.[1] This act had an important effect on the labor market for first-class professional footballers but virtually no impact on the economy as a whole. Since there are few occupational switches between football players and other professions, confounders and general equilibrium effects are not relevant concerns. Moreover, the end of those non-compete clauses was an exogenous policy change. Hence this is a particularly good setting for studying how non-compete agreements affect wages and efficiency.

[1]Law 9615 from 24 of March 1998. The Bosman Ruling in 1995 had a similar effect on the market for football players in Europe.

The model considers a worker (or player) through his career. His productivity depends on his age, a fixed individual effect, and the quality of the match between player and firm (or club). Unlike most models in this literature, the wage is a state variable, and agreements can last for more than one season. Moreover, there is imperfect information about the match quality, which leaves room for inefficiencies in the allocation of players to clubs.

While the agreement is on, a club can pay a transfer fee to hire the player. When the agreement expires, the current club and a competitor bid for the player in an auction. In the absence of non-compete clauses (the post Pele Act period), the auction is a standard second-price one. In the pre Pele Act period, the non-compete clause is captured by a fee the current club receives for allowing the player to go after the labor contract has expired.

The model captures the main elements of the rich contractual environment of labor markets for professional athletes and some other high-paid occupations: long-term contracts, wages as state variables, transfer costs, incomplete information, and asymmetric auctions when non-compete clauses are in place. Nevertheless, the model is still sufficiently tractable. We can estimate its parameters to match some key moments from the data.

Using a matched employer-employee dataset with information on wages (RAIS), we identify professional athletes working for the main Brazilian football clubs. We then estimate the relationship between wages and players' age, controlling for fixed effects, for the years surrounding the Pele Act's enactment. Players' lifetime income increased substantially in the years following the Act. Interestingly, the age-earnings profile changed. Players at age around 28 gained the most, but the wage of young players fell.

We estimate the model parameters to match the wage profile and turnover from the post Pele Act period. We then show that raising the fee parameter from zero to a positive number – i.e., introducing non-compete frictions – changes the wage as in the data: a player's lifetime income goes down, but the salary for young players rises. Non-compete agreements in the model thus generate the observed patterns.

From the model, we can recover the equilibrium match factors with and without non-compete agreements. We find that the average match quality goes up a bit with the Pele Act. However, this effect is minimal and accounts for less than 1% of the increase in players' lifetime income. The negative impact of non-compete agreements on match efficiency is very small.

The main driver of the effects on wages, wage profile, and efficiency is the auction between clubs after an agreement expires. In a situation with non-compete agreements, the current club gets a fee if it loses the auction, paid by the winning club. Hence both clubs have incentives to bid less for the player. This substantially reduces player wages. The current club has an incentive to bid a bit more to raise the value of the player and, consequently, the transfer fee, and this has an effect on match efficiency: at times, the player will remain at the current club even though it would be more efficient to move on. But this effect is much smaller than the distributional impact.

With non-compete agreements, the asset value of a player for a club is higher because the club gets some money for the player even if the agreement expires. Hence clubs bid more for younger players, which raises their wages. For players at the end of their careers, non-compete clauses have a smaller effect. This explains the changes in the wage profile.[2]

One could think that transfers while the agreement is on would also be less efficient in the presence of non-compete agreements. Indeed, clubs charge a higher fee to "sell" players, as their asset values are higher. However, incoming clubs are also more willing to pay a higher fee for the exact same reason. There are inefficiencies in the transfer process: owing to asymmetric information, some efficient transfers do not occur. But non-compete agreements do not exacerbate this problem.

To the best of our knowledge, this is the first paper to build a model suitable for labor

[2]One could think that the changes in wage profile could be explained by a Ben-Porath-type model (Ben-Porath, 1967): players would be investing in learning early on in their careers to get the fruits later on, which would raise their future earnings but reduce their wages when young. There are however several problems with this explanation. First and foremost, for professional athletes, playing and learning by doing is crucial (Terviö, 2006, 2009). Playing well when young is the best way to get you a good career. Second, it is at best unclear that this explanation would generate the large immediate effects on wages of older players and no large effects later on (when the presumed learning of young players would have kicked in). Third, if leisure is a normal good, a positive shock to the players' share does not necessarily raise their optimal effort levels.

markets under non-compete frictions, structurally estimate its parameters and quantitatively assess its implications following a plausibly exogenous policy change. Although the model was tailored to the market of professional athletes, the main insights apply more generally. In the presence of non-compete agreements, workers will be in a weaker bargaining position, and firms will bid less for workers (either because current firms would be compensated to let the employee go or because competing firms would have to compensate the current employer). This has a first-order negative effect on the equilibrium bid of all potential employers. It also raises the asset value of an employee for all firms, which affects the wage profile. Since all potential employers are affected in similar ways, the efficiency effects from non-compete clauses tend to be much smaller than the distributional effects.

1.1 Related Literature

This paper is related to an empirical literature focused on the effects of non-compete agreements in wages and turnover. Its findings are generally consistent with our results. Most of the literature shows that non-competes increase job mobility. For example, Marx, Strumsky and Fleming (2009) study the job mobility of inventors following the (inadvertent) end of the prohibition on non-compete agreements in Michigan in 1985, finding that the enforcement of non-competes attenuated mobility in the state (relative to others).[3]

There is also evidence that policy-induced bans on non-compete agreements raise workers' income – as the Pele Act did. Balasubramanian et al. (2020) show that banning non-compete covenants increased mobility and raised new-hire wages of technology workers in Hawaii.

[3] Part of the literature studies how the change in allocation of property rights (over players) arising from non-competes affect mobility of professional athletes and the distribution of talent in sports. Krautmann and Oppenheimer (1994) study the main factors behind professional baseball players' migration decisions after the prohibition of non-compete (or reserve) clauses in the sport in 1976. They find that players tend to move to big cities after the end of the reserve clause and that migration decisions are different before and after the prohibition of non-competes. Their findings suggest that the final distribution of players depends on the allocation of property rights, i.e., Coase's Theorem may not hold in the market for baseball players. Hylan, Lage and Treglia (1996) also study the mobility of professional baseball players before and after 1976, finding further support for the rejection of the invariance thesis of Coase's Theorem. Contrary to most part of the literature, they find that pitchers with greater longevity in the league were less likely to move after gaining free agency status.

Similarly, Lipsitz and Starr (2021) find that prohibiting non-compete agreements increased job turnover and hourly wages of low-wage workers in Oregon, with the last effect being stronger for female workers.

In general, since non-compete convenants are endogenous, there is no reason to expect a negative relation between non-competes and wages. Indeed, Kini, Williams and Yin (2020) study the effects of non-competes on CEOs' payments using a novel survey data and show that total compensation and incentive pay are higher when CEOs have enforceable non-compete agreements.[4] Lavetti, Simon and White (2019) analyze if physician practices use non-compete agreements to retain control over patient relationships (that may be lost if an employee moves to a competitor practice). They find that physician practices that use non-competes have lower job turnover and manage to retain more of their high-reimbursement patients. This partially contributes to higher generated revenue (per hour) and to higher returns to job tenure for physicians signing non-competes.[5]

We also contribute to a theoretical literature that analyzes the role of non-competes in labor contracts. Burguet, Caminal and Matutes (2002) find that labor contracts are expected to have high quitting fees when worker's performance is publicly observable, as this helps to seize the surplus from workers' reallocations. Feess and Muehlheusser (2003*b*) study the consequences of transfer fees regulations in football, showing that restrictions on fee levels (and contract length) may decrease club's incentives to invest in the training of

[4]They also find that non-competes will affect how the board of directors disciplines the CEO for poor performance. Without non-competes, the board will be reluctant to fire the CEO for poor performance because the CEO can join a competitor and potentially cause damage to the firm.

[5]In related work, Johnson and Lipsitz (2020) show that firms in low-wage sectors use non-compete agreements when frictions to adjust wages downward are present, i.e., non-competes are used to decrease workers' compensation packages. They find that shifts in labor supply and increases to the local unemployment rate lead to more use of non-competes as they benefit employers. Increases in the minimum wage also lead to more non-competes by limiting the transferability of utility between employer and employee via payments.

players.[6] Terviö (2006) considers a model without training and shows that transfer fees are necessary to efficiently allocate playing opportunities among players of distinct age and ability, i.e., total surpluses are higher in the presence of transfer fees (even in the absence of club's investment decisions). Kräkel and Sliwka (2009) build a general principal-agent model in which the firm can use non-compete clauses (not necessarily transfer fees) in their labor contracts. It may be optimal for firms not to use such device, as it can create implicit incentives for workers to under-perform.

Different from the previous papers, we are able to quantitatively assess the implications of our model using an administrative dataset. One advantage of our structural framework is that it allows us to assess labor market outcomes not directly observed in the data, such as efficiency and surplus division between firms and workers.

Our paper is also related to the literature studying coercive labor contracts and property rights over workers.[7] And, more broadly, we contribute to the vast literature on workers mobility frictions, including those of professional athletes.[8]

[6]They also show that these restrictions increase selling clubs' pay-offs but the effects on players' welfare are ambiguous. In Feess and Muehlheusser (2003*a*) they consider a version of the model without effort, finding similar conclusions for club's incentives do provide training. In this version of the model, however, both selling clubs and players are unambiguously worse off with restrictions on fees and contract lengths. Feess and Muehlheusser (2002) point out that such restrictions may hurt football clubs. Feess, Frick and Muehlheusser (2004) build and a test a model to analyze the impact of transfer fees regulations for professional footballers using data for the German league between 1994 and 2001. They find evidence that an environment with legal restrictions on transfer fees and contract lengths, as after the Bosman ruling, produces higher length contracts. They also show that increases in the (remaining) duration of a contract augments the transfer fee paid by the new club and decreases players' annual wages (in the new club); and that new wages are increasing in the length of the new agreements. The last two effects were stronger before the Bosman ruling.

[7]Naidu and Yuchtman (2013), who examine the effects of labor demand shocks in prosecutions against employees in 19^{th} century Britain, where until 1875 employee contract breach was considered a criminal offence. They find that positive shocks in some industries increased prosecutions, and that the abolition of criminal sanctions led to higher relative wage growth in British counties where the enforcement of the law was stronger (counties with more prosecutions). Naidu (2010) analyzes the effects of recruitment restrictions on mobility and wages in the postbellum U.S. South. He finds that an increase in fees for recruiting workers already under contract (enticement fees) lowered wages and turnovers of black sharecroppers.

[8]For example, Kleven, Landais and Saez (2013) analyze the effects of (top) tax rates on football player's international migration decisions, showing strong mobility responses to differential tax rates across countries. See also Rosen and Sanderson (2001) for a survey of the literature of labor markets in professional sports.

2 The model

Players indexed by i live for N periods. A player is characterized by his idiosyncratic ability y_i, fixed through his life and known since he is born. We denote his first period of life by $t = 1$. The time discount factor for players and teams is β.

When player i signs a contract with team j, they generate output $c_j y_i \mu(t)$, where c_j is a factor specific to the match player-team (the i subscript is omitted for simplicity), and $\mu(t)$ is a time-dependent productivity factor, to capture the relation between productivity and age. The agreement is still valid in the following period with probability $\delta_t \in (0, 1)$.

At the start of the first period, player i draws two clubs, j and k, characterized by match factors c_j and c_k respectively. These are random draws from a distribution with cdf given by

$$\left(\frac{c - c_L}{c_H - c_L}\right)^{\zeta}$$

where ζ is a choice variable that captures the search intensity of a player at $t = 1$. The initial search cost is

$$\chi \frac{\zeta^2}{2}$$

The key idea here is that at $t = 1$, a player has not been watched by others and it is costly for him to show himself to football clubs. In subsequent periods, other clubs watch him playing.

At $t = 1$, clubs j and k make an offer for the player, which is characterized by a wage offer (the duration of the contract is always determined by the exogenous vector δ_t). This is a second price auction, capturing the idea that clubs compete for players with open bids. Each club knows its own match factor, but nothing about the other club (besides the distribution of c).

For every $t \geq 2$, $c_{j,t+1}$ is given by

$$c_{j,t+1} = \lambda c_{j,t} + (1 - \lambda) c$$

where $\lambda \in (0, 1)$ and c is a random draw from a uniform distribution in $[c_L, c_H]$. The idea is that the match factor is persistent but changes over time. Examples of a real-world counterpart for this match-specific change include: the main goalkeeper of the team gets injured, the substitute becomes more important; the club hires a midfielder whose style of play is a good fit with a particular striker; the player is too good (or too bad) for that particular club, etc. There are no shocks to y_i, i.e., we are considering players with fixed and known idiosyncratic abilities.

At the start of every period $t \geq 2$, a player is linked to a club with match quality c_j and wage w and draws one club characterized by a randomly drawn match factor c_k. The pdf and cdf of all random draws of match factors are f_k and F_k, respectively, with support in $[c_L, c_H]$. The cdf is given by

$$F_k(c) = \left(\frac{c - c_L}{c_H - c_L} \right)^{\xi} \tag{1}$$

where ξ is a positive constant. At this stage, the current club and player know their match factor, but nothing about the other club. In turn, club k knows its own match factor and the match factor of club j in the past period.

In every period $t \geq 2$, if the contract between player and team j is still valid, the team chooses a price for the transfer T and the player chooses the wage w_k it would like to get. Club k then chooses whether it meets the requests and hires the player or not – in which case the player continues to play for club j.

If the agreement between the player and team j is not valid any more, clubs j and k compete for the player in a second price auction. However, in the pre Pele Act case, the auction is modified to capture the key element of non-compete agreements in this setting: club k has to pay a transfer fee to club j in case the player chooses its offer. The transfer fee is assumed to be equal to a fraction ϕ of the player's value function, a variable that summarizes the expected discounted wages of the player.

Timing Inside each period t, the timing is as follows.

1. Player and club learn whether c_j has changed and, in this case, the new value of c_j.

2. Offers and transactions are made.

3. Player plays, output is realized.

2.1 Equilibrium and value functions

The value functions at the start of periods $t \geq 2$ (before drawing a team) are

- $W(t, c_j, w)$: value function of the player in an agreement with team c_j and wage w.

- $U(t, c_j)$: value function of the player still matched but with no agreement with team c_j (agreement expired).

- $V(t, c_j, w)$: value function of team c_j in an agreement with the player with wage w.

- $L(t, c_j)$: value function of team c_j still matched but without an agreement with the player (agreement expired).

- $M(t, c_j, w)$: $W(t, c_j, w) + V(t, c_j, w)$.

To economize on notation it is convenient to define the value functions before the player and club learn about their own c_j:

$$\widehat{W}(t, c_j, w) = \int_{c_L}^{c_H} W(t, \lambda c_j + (1-\lambda)c, w)\frac{1}{c_H - c_L}dc$$

$$\widehat{U}(t, c_j) = \int_{c_L}^{c_H} U(t, \lambda c_j + (1-\lambda)c)\frac{1}{c_H - c_L}dc$$

$$\widehat{V}(t, c_j, w) = \int_{c_L}^{c_H} V(t, \lambda c_j + (1-\lambda)c, w)\frac{1}{c_H - c_L}dc$$

$$\widehat{L}(t, c_j) = \int_{c_L}^{c_H} L(t, \lambda c_j + (1-\lambda)c)\frac{1}{c_H - c_L}dc$$

After the random draw and transactions, but before output is realized, the value functions are:

- $X(t, c_j, w)$: value function of the player that plays for team c_j and gets wage w.
- $Y(t, c_j, w)$: value function of team c_j with the player getting wage w.
- $Z(t, c_j, w)$: $X(t, c_j, w) + Y(t, c_j, w)$.

2.1.1 Value functions after any transfers

In the last period,

$$X(N, c_j, w) = w$$

and

$$Y(N, c_j, w) = c_j y_i \mu(N) - w$$

For $t < N$,

$$X(t, c_j, w)^s = w + \beta\left(\delta_t \widehat{W}(t+1, c_j, w) + (1-\delta_t)\widehat{U}(t+1, c_j)\right),$$

and

$$Y(t, c_j, w)^s = c_j y_i \mu(t) - w + \beta\left(\delta_t \widehat{V}(t+1, c_j, w) + (1-\delta_t)\widehat{L}(t+1, c_j)\right),$$

where s indexes the active system, pre or post. In the pre-act period, we assume that agents attribute some exogenous probability p for the Act to be implemented. The new state is absorbing (in the post-act period, $p = 1$). Hence, the value functions can be written as (for $t < N$):

$$X(t, c_j, w) = pX(t, c_j, w)^{post} + (1-p)X(t, c_j, w)^{pre}$$

and

$$Y(t, c_j, w) = pY(t, c_j, w)^{post} + (1-p)Y(t, c_j, w)^{pre}$$

2.1.2 Value functions of player and team in an agreement

Consider that the player starts period t in an agreement with team c_j. Another team is randomly drawn, call it c_k, and team j and the player do not know c_k.

Team k will buy the player as long as:

$$Y(t, c_k, w_k) - T > 0$$

where w_k and T are chosen by the player and by club j, respectively. Efficiency in the transfer market requires a transfer whenever $c_k > c_j$.

Since Y is increasing in c_k, The player will be transferred to team k as long as $c_k > \bar{c}$, implicitly defined by

$$Y(t, \bar{c}, w_k) = T \tag{2}$$

Team j maximizes

$$Y(t, c_j, w_j)F_k(\bar{c}) + T(1 - F_k(\bar{c}))$$

where F_k is the cdf of c_k (equation 1).

Taking the first order condition with respect to $\bar{c}$, where T is given by (2), and manipulating yields

$$f_k(\bar{c})\left[Y(t, \bar{c}, w_k) - Y(t, c_j, w_j)\right] = (1 - F_k(\bar{c}))\,\frac{\partial Y(t, \bar{c}, w_k)}{\partial \bar{c}} \tag{3}$$

The LHS is the loss of increasing $\bar{c}$ a little bit, and it is given by the probability density this increase is a deal breaker $f_k(\bar{c})$ times the gain from selling the player (term in square brackets). The RHS is the gain from increasing $\bar{c}$ a little bit, given by the probability the player will be sold times the increase in the transfer that corresponds to this increase in $\bar{c}$. The condition for efficiency does not hold: a team will set a transfer fee larger than $Y(t, c_j, w_j)$. This is particularly important for a team with low c_j, because the gains from selling the player might be very large.

The player maximizes

$$X(t, c_j, w_j)F_k(\bar{c}) + \int_{\bar{c}}^{c_H} X(t, c, w_k) f_k(c) dc$$

We'll say he chooses $\bar{c}$ taking into account that w_k is a function of $\bar{c}$. The first order condition yields

$$f_k(\bar{c}) \left[X(t, \bar{c}, w_k) - X(t, c_j, w_j) \right] = \int_{\bar{c}}^{c_H} \frac{\partial X(t, c, w_k)}{\partial w_k} \frac{\partial w_k}{\partial \bar{c}} f_k(c) dc \tag{4}$$

where, using the implicit theorem function in (2),

$$\frac{\partial w_k}{\partial \bar{c}} = -\frac{\frac{\partial Y(t,\bar{c},w_k)}{\partial \bar{c}}}{\frac{\partial Y(t,\bar{c},w_k)}{\partial w_k}}$$

The intuition for (4) is similar to the intuition for (3). The LHS is the loss of increasing $\bar{c}$ a little bit, the player may lose a transfer to a better team. The RHS is the gain from increasing the wage request a little bit.

We then have two equations, (3) and (4), that yield two unknowns, $\bar{c}$ and w_k. We need to solve that for each pair (c_j, w_j) and for each t. With $\bar{c}$ and w_k, we get T using (2).

The value functions of player and team in a contract are then:

$$W(t, c_j, w_j) = F_k(\bar{c}) X(t, c_j, w_j) + \int_{\bar{c}}^{c_H} X(t, c, w_k) f_k(c) dc \tag{5}$$

and

$$V(t, c_j, w_j) = F_k(\bar{c}) Y(t, c_j, w_j) + (1 - F_k(\bar{c})) Y(t, \bar{c}, w_k) \tag{6}$$

The problem seems complicated, but Proposition 1 drastically simplifies the problem.

Proposition 1. *At any time t, it must be that:*

1. *The threshold $\bar{c}$ does not depend on w_j. It solves:*

$$f_k(\bar{c}) \left[Z(t, \bar{c}) - Z(t, c_j) \right] = 2 \left(1 - F_k(\bar{c})\right) \frac{\partial Y(t, \bar{c}, w)}{\partial \bar{c}}$$

2. *Given $\overline{c}$, w_k solves:*

$$Y(t, \overline{c}, w_k) - Y(t, c_j, w_j) = X(t, \overline{c}, w_k) - X(t, c_j, w_j)$$

3. *The value of the match is independent of the wage:*

$$\frac{\partial Z(t, c_j, w)}{\partial w} = 0 \ , \ \frac{\partial M(t, c_j, w)}{\partial w} = 0$$

   Hence we can simply write $Z(t, c_j)$ and $M(t, c_j)$.

4. *The derivatives of value functions with respect to c do not depend on the wage (and vice-versa):*

$$\frac{\partial^2 X(t, c, w)}{\partial c \partial w} = 0 \ , \ \frac{\partial^2 Y(t, c, w)}{\partial c \partial w} = 0 \ , \ \frac{\partial^2 W(t, c, w)}{\partial c \partial w} = 0 \ , \ \frac{\partial^2 V(t, c, w)}{\partial c \partial w} = 0$$

Proof: See appendix A.

For a team, a player is valuable for two reasons: it produces (the production value) and it might be sold (an option value). For a low-c team, the first is less important; while for a high-c team, the second is less important. One could think that clubs paying a high wage w_j (relative to the match factor c_j) would be willing to sell the player for a cheaper price (which is true), which would lead to a lower threshold $\overline{c}$. This is, however, not true.

The first statement of Proposition 1 tells us that $\overline{c}$ is chosen in a way that maximizes the expected total gains from a transfer for the player and its current club. The second statement tells us that the gains from the transfer to the marginal buyer club are equally divided between the player and the seller club.[9] Linearity of payoffs on wages plays a role

[9] The player gains depend not only on the new wage w_k, but also on the new match factor c_k. A higher match factor leads to higher expected match factor and higher future wages once the agreement expires; but it also makes the new club less willing to sell the player, which reduces the potential gains for the player from future transfers. Quantitatively, in our estimations, the first effect dominates, the value function of the player $X(t, c, w)$ is increasing in c for a given w.

in this result. But it is important that the value of the match Z is independent of the wage (third statement), hence changes in wages only affect the distribution of gains between club and player. Hence the statements of the proposition depend on each other.

In the last period, the total surplus Z is independent of wages: the player will produce $y_i c_j \mu_t$. Hence in the last period, the threshold $\overline{c}$ that maximizes the gain from a transfer does not depend on w_j. Now the total surplus in the second-to-last period depends on how much will be produced then and on what will happen in the last period: if the contract expires, w_j becomes irrelevant; if not, w_j will not affect $\overline{c}$ hence it will have no effect on transfers. Hence the total surplus in the second-to-last period is independent of w_j. Following this argument by induction, we obtain the results in Proposition 1

This result makes the model much simpler and quicker to solve. It also helps us to understand the implications for efficiency while the agreement is on.

The non-compete agreement raises the option value of the player for a team, because the player cannot freely move away once the agreement expires, but it does not affect how much a player produces (for a given c_j). One could think that it could have important efficiency effects through transfers (low-c clubs could be less willing to sell the player with non-compete agreements). Proposition 1 shows, indeed, that the transfer process will reflect inefficiencies that affect Z and $\partial Y/\partial \overline{c}$, but that is all. The source of any extra inefficiencies with non-compete agreements must come from the auction when agreements have expired.

2.1.3 Value function of player and team without an agreement

Now, clubs j and k bid for the player in a second-price auction. Club j knows c_j but does not know c_k. Club k knows $c_{j,t-1}$, but does not know the draw of c at time t for team j.

Post Pele Act scenario In the absence of non-compete clauses, club j and club k compete to sign the player on an equal footing. Clubs j and k bid $Z(t, c_j)$ and $Z(t, c_k)$, respectively. The bids are the amount paid to players (X's). Since this is a second price auction, each club bids its total surplus Z, which is its valuation in this context. The winner club's value function Y will be its own total value Z minus whatever X they have to give to the player, which is the other club's total value Z.

If $c_j > c_k$, team j gets $Z(t, c_j) - Z(t, c_k)$, otherwise it gets zero. Hence

$$L(t, c_j) = \int_{c_L}^{c_j} [Z(t, c_j) - Z(t, c_k)] f(c_k) dc_k$$

If $c_j > c_k$, the player gets $Z(t, c_k)$, otherwise it gets $Z(t, c_j)$. Hence

$$U(t, c_j) = \int_{c_L}^{c_j} Z(t, c_k) f(c_k) dc_k + [1 - F(c_j)] Z(t, c_j)$$

Note that we don't need to obtain the wages to compute the value functions. But we do need the wages to compute the distributions. The wage w solves

$$X(t, \max(c_j, c_k), w) = Z(t, \min(c_j, c_k)) \tag{7}$$

In the post Pele Act scenario, once the agreement is over, there are no inefficiencies: the player goes to the team with a higher c, which is the team with the highest bid.

Pre Pele Act period Now, the player is still linked to his previous club j, in the sense that if club k signs the player, it needs to pay a fee to club j. We assume that the transfer is a fixed proportion of the bid offered by the winner club k, which in a second price auction implies

$$T = \phi b_j(c_j).$$

Club j wins the auction if $b_j(c_j) = X(t, c_j, w_j) > X(t, c_k, w_k) = b_k(c_k)$. Hence club j chooses b_j to maximize

$$F_k(b_k^{-1}(b_j)) Z(t, c_j) - \int_0^{b_k^{-1}(b_j)} b_k(c) f_k(c) dc$$

$$+(1 - F_k(b_k^{-1}(b_j)))\phi b_j$$

The usual trade-off in an auction is that a higher bid raises the chances of winning but reduces the payoff from winning. Here, there is an extra term, since losing still entails a payment. This payment is proportional to its bid.

Club k chooses b_k to maximize

$$F_j(b_j^{-1}(b_k))Z(t, c_k) - (1+\phi)\int_0^{b_j^{-1}(b_k)} b_j(c)f_j(c)dc$$

For club k, the problem resembles a usual second price auction. The only difference is that the other club's bid is multiplied by $1+\phi$. Now we have asymmetric bidding strategies for two reasons. First, clubs have different distribution probabilities over c (but this source was also present in the post act case). Second, the non-compete clause will be enforced.

Solving for b_k, we get:

$$\frac{\partial b_j^{-1}(b_k)}{\partial b_k} f_j(b_j^{-1}(b_k))(Z(t, c_k) - (1+\phi)b_k) = 0,$$

implying that

$$b_k = Z(t, c_k)/(1+\phi). \tag{8}$$

Club k bids less than it would otherwise, because it has to pay a fee to club j in case it wins the auction. Hence it bids its valuation plus the maximum fee it would pay.

The expression in (8) defines a function $\hat{c_k}(b)$ where $\hat{c_k}$ solves

$$Z(t, \hat{c_k}) = b(1+\phi)$$

Solving for $b_j = b_j(c_j)$, we have that:

$$\frac{\partial \hat{c_k}(b_j)}{\partial b_j} f_k(\hat{c_k}(b_j))(Z(t, c_j) - (1+\phi)b_j) + (1 - F_k(\hat{c_k}(b_j))\phi = 0. \tag{9}$$

The condition in (9) reveals an important difference between club j's bid and the optimal bid in a standard second price auction. An increase in b_j raises the amount club j receives in case it loses the auction.

Hence, this non-compete agreement has two effects on the auction. First, both clubs bid less because club k has to pay a fee if it wins and club j does not receive a fee if it wins, so winning is less attractive for both. This implies lower bids and lower wages for players, but does not lead to any inefficiency.

Second, club j has an incentive to make the player look more valuable in order to boost the transfer it gets. This implies that club j will (generically) bid more than club k for a given c and might win the auction despite having a lower c. This entails an inefficiency, since the player will remain in the club for longer when it would have been more efficient for him to leave.[10]

If $b_j > b_k$, which implies $c_k < \hat{c_k}(b_j)$, team j gets $Z(t,c_j) - Z(t,c_k)/(1+\phi)$ and the player gets b_k. Otherwise the club gets ϕb_j and the player gets b_j. Hence

$$L(t,c_j) = \int_{c_L}^{\hat{c_k}(b_j)} \left[Z(t,c_j) - \frac{Z(t,c_k)}{1+\phi} \right] f(c_k) dc_k + (1 - F(\hat{c_k}(b_j)))\phi b_j$$

$$U(t,c_j) = \int_{c_L}^{\hat{c_k}(b_j)} \frac{Z(t,c_k)}{1+\phi} f(c_k) dc_k + (1 - F(\hat{c_k}(b_j)))b_j$$

Again, we don't need to obtain the wages to compute the value functions. But we do need

[10] Workers in several occupations perceive that non-competes may restrict wage growth and mobility. When this form of non-compete clause was valid in Brazil, Zinho, a successful midfielder who played for Flamengo and was in the Brazilian 1994 World champion squad, stated that: "At that time, the major problem was when big clubs came to hire me, like Inter Milan and Benfica, and Flamengo wouldn't sell me, and I had to stay. Sometimes the offer was not good for the club, but it was good for me. Even after the contract expired, I had to stay in the club. Almost slavery.".

the wages to compute the distributions. The wage w solves

$$\begin{aligned} X(t, c_j, w) &= \frac{Z(t, c_k)}{1+\phi} \quad \text{if} \quad c_k \leq \hat{c}_k(b_j) \\ X(t, c_k, w) &= b_j \quad \text{if} \quad c_k > \hat{c}_k(b_j) \end{aligned}$$

2.1.4 Value functions and distributions at $t = 1$

For a given ζ, we have a simple *symmetric* second-price auction. Clubs j and k bid $Z(1, c_j)$ and $Z(1, c_k)$, respectively. The cumulative distribution of $\min(c_j, c_k)$ is given by:

$$1 - [1 - F_\zeta(c)]^2$$

Hence the probability density is

$$f_I = 2[1 - F_\zeta(c)]f_\zeta(c) = 2\left[1 - \left(\frac{c - c_L}{c_H - c_L}\right)^\zeta\right]\zeta\frac{(c - c_L)^{\zeta-1}}{(c_H - c_L)^\zeta}$$

Hence the initial value is given by

$$I(\zeta) = \int_{c_L}^{c_H} Z(1, c)f_I(c)dc$$

and ζ solves

$$\frac{\partial I}{\partial \zeta} - \chi\zeta = 0$$

The wage is then given by (7).

3 Institutional Background

Football is the most popular and most watched sport in the world. In Europe, the European professional football market's total revenue was approximately USD 33 billion in the 2018/2019 season. This value is very similar to the revenues from the US basketball (NBA), baseball (MLS), and (American) football (NFL) leagues combined over the same period.[11] In Brazil, football is also the number one sport. The "football production chain" was responsible for 0,72% of the GDP of the country in 2018 (or equivalently to USD 13.6 billion).[12]

Generally, the labor market for footballers involves the payments of transfer fees. For example, in August 2020, Lionel Messi made public his intentions of leaving FC Barcelona. The contract between the club and the player was due to expire in 2021, so another club would need to pay a USD 840 million fine to have Messi in its squad. Since no club was willing to pay that much money, Messi decided to stay one more year and leave Barcelona at no cost after the end of the contract.

Despite being a common feature in the market for professional footballers nowadays, moving freely by the end of contracts was not always an option. Until 1995, clubs in the European Union could demand transfer fees even after the contract had expired. This ended with the Bosman Ruling in that same year.[13]

In Brazil, before 1998, the legal arrangements between players and clubs were as those in Europe before the Bosman Ruling. A player could not move to a different team without the current employer's allowance even after the contract had ended. In effect, the current team had the right to charge a transfer fee even when the contract had expired. The Pele Act was sanctioned on the 24th of March, 1998 ("Lei N^o 9.615"). It was named after one of the greatest players of all time, Pele, the Sports Minister by then. Following the Act, players could freely move to other teams after the expiration of their contracts. Contracts could still

[11]Information from www.statista.com. MLB and NBA revenues were 10.4 in 2019 and 8.8 billions in 2018/19, respectively. NFL revenue was 14.5 billions in 2018. Exchange rate (31st December 2018, Bank of England) used to convert Euros to US dollars equals to 1.1453.

[12]Information from https://epocanegocios.globo.com/Economia/noticia/2019/12/futebol-brasileiro.

[13]Jean-Marc Bosman played for RFC Liège (Belgium). His contract had expired in 1990, and he wanted to move to a new club, Dunkerque in France. However, the two clubs could not agree on a transfer fee, and the Belgium club blocked the transfer. The player took his case to the European Court of Justice and won. The ruling implied that all football players could freely transfer (within the EU) by the end of their contracts after December 1995.

include clauses demanding transfer fees, but only during the validity of the labor contract (Brazilian law stipulates a maximum period of five years for a player-club contract).

In 1998, a decree ("Decreto N^o 2.574") from the Brazilian government established a three year transition period in which a newly signed contract could still contain a clause demanding a transfer fee after its expiration. However, there is anecdotal evidence suggesting that the law encouraged players to file lawsuits against their clubs demanding free-agent status.[14]

The Pele Act also changed other aspects of the sports market in Brazil. It extended the maximum duration of a contract from three to five years. It contained several articles aimed at improving corporate governance in Brazilian football. It also indirectly created a legal entity known as a player's economic rights. Its creation allowed individuals or firms other than clubs to purchase those economic rights (Perdomo and Luz, 2019).[15] Despite these modifications, we believe that the most relevant aspect of the Act was the extinction of transfer fees by the end of contracts, a non-compete friction that is the focus of the paper.[16]

4 Data, Summary Statistics and Preliminary Analysis

The empirical analysis explores Brazilian data from the Annual Report of Social Information (RAIS), provided by the Brazilian Ministry of Labor. It is an administrative dataset and includes all formal employers and employees in the country. It has information on wages, tenure, occupation, schooling level, gender, age, among other social-demographic characteristics.

In the main exercise, we use data from 1996 to 2001. We focus the analysis on male athletes because female professional football players were almost non-existent at that time. RAIS classifies professional athletes as a single occupation, but does not identify the athlete's

[14]See, for example, https://www1.folha.uol.com.br/fsp/esporte/fk23059929.htm.

[15]Information from http://globoesporte.globo.com/programas/esporte-espetacular/noticia/2014/10/base-lei-pele.

[16]The Act encompassed other aspects: it extended some consumer rights to football team supporters; it established that the Supreme Court of Sports Justice ("Superior Tribunal de Justiça Desportiva - STJD") would be responsible for organizing a justice system for sports; and it brought new regulations to other "sports".

sport. However, at that time, players in other sports were generally considered amateur players, and hence, the professional athlete occupation mainly included football players. Therefore, we filter football players using worker's age and employer's information. We classify a professional athlete as a football player if he is between 18 and 35 years old. There are a total of 11,841 male athletes at this age range in RAIS (22,171 observations). Many of those are semi-professional players, i.e., part-time players, especially in the lower divisions. Therefore, we keep 5,481 players employed in teams that competed on the first two divisions of the national football championship. Moreover, we drop anyone that were also registered with a different occupation in any year of our sample. We end up with 3,943 players (8,373 observations).

RAIS has information on workers with a formal contract job only. Therefore, a player with no formal contract does not appear in our sample. However, virtually no informal player is hired by teams at the first two divisions in Brazil.[17] We calculate the monthly salaries in 1995 Reais (Brazilian currency) and turnover rate as the proportion of workers who changed their employers from year τ to $\tau + 1$.

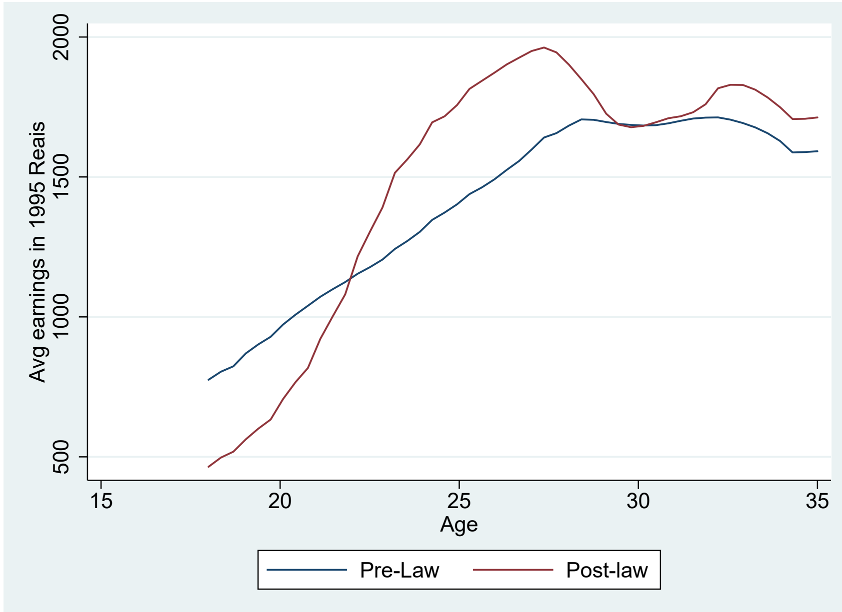
Figures 1 and 2, respectively, depict average wages and turnover rates two years before (1996 and 1997) and two years after (1999 and 2000) the Pele Act by career time.[18] The graphs show local polynomial fits of wages and turnover on age. Three main facts emerge: (i) wages are higher in the beginning of players' careers before the Pele Act; (ii) wages grow faster (for players below 30) after the Pele Act - players in their early twenties are already making more money without the non-compete friction; and (iii) average turnover is slightly higher after the Act. Shortly, we will see that our model will be able to match those facts.

Table 1 depicts descriptive statistics of our final sample by year. We compare salaries and turnover rates of football players across years before and after the Act. We define the

[17] Besides, we checked at the Brazilian National Household Survey (*PNAD*) and only 4% of the players wages within the interquartile range of wages of our sample are informal.

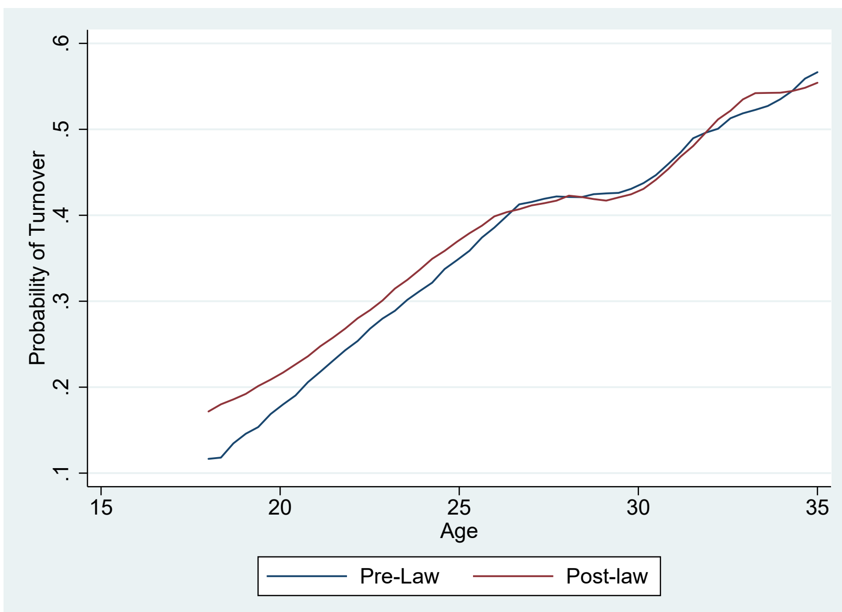
[18] We drop 1998 of the analysis since the Act was signed in March of that year. We only use 2001 data to calculate the turnover rate in 2000.

Figure 1: Wages - Pre-act vs. Post-act



NOTES: Figure displays the local polynomial fits of earnings on age. Pre-act includes the years of 1997 and post-act includes 1999 and 2000. Earnings are in Brazilian Reais of 1995. We use the Brazilian CPI (IPCA) to deflate earnings.

Figure 2: Turnover - Pre-act vs. Post-act



NOTES: Figure displays the local polynomial fits of turnover probability on age. Pre-act includes the years of 1997 and post-act includes 1999 and 2000.

period pre-act period from 1996 to 1997 and the post-act from 1999 to 2000. The table shows an increase in the number of formal players over the period. The proportion of young players augments each year, and since they receive lower wages, the average earnings also decrease during the analyzed period.

Table 1: Descriptive Statistics of football Players

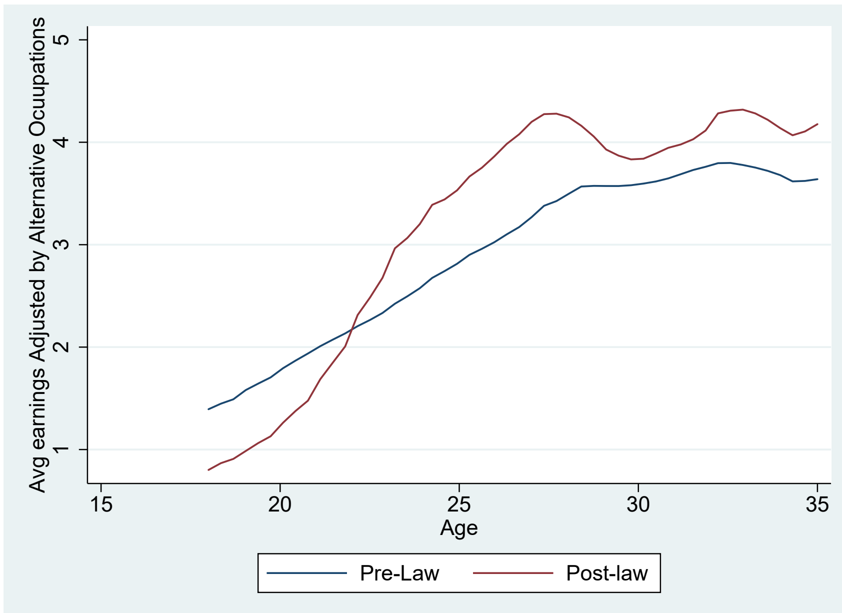
Year	Monthly Salary	Turnover Rate	Age	N
		Pre Pele Act		
1996	1229.26	0.31	23.92	1,540
1997	1274.88	0.28	23.52	1,757
		Post Pele Act		
1999	1136.17	0.28	22.84	2,365
2000	1192.92	0.29	22.62	2,711

NOTES: Players in teams at 1st and 2nd division of the Brazilian National Championship. Monthly salaries in 1995 Reais. Turnover is defined by the change in the employer from year τ to $\tau + 1$.

We claim that the change in the earnings-age profiles observed after 1998 is mainly due to the Pele Act according to the mechanism described in the model. However, some concerns emerge. First, it is possible that the Act induced a change in the composition of players. The Pele Act may have impacted teams' incentives to invest in new players formation, and hence, affected the quality of the new pool of players. Indeed, Table 1 shows that the number of formal players increased in the period. Besides, players became younger on average. It is possible that a pool of less skilled young players entered in the market after the Act, left it over the years, and only the most skilled ones remained hired. If that is the case, the observed increase in the age-earnings profile after the Act was due to a change in the selection of players over the years and not because of the mechanisms described in the model. We address this issue by exploring the longitudinal structure of the data and controlling for players' fixed-effects. Therefore, we are able to control for the players' inherent ability (y_i) and be sure that changes in non-observed fixed characteristics are not driving our results.

Figure 3 shows the pre and post-act age profiles of the residuals of the log earning regressions on individuals' fixed-effects. Age-earning profiles with and without fixed-effects are very similar to each other, suggesting that changes in composition were not key to the pattern found. Moreover, average wages increase after the act when we control for the players' fixed effects.

Figure 3: Wages - Pre-act vs. Post-act



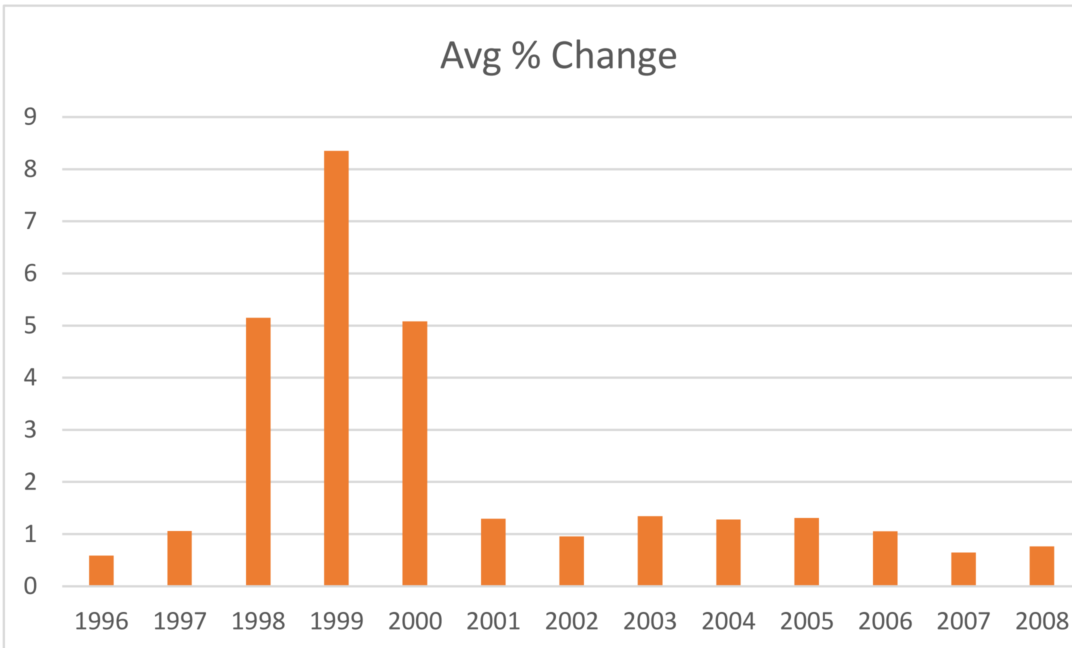
NOTES: Figure displays the local polynomial fits of earnings on age. Pre-act includes the years of 1997 and post-act includes 1999 and 2000. Earnings are the residuals of a log wage regression on the players' fixed-effects. We use the Brazilian CPI (IPCA) to deflate earnings.

A second concern is the presence of pre-existent trends in the age-earnings profile. It is possible that the relationship between wages and age is changing overtime even before the Act.

We check whether the age-earnings gradients change overtime by analyzing the data from 1994 to 2010. Figure 4 shows the ratio of the percentage increase in earnings (35 to 18 years old) in several alternative exercises. We compare the increase in the two years before to the increase two years after the baseline, i.e., for baseline year τ, the ratio is the average return to experience in years $\tau+1$ and $\tau+2$ over the average return to experience in years $\tau-1$ and $\tau-2$. We can see that the changes in the years 1998, 1999 and 2000 are substantially larger than in the others. The reason behind this is that these are the only years that actually compare years before the act (1998 and below) to years after the act (1998 and above).

The year 2000 analysis, for example, compares 2001/2002 (both post-act) to 1998/1999 (one post-act and the other pre-act), while the 2001 analysis compares 2002/2003 to 1999/2000 (all post-act years).[19] This is evidence that the Act indeed changed players' wage profile.

Figure 4: % increase in earnings (35 to 18 years old)



NOTES: Bars show the ratio of the percentage increase of earnings (35 to 18 years old) between post and pre years. We compare the increase of the two years before and two years after the baseline, i.e., for baseline year τ, the ratio is the average return to experience in years $\tau + 1$ and $\tau + 2$ over the average return to experience in years $\tau - 1$ and $\tau - 2$.

During the period, there were overall changes in the Brazilian economy: increase in the value of the minimum wage, exchange rate depreciation, economic crisis and unemployment increase. These shocks could explain the profile differences observed before and after the Act. To rule out this possibility, we need a comparison group to control for the overall changes in the economy. Therefore, we also calculate the salaries and turnovers for workers in "similar occupations", defined in the following way. Among the 11,841 male athletes in RAIS, many

[19]In the appendix we plot the age-earnings profiles for different years. Figure A1 shows the evolution of the profiles over the years. All graphs compare the profiles of the two years before and two years after the baseline. As expected, only in the years around the Act we have a similar change in the profile as seen in Figure 3.

leave the football-player career and change their main occupation, at least temporarily. We use this fact to define similar occupations as the ten most typical occupations in which football players move into.[20].

There are around 11 millions observations (from approximately 3 million workers) of similar occupations in the period considered. Table 2 shows wages, turnover and age of the workers in those similar occupations. It shows a pattern analogous to that of football players: increase in formalization, decrease in wages and in age over the years.

Table 2: Descriptive Statistics of Workers at Similar Occupations

Year	Monthly Salary	Turnover Rate	Age	N
		Pre Pele Act		
1996	330.22	0.36	26.0	2,618,502
1997	326.67	0.35	25.9	2,714,982
		Post Pele Act		
1999	301.56	0.34	25.6	2,868,539
2000	299.12	0.35	25.3	2,994,243

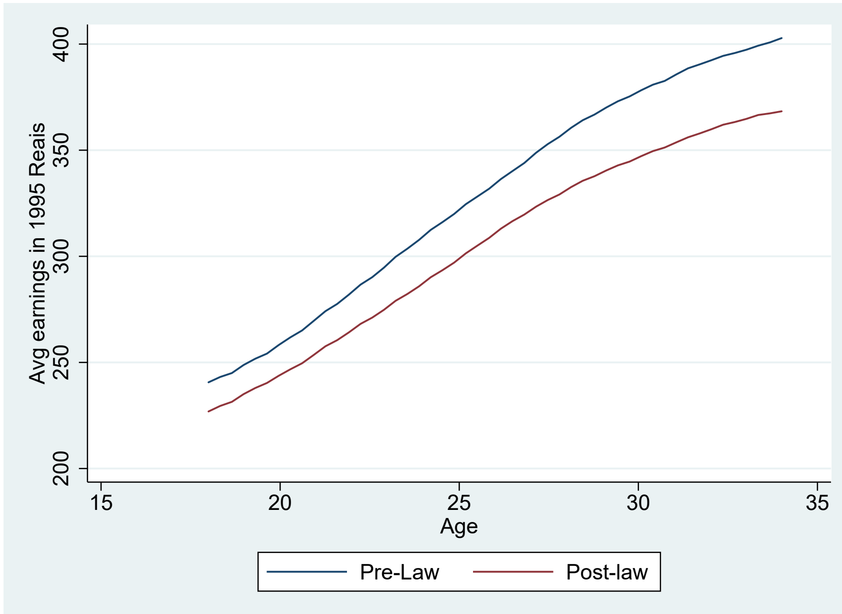
NOTES: Monthly salaries in 1995 Reais. Turnover is defined by the change in the employer from year τ to $\tau + 1$.

Figure 5 shows the age-earnings profiles (in 1995 Reais) of workers in similar occupations before and after the Pele Act. We see parallel profiles before and after the Act with an overall reduction in wages due to the economic crisis of 1999. Therefore, we argue that it is unlikely that the change in the age-earnings profile before and after the Pele Act is solely related to shocks in the overall economy during the period.

Figure A2 in the Appendix shows the age-earnings profile of football players after controlling for the evolution of wages of similar occupation and players fixed effects. It shows a very similar pattern to the one seen in Figure 1, corroborating the claim that shocks in the overall economy are not the main driving forces of the observed changes in age-earnings

[20]The similar occupations are: office support workers, security guard, sports instructors and coaches, other handwork activities, contractors, stock clerks, administrative support worker, sales and related workers.

Figure 5: Wages - Pre-act vs. Post-act



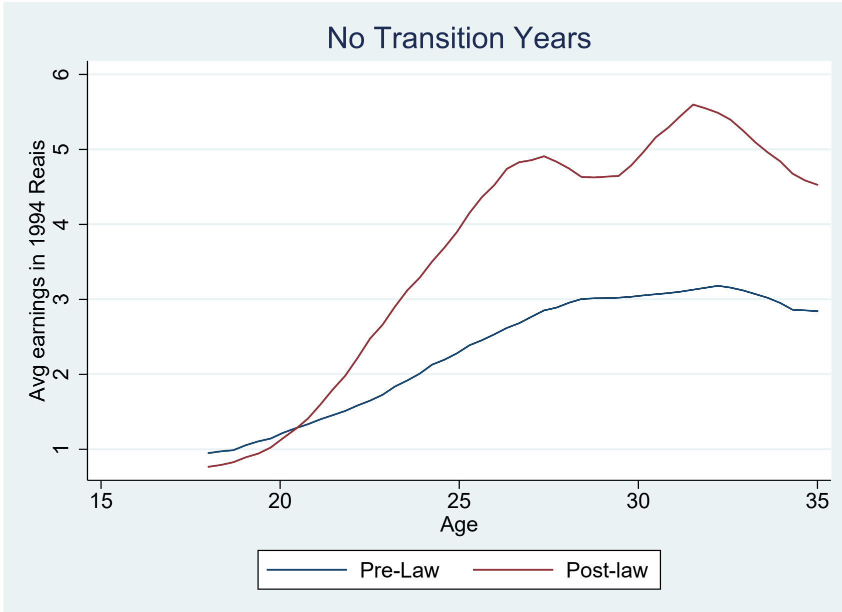
NOTES: Figure displays the local polynomial fits of earnings on age. Sample includes workers on similar occupations. Pre-Act includes the years of 1997 and post-Act includes 1999 and 2000. Earnings are the residuals of a log wage regression on the workers' fixed-effects. We use the Brazilian CPI (IPCA) to deflate earnings.

profiles before and after the Act.

A fourth concern has to do with the transition period. As discussed in the previous section, the Pele Act stipulated a 3-year transition period, where the Act was not enforced. However, several players gained free-agent status during the transition after filing lawsuits. Therefore, we think that clubs and players generally behave as if the Act was already fully valid. Even if it was not the case, this transition period would reduce the impact of the Act from 1999 to 2001, and we would estimate a lower bound of the actual impact of the Act. Nevertheless, as a robustness check, we exclude the transition period of the analysis and set the post-Act period after 2001. Figure 6 shows the earning-age profiles (controlling for players fixed effects) before the Act sanction (1996 and 1997) and after the transition period (2002 and 2003). We still find a difference across wage profiles in the pre and post-Act periods. The differential effect seems stronger for older players, and weaker for younger ones.

Misclassification of players in our dataset could also be a concern. We could be classifying professional athletes of other sports as professional football players when, in fact, the are

Figure 6: Wages - Pre-Act vs. Post-Act



NOTES: Figure displays the local polynomial fits of earnings on age. Pre-Act includes the years of 1997 and post-Act includes 2002 and 2003. Earnings are the residuals of a log wage regression on the players' fixed-effects. We use the Brazilian CPI (IPCA) to deflate earnings.

not. Fortunately, from 2002 onwards, RAIS expanded the occupation classification, allowing us to identify the exact sport of all professional athletes. Hence, we use the longitudinal structure of RAIS to check how many athletes in 2001 we misclassified as football players. Indeed, very few. We could find 80% of the 2001 sample at 2002 RAIS, and, out of those, more than 90% were classified as football players in 2002.

Finally, it is common in the Brazilian football labor market that only a share of players earnings is registered as salary. Players may receive part of his own economic rights (share of a future transfer's fee) as payment.[21] If the Pele Act induced a change in those payment shares, the new observed earnings-age profile could be due to changes in the payment format. Unfortunately, we do not have information on these other payment forms. RAIS only registers players salaries. However, we indirectly investigate the second issue by collecting balance sheet data in recent years for the teams in the Brazilian first division championship that make their balance sheet public available. We are then able to observe the share of play-

[21]It is also common that part of player's total compensation is paid as "image rights" for tax purposes.

ers' economic rights owned by each team. We did not find any correlation between players' ages and the shares their own teams would earn after eventual transfers. This suggests that the allocation of shares of players' economic rights is not a major factor behind Brazilian players' age-earnings profiles.

5 Estimation

We estimate the key parameters by matching moments of the model to their data counterparts. We assume that the productivity shifter $\mu(t)$ can be expressed as a quadratic function of players' career time,

$$\mu(t) = \mu_a t + \mu_b t^2 + \mu_c, \tag{10}$$

for t $\in [1, N]$. Similarly, we assume that the probability of survival of the contract, $\delta(t)$, can be written as

$$\delta(t) = \delta_a t + \delta_b t^2 + \delta_c, \tag{11}$$

for t $\in [2, N]$. We first set $N = 18$, set $\beta = 0.86$ (from Reis, 2016), $c_L = 0.5$, $c_H = 1$ and $p = 1/3$.[22] We then estimate μ_i's (i $\in \{a, b\}$) and δ_j's (j $\in \{a, b, c\}$), together with ξ, λ and χ, by simulated method of moments. We set $\mu(t = 1) = 0.01$ (a low value that helps us to match wages at t=1). We match observed wages by age (from age 18 to 35) and observed turnovers by age (from age 19 to 35) to their observed values in the post-act period. To adjust for the different scales, we multiply wages and turnovers (both data and model) by the inverse of the mean (across years) of observed wages and turnover, respectively.

Table 3 shows the results of our estimation procedure.[23] The productivity parameters and the intercept of the survival probability function are statistically significant at standard levels. The other parameters are not statistically different from zero. However, to identify

[22] We calibrate p by using the fact that the Pele Act was implemented three years after the Bosman Ruling. So the act could be implemented with equal chances in any year after the ruling.

[23] We calculate the var-covar matrix following Cocci and Plagborg-Møller (2019). We consider the case that the var-covar matrix of the moments is known and assuming that its off diagonal elements are zero, as in Dix-Carneiro (2014).

the other parameters more precisely (especially χ, ξ and λ), we would need additional data. For example, to identify χ we would need data on search intensity and job offers of young players, something not readily available as far as we know.

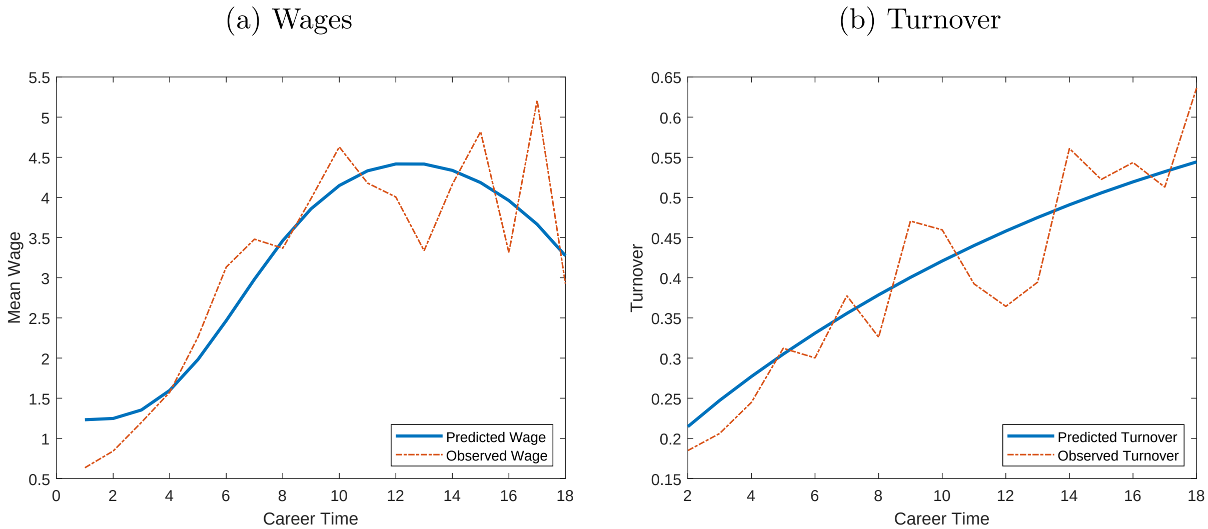
Table 3: Estimatives

Parameters	
Productivity Shifter	
μ_a	1.125
	[7.014]
μ_b	-0.045
	[-2.502]
Contract Survival Probability	
δ_a	-0.088
	[-0.989]
δ_b	0.001
	[0.321]
δ_c	1.076
	[4.486]
Efficiency Distribution (for $t > 2$)	
ξ	1.572
	[0.650]
Match Persistence	
λ	0.366
	[0.140]
Search Cost ($t = 0$)	
χ	0.066
	[0.102]

NOTES: Estimated parameters of the model via simulated method of moments. Robust t-stats in square brackets. μ and δ assumed to be quadratic functions of career years - see equations 10 and 11. μ_c calibrated to 0.01. $\beta = 0.86$, $p = 1/3$, $N = 18$, $c_L = 0.5$ and $c_H = 1$. Implied , $\zeta = 0.827$.

Figure 7 shows the model fit. We are able to match wages and turnovers trends well. In the case of wages, we are able to capture the fact that wages first go up and then fall slightly in players' careers (the same pattern emerges if we fit wages directly using a quadratic polynomial function). One difficulty is to match wages at the initial years. Given that matches are relatively productive for older players, clubs are always willing to pay substantial wages for young players even if their current productivity is close to zero, just to profit from productive matches in the future.

Figure 7: Model Fit: Pos-act



NOTES: Observed and fitted model wages (Panel a) and turnovers (Panel b). Observed data from RAIS. Average wages and turnovers in the data calculated for the years 1999 and 2000. $t = 1$ corresponds to $age = 18$. Observed wages are adjusted for players' individual effects, i.e., they are the (exponentiated) residuals of a log earnings regression of wages on individuals' fixed effects. Turnover is calculated as the share of players moving clubs from career year $t - 1$ to t.

5.1 Non-compete Frictions

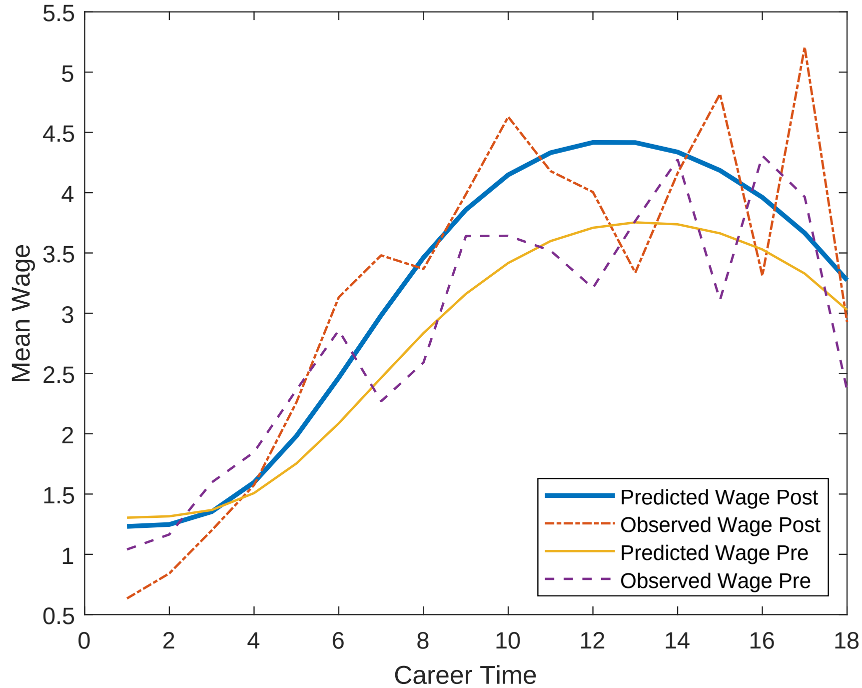
Next, we allow for an additional source of non-compete friction to mimic the pre-act period. We do this by setting $\phi > 0$. The value of ϕ is calibrated such that the (absolute) distance between wages and turnover (scaled by their standard deviation across years) in the pre-act period and in the data are minimized, implying $\phi \approx 0.1$.[24]

Figure 8 presents the wage results. By adjusting only one parameter of the model, we are able to show that younger workers loose and older workers gain in terms of wage after the Pele Act, as suggested by the data. In principle, we could have considered changes in other parameters to match the pre-period variables. For example, it is possible that the process governing the quality of the matches may change with the act, implying different values for λ and ξ. We prefer to focus our exercise on shifts in ϕ for two reasons. First, it is the only parameter related to non-compete frictions that is undoubtedly changing with

[24] In the Appendix, we provide results considering a value of $\phi \approx 0.07$, obtained by minimizing the sum of the quadratic distance between wages in the pre-act period and in the data and the quadratic distance between the turnover in the pre-act period and in the data (weighted by their respective means) - see Figures A3 and A4.

the act. Second, allowing only one parameter to change is a more conservative approach, as incorporating changes in other parameters would only improve our match.

Figure 8: Wages

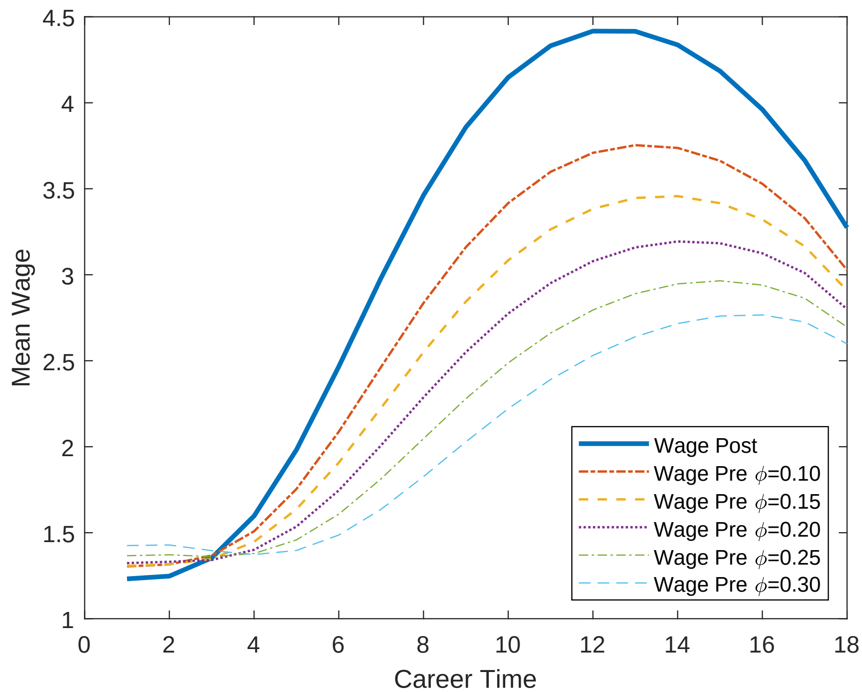


NOTES: Observed and fitted model wages in the pre- and post-act periods. Observed data from RAIS. Average wages in the data calculated for the years 1996 and 1997 (pre) and 1999 and 2000 (post). $t = 1$ corresponds to $age = 18$. Observed wages are adjusted for players' individual effects, i.e., they are the (exponentiated) residuals of a log earnings regression of wages on individuals' fixed effects. In the pre-act period, $\phi \approx 0.1$

In the next section, we provide more intuition about the wage crossing pattern between the pre- and post-act periods, but it is important to highlight that this result is robust to our choice of ϕ, as shown in Figure 9. Hence, the value ϕ in the pre-act period is not fundamental to understand our main results (as long as $\phi > 0$). We are simply choosing one value that matches the model to the data reasonably well.

Our exercise also shows that turnovers increase slightly after the act (Figure 10). However, we are not able to match the fact that turnovers rise more steeply for younger players than for older ones.

Figure 9: Wages - Higher ϕ's



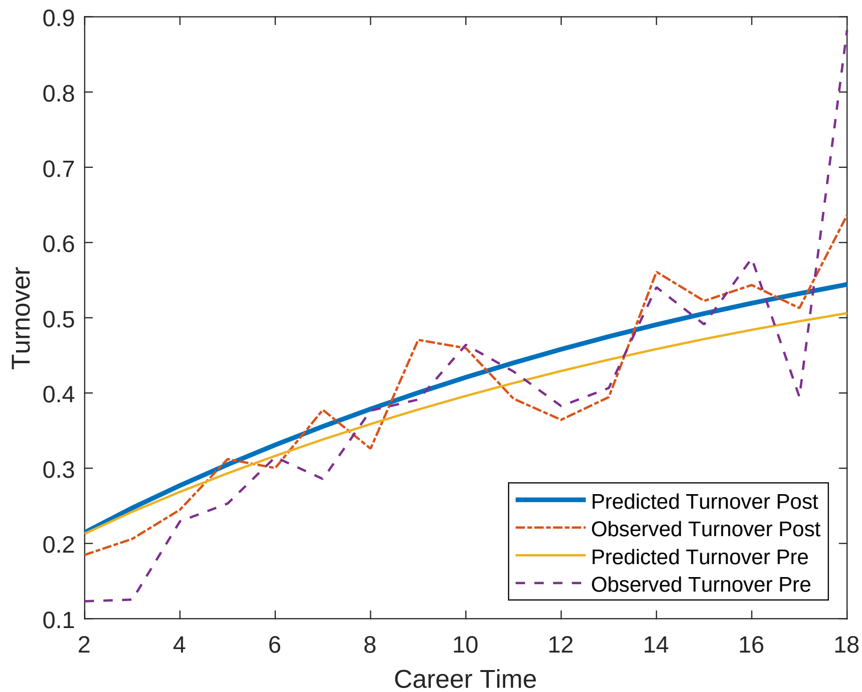
NOTES: Fitted model wages in the pre- and post-act periods. $t = 1$ corresponds to $age = 18$. Different pre-act period curves consider different values of ϕ: from 0.1 to 0.3.

6 Efficiency and wages

Our model allows us to study one aspect not directly observed in the data: efficiency. Figure 11 displays the average match-specific efficiency value, $\bar{c}$, for the pre- and post-act periods over time. We can observe that average efficiency increases over players' career both in the pre- and post-act periods. Players will tend to move to better matches as they get older, and hence, efficiency will likely increase both with and without non-competes.[25] Average match efficiency rises faster in the post-act period as players move more easily to better matches.

[25]Note that at t=1 efficiency is slightly higher in the pre-act scenario. The reason behind this is that workers choose to search more intensively for better matches under the presence of non-competes (i.e., they choose a slightly higher ζ) as they anticipate that is going to be harder to switch jobs later in their careers. However, from t=2 onwards average match efficiency increases faster in the post-act period as players to move more easily to new clubs in search of better matches.

Figure 10: Turnover



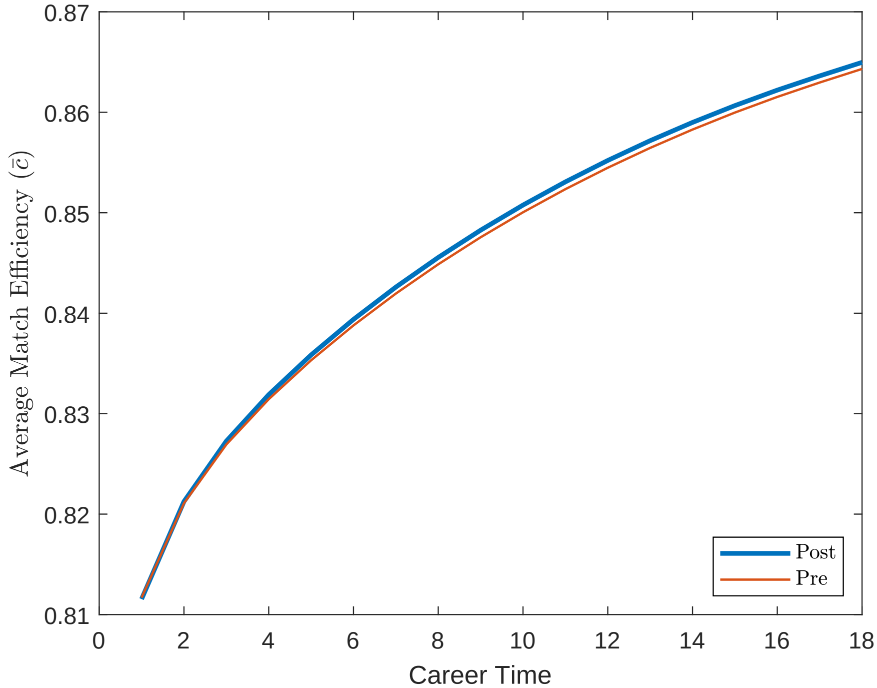
NOTES: Observed and fitted model turnovers in the pre- and post-act periods. Observed data from RAIS. Average turnovers in the data calculated for the years 1996 and 1997 (pre) and 1999 and 2000 (post). $t = 1$ corresponds to $age = 18$. Turnover is calculated as the share of players moving clubs from career year $t-1$ to t. In the pre-act period, $\phi \approx 0.1$

The difference between the two periods, however, is quantitatively negligible.[26]

The small efficiency gap is evidence that the observed wage differences are due mainly to distributional forces. We further investigate this result by running an experiment using the pre-act parameters but augmenting both c_L and c_H by the amount necessary to obtain the same average (weighted by μ) efficiency generated by our model in the post-act period. In this experiment, only shifts in efficiency increase wages, and hence, distributional effects should be zero. Figure 12 shows the result. We can see that there are almost no wage changes due solely to efficiency, implying that the observed wage changes between the pre- and post-act periods are mostly distributional, i.e., matches surplus (Z) are divided differently before

[26] We can also look at other moments of the efficiency distribution. Figure A5 in the Appendix displays the 10^{th} and the 90^{th} percentiles of the match efficiency distribution. It is clear that the 10^{th} percentiles grow over time and that the 90^{th} percentiles grow only at early stages of players' careers and remain constant afterwards, both in the post- and pre-act periods. This suggests that inequality may be falling more rapidly in the post-act period. Indeed, Appendix Figure A6, that displays the ratio of the 90^{th} to the 10^{th} percentiles, shows that this is actually the case, providing evidence that higher labor mobility contributes to a faster decline of (this measure of) inequality.

Figure 11: Average Match Efficiency

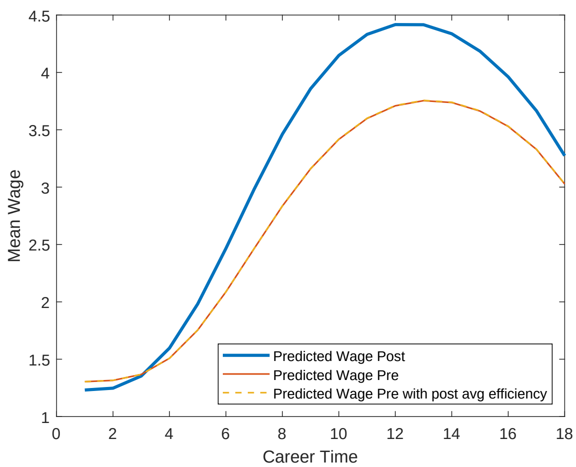


NOTES: Average match efficiency from the model in the pre- and post-act periods. $t = 1$ corresponds to $age = 18$. Average match efficiency is calculated as the average value of c at every point in time. In the pre-act period, $\phi \approx 0.1$

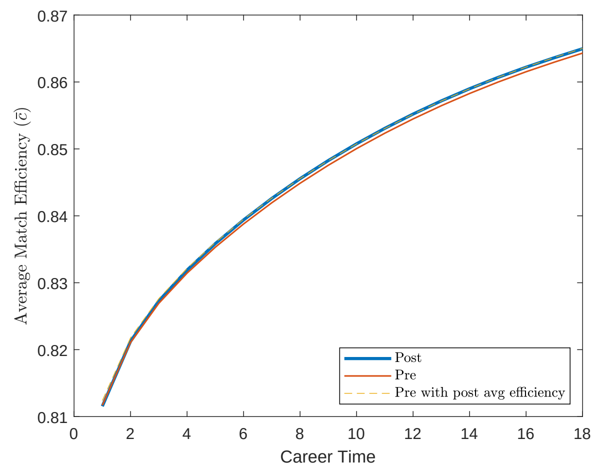
and after the act.

Figure 12: Wages and Efficiency

(a) Wages



(b) Efficiency



NOTES: Model wages (Panel a) and efficiency (Panel b). Average match efficiency is calculated as the average value of c at every point in time. In the pre-act period, $\phi \approx 0.10$. "Predicted wage pre with post avg. efficiency" obtained by running an experiment using the pre-act parameters but augmenting both c_L and c_H by the amount necessary to obtain the same average (weighted by μ) efficiency generated by our model in the post-act period. In this experiment, only shifts in efficiency increase wages, and hence, distributional effects should be zero.

The effects on wages are heterogeneous across ages, as shown previously in Figure 8. Older workers get a lower share of the surplus before the act as clubs bid less aggressively when $\phi > 0$. The intuition is as follows. Potential buyers bid less as they have to pay a transfer fee on top of wages. Clubs in contracts with players also offer lower wages as losing the auction is not so bad with a non-compete clause (they receive a payment if this case). But with $\phi > 0$, clubs linked to a player bid more aggressively than potential buyers because their bid increase the value of the transfer in the second-price asymmetric auction.

On the other hand, younger players receive higher wages before the act. At first glance, a fall in wages seems puzzling given that clubs bid more aggressively in the post-act period and match efficiency increases slightly. To understand why young players' wages fall without non-competes, first note that the auction at $t = 1$ is symmetric, implying that changes in ϕ do not affect the division of the surplus directly in the first period. Second, in the post-act period, the option value of retaining a player falls as players leave the club more easily. This implies that clubs are willing to pay less for players in general (Y and T go down). The fact that clubs' option values fall after the act outweighs (minor) increases in efficiency, driving down the total value of the match (Z falls). Hence, at $t = 1$, clubs offer lower wages than before the act, and match persistence keeps wages relatively low for a short period after that.

6.1 Effects of other parameters

To verify if the quantitatively negligible efficiency effects observed previously are due to a limitation of our model, we run other counterfactuals considering the same $\Delta\phi = 0.1$ between the pre- and post-periods, but different values for other parameters. Table 4 shows the changes in average efficiency (with and without μ as weights) arising from the counterfactuals in the second and third columns. The last column shows a back-of-the-envelope contribution of efficiency to (average) wage changes. The number is obtained by multiplying average wages in the pre-period by one plus the average growth of c (weighted by μ), and dividing it by the difference in average wages between the pre and post periods.

Table 4: Counterfactuals: Other Parameters

		Δ Average Efficiency	Δ Average Efficiency (μ weight)	Δ Wage: Efficiency Share
$\xi =$	0.50	0.02%	0.03%	0.02%
	3.25	0.69%	0.82%	0.46%
$\chi=$	0.05	0.07%	0.08%	0.04%
	10.0	0.07%	0.08%	0.04%
$\lambda=$	0.10	0.05%	0.07%	0.04%
	0.70	0.07%	0.07%	0.04%
$\delta=$	0.05	0.08%	0.08%	0.04%
	0.95	0.00%	0.01%	0.01%
Baseline		*0.07%*	*0.08%*	*0.52%*

NOTES: Table of counterfactuals considering the same $\Delta\phi = 0.1$ between the pre- and post-periods, but different values for other parameters. Column 1 shows the values of the parameters of interest considered in the counterfactual, i.e., the values of the parameters that are different from our baseline specification. Different counterfactuals are considered in different rows. Columns 2 and 3 show the changes in average efficiency with and without μ as weights, respectively. The last column shows the contribution of efficiency to (average) wage changes obtained by multiplying average wages in the pre-period by one plus the average growth of c (weighted by μ), and dividing it by the difference in average wages between the pre and post periods. The last rows shows the changes between pre- and post-act periods in our baseline version of the model.

We can see that shifts in χ, λ and δ do not seem to magnify efficiency gains substantially. On the other hand, higher ξ generates larger shifts in efficiency, even though the overall effect is still small.

We also verify if changes in combinations of parameters can magnify efficiency effects. We run a similar exercise by combining a higher ξ with a lower δ. Results in the first two rows of Table 5 show gains in efficiency that are several times greater than in our baseline case. And if contracts are more persistent (higher λ) and player's play for a very long time (N=600, for example), the absence of non-competes makes an even greater difference in efficiency.

In sum, our model is able to generate non negligible efficiency effects under different combinations of parameters (but with the same level of non-compete frictions observed in the data). This suggests that the minor efficiency gains between the pre- and post-act periods are not being mechanically generated by the model, but rather reflect that the Pele Act did

Table 5: Counterfactuals: Other Parameter Combinations

	Δ Average Efficiency	Δ Average Efficiency (μ weight)	Δ Wage: Efficiency Share
$\delta = 0.05$ and $\xi = 2.5$	3.36%	3.08%	1.72%
$\delta = 0.01$ and $\xi = 2.5$	3.47%	3.19%	1.78%
$\delta = 0.01$, $\xi = 2.5$, $\mu = 1$, $\lambda = 0.7$ and $N = 600$	6.14%	6.14%	3.42%
Baseline	*0.07%*	*0.08%*	*0.52%*

NOTES: Table of counterfactuals considering the same $\Delta\phi = 0.1$ between the pre- and post-periods, but different values for other parameters. Column 1 shows the values of the parameters of interest considered in the counterfactual, i.e., the values of the parameters that are different from our baseline specification. Different counterfactuals are considered in different rows. Columns 2 and 3 show the changes in average efficiency with and without μ as weights, respectively. The last column shows the contribution of efficiency to (average) wage changes, obtained by multiplying average wages in the pre-period by one plus the average growth of c (weighted by μ), and dividing it by the difference in average wages between the pre and post periods. The last rows shows the changes between pre- and post-act periods in our baseline version of the model.

not improve the quality of matches substantially.

7 Conclusion

Our paper speaks to a recent policy debate around non-competes (U.S. Department of the Treasury, 2016; Krueger, 2017; Nunn, 2020). Non-compete clauses might be beneficial for protecting trade secrets and incentivizing training, but might be costly for adversely affecting wages and match efficiency. But how important are these effects?

We shed light on this topic by developing a model to study non-compete agreements and exploring a policy change in the market for professional footballers in Brazil. This environment is particularly interesting because professional footballers' mobility across occupations is low, so policies and unobserved shocks affecting other sectors of the economy are not a major source of concern to isolate the effect of the non-compete ban on wages and turnovers. Our structural approach provides insights into the mechanisms driving these outcomes.

Krueger and Posner (2018) propose banning or severely restricting non-competes that bind low-wage workers in the US. They are particularly worried about distributional effects. One question is whether problems with non-competes are actually a matter of inadequate information, as discussed by Krueger and Posner (2018). In our setting, this is not a relevant issue as players were generally aware of the non-compete clauses. Still, we find that non-compete agreements have large effects on wages. After the non-compete ban, the average wage of a player throughout his career significantly rises. Young players' salaries go down, because the option value of retaining them is higher under non-competes, but wage gains at later stages of players' careers largely outweigh the initial losses.

For high-paid workers, distributional concerns are less relevant, and efficiency issues are crucial. In particular, match efficiency is an important consideration. Do non-competes inefficiently reduce turnover? This might be critical, especially at sectors with frequent shocks in the worker-firm match productivity. We find that non-competes do reduce turnover, but the effect is quantitatively unimportant. In our setting, the worker can be transferred to another firm for a fee. This reduces the bids of other firms for a worker, but it also reduces the bid of its current employer. The distributional effect is strong, but in terms of match-efficiency, not much is lost.

Although we are studying one particular setting, our structural approach allows us to understand the channels through which non-competes affect wages and efficiency and has implications for the debate. The model insights and the data analysis provide support for restrictions on non-competes for low-income workers, but not for high-paid employees.

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A Proof of Proposition 1

We prove the result by induction. We show the following:

1. The first and second statements for X, Y and Z hold (a) in the last period ($t = N$), and (b) at any $t < N$ if the first and second statements hold for W, V and M at $t+1$.

2. The third and fourth statements hold at any t if the first and second statements for X, Y and Z also hold in that period.

3. The first and second statements for W, V and M hold at t if the first and second statements for X, Y and Z and the third and fourth statements also hold in that period.

Putting all together, we get the claim.

We present the result in 3 lemmas. The proof of the first one is immediate, but the others are not.

Lemma 1. *It must be that*

$$\frac{\partial Z(t,c,w)}{\partial w} = 0 \ , \ \frac{\partial^2 X(t,c,w)}{\partial c \partial w} = 0 \ , \ \frac{\partial^2 Y(t,c,w)}{\partial c \partial w} = 0$$

for $t = N$ and for any $t < N$ if

$$\frac{\partial M(t+1,c,w)}{\partial w} = 0 \ , \ \frac{\partial^2 W(t+1,c,w)}{\partial c \partial w} = 0 \ , \ \frac{\partial^2 V(t+1,c,w)}{\partial c \partial w} = 0$$

Proof. For $t = N$, $Z(t,c,w) = X(t,c,w) + Y(t,c,w) = cy_i\mu(N)$, which does not depend on w. Simply deriving $X(t,c,w)$ and $Y(t,c,w)$ yields the claim.

For $t < N$ if the conditions for $M(t,c,w)$, $W(t,c,w)$ and $V(t,c,w)$ hold, then the argument is similar. Simply doing $Z(t,c,w) = X(t,c,w) + Y(t,c,w)$ and deriving $Z(t,c,w)$, $X(t,c,w)$ and $Y(t,c,w)$ yield the claim. $\square$

Lemma 2. *For any t, if*

$$\frac{\partial Z(t,c,w)}{\partial w}=0 \quad , \quad \frac{\partial^2 X(t,c,w)}{\partial c \partial w}=0 \quad , \quad \frac{\partial^2 Y(t,c,w)}{\partial c \partial w}=0$$

then $\overline{c}$ does not depend on w_j and solves:

$$f_k(\overline{c})\left[Z(t,\overline{c})-Z(t,c_j)\right]=2\left(1-F_k(\overline{c})\right)\frac{\partial Y(t,\overline{c},w)}{\partial \overline{c}}$$

and w_k solves:

$$Y(t,\overline{c},w_k)-X(t,\overline{c},w_k)=Y(t,c_j,w_j)-X(t,c_j,w_j)$$

Proof. From (4) and the expression for $\partial w_k/\partial \overline{c}$, we get:

$$\begin{aligned}
f_k(\overline{c})\left[X(t,\overline{c},w_k)-X(t,c_j,w_j)\right] &= -\int_{\overline{c}}^{c_H}\frac{\partial X(t,c,w_k)}{\partial w_k}\frac{\frac{\partial Y(t,\overline{c},w_k)}{\partial \overline{c}}}{\frac{\partial Y(t,\overline{c},w_k)}{\partial w_k}}f_k(c)dc \\
&= \int_{\overline{c}}^{c_H}\frac{\partial Y(t,c,w_k)}{\partial w_k}\frac{\frac{\partial Y(t,\overline{c},w_k)}{\partial \overline{c}}}{\frac{\partial Y(t,\overline{c},w_k)}{\partial w_k}}f_k(c)dc \\
&= \int_{\overline{c}}^{c_H}\frac{\partial Y(t,\overline{c},w_k)}{\partial \overline{c}}f_k(c)dc \\
&= (1-F_k(\overline{c}))\frac{\partial Y(t,\overline{c},w_k)}{\partial \overline{c}} \qquad (12)
\end{aligned}$$

The second equality comes from $\partial Z(t,c,w)/\partial w=0$, that implies $\partial X(t,c,w)/\partial w=-\partial Y(t,c,w)/\partial w$. The third equality comes from $\partial^2 Y(t,c,w)/\partial c\partial w=0$, which implies that $\partial Y(t,c,w)/\partial w$ is the same for any c. Adding (12) and (3), noting that Z does not depend on w, yields the expression for $\overline{c}$.

Subtracting (12) from (3) and rearranging yields the expression for w_k.

□

Lemma 3. *For any t, if*

$$\frac{\partial Z(t,c,w)}{\partial w}=0 \quad , \quad \frac{\partial^2 X(t,c,w)}{\partial c \partial w}=0 \quad , \quad \frac{\partial^2 Y(t,c,w)}{\partial c \partial w}=0$$

then

$$\frac{\partial M(t,c,w)}{\partial w}=0 \ , \ \frac{\partial^2 W(t,c,w)}{\partial c\partial w}=0 \ , \ \frac{\partial^2 V(t,c,w)}{\partial c\partial w}=0$$

Proof. Adding (5) and (6) yields the expression for $M(t,c_j)$:

$$M(t,c_j,w_j)=F_k(\bar{c})Z(t,c_j)+\int_{\bar{c}}^{c_H}(X(t,c,w_k)+Y(t,\bar{c},w_k))f_k(c)dc$$

From Lemma 2, $\bar{c}$ does not depend on w_j, hence $F_k(\bar{c})Z(t,c_j)$ does not depend on w_j (using $\partial Z(t,c,w)/\partial w=0$). However, w_k does depend on w_j. We need to show that

$$\int_{\bar{c}}^{c_H}(X(t,c,w_k)+Y(t,\bar{c},w_k))f_k(c)dc$$

does not depend on w_k. Adding and subtracting $Y(t,c,w_k)$ from this integral yields

$$\int_{\bar{c}}^{c_H}(Z(t,c)+Y(t,\bar{c},w_k)-Y(t,c,w_k))f_k(c)dc$$

(using again that Z does not depend on w). But $\partial^2 Y(t,c,w)/\partial c\partial w=0$ implies that $\partial Y(t,c,w)/\partial c$ is the same for all w, hence $Y(t,\bar{c},w_k)-Y(t,c,w_k)=Y(t,\bar{c},w)-Y(t,c,w)$ for any w, so the integral term does not depend on w_j as well. This proves $\partial M(t,c,w)/\partial w=0$.

For the following statement, taking derivative of (5) with respect to w_j (and noting that the derivatives of X and Y do not depend on c) yields

$$\frac{\partial W(t,c_j,w_j)}{\partial w_j}=F_k(\bar{c})\frac{\partial X(t,c,w_j)}{\partial w_j}+\int_{\bar{c}}^{c_H}\frac{\partial X(t,c,w_k)}{\partial w_k}\frac{\partial w_k}{\partial w_j}f_k(c)dc \tag{13}$$

where we used that $\bar{c}$ does not depend on w_j. Now, since $\bar{c}$ is not affected by the wage, the implicit function theorem on the expression for w_k in Lemma 2 yields

$$\begin{aligned}\frac{\partial w_k}{\partial w_j} &= \frac{\frac{\partial Y(t,c,w_j)}{\partial w_j} - \frac{\partial X(t,c,w_j)}{\partial w_j}}{\frac{\partial Y(t,c,w_k)}{\partial w_k} - \frac{\partial X(t,c,w_k)}{\partial w_k}} \\ &= \frac{\frac{\partial X(t,c,w_j)}{\partial w_j}}{\frac{\partial X(t,c,w_k)}{\partial w_k}}\end{aligned}$$

where the second equality used $\partial Y(t,c,w)/\partial w = -\partial X(t,c,w)/\partial w$. Plugging this expression into (13) yields

$$\begin{aligned}\frac{\partial W(t,c_j,w_j)}{\partial w_j} &= F_k(\bar{c})\frac{\partial X(t,c,w_j)}{\partial w_j} + \int_{\bar{c}}^{c_H} \frac{\partial X(t,c,w_j)}{\partial w_j} f_k(c)dc \\ &= F_k(\bar{c})\frac{\partial X(t,c,w_j)}{\partial w_j} + (1-F_k(\bar{c}))\frac{\partial X(t,c,w_j)}{\partial w_j} \\ &= \frac{\partial X(t,c,w_j)}{\partial w_j}\end{aligned}$$

Since $\partial X(t,c,w_j)/\partial w_j$ does not depend on c, taking the derivative of $W(t,c_j,w_j)$ with respect to c_j yields the claim.

A similar argument yields

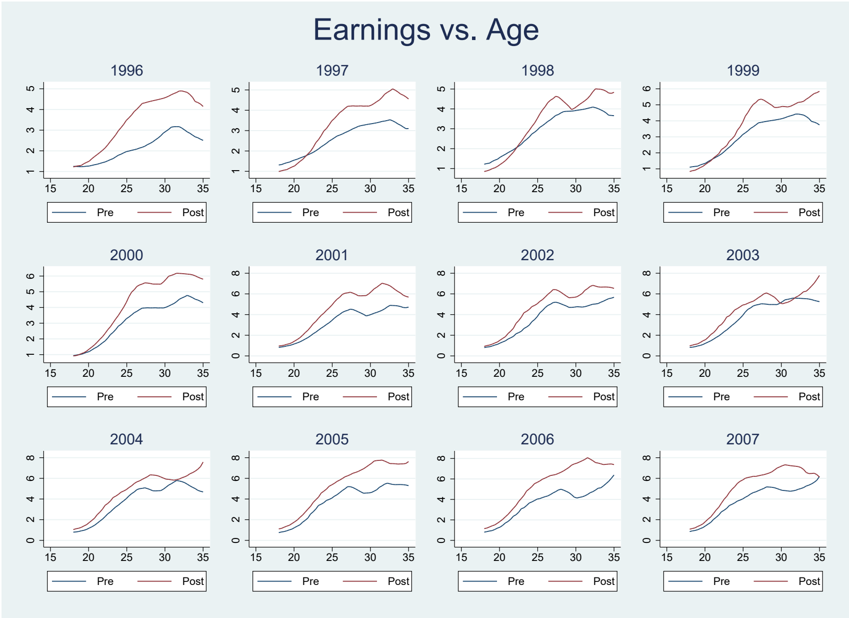
$$\frac{\partial V(t,c_j,w_j)}{\partial w_j} = \frac{\partial Y(t,c,w_j)}{\partial w_j}$$

and taking the derivative of $V(t,c_j,w_j)$ with respect to c_j yields the claim.

$\square$

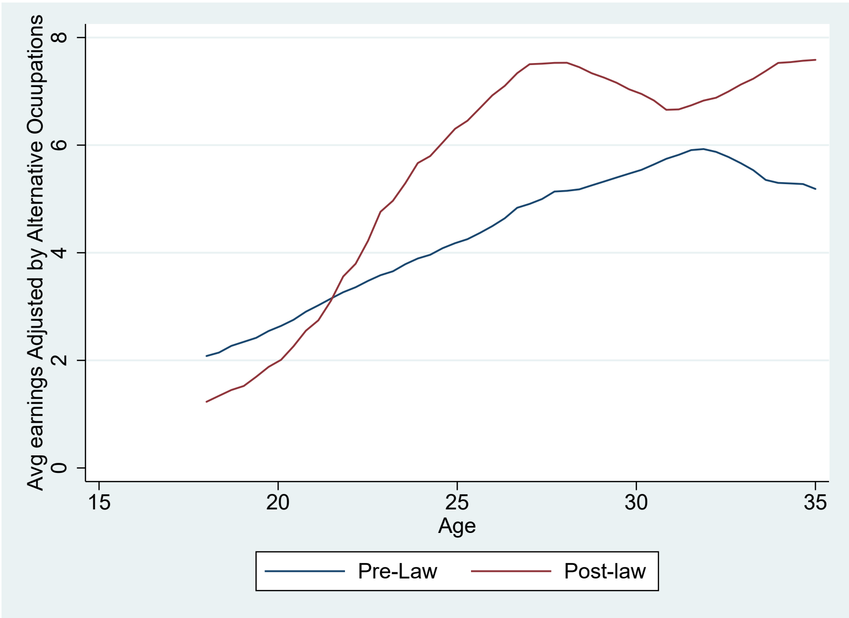
B Other Figures

Figure A1: Wages - Pre-act vs. Post-act: Several Years



NOTES: Figure displays the age-earnings profiles for several years. All graphs compare the profiles of the two years before ($t-1$ and $t-2$) and two years after ($t+1$ and $t+2$) the baseline (t).

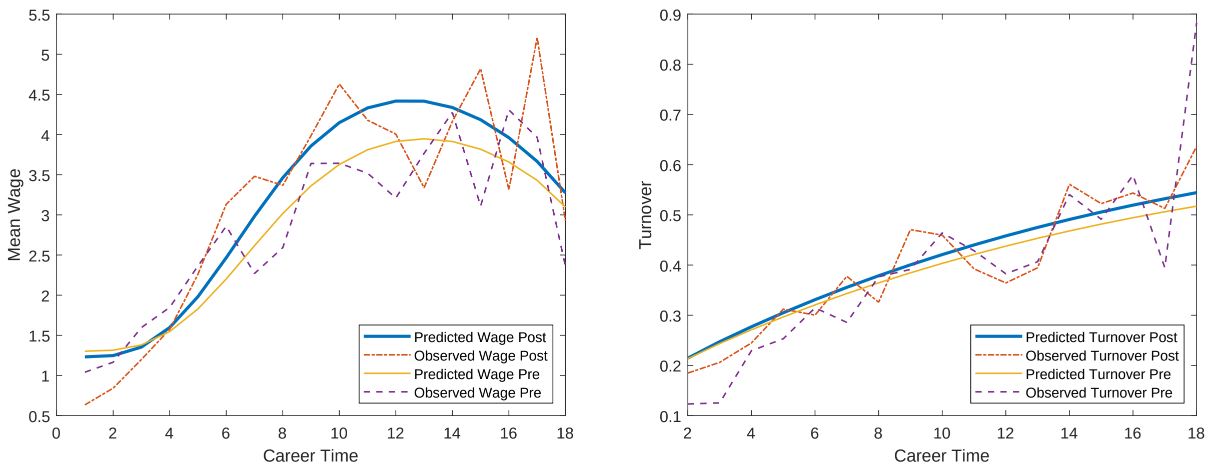
Figure A2: Wages - Pre-act vs. Post-act



NOTES: Figure displays the local polynomial fits of earnings on age. Pre-act includes the years of 1997 and post-act includes 1999 and 2000. Earnings are in Brazilian Reais of 1995. We use the variation in the earnings of similar occupations to deflate the players earnings.

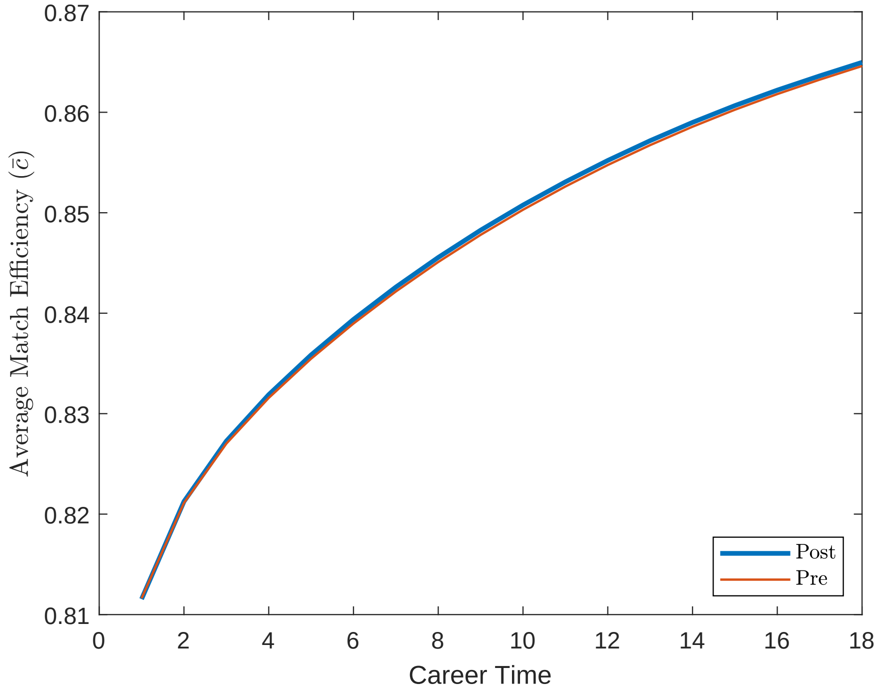
Figure A3: Wages and Turnover: Alternative ϕ

(a) Wages (b) Turnover



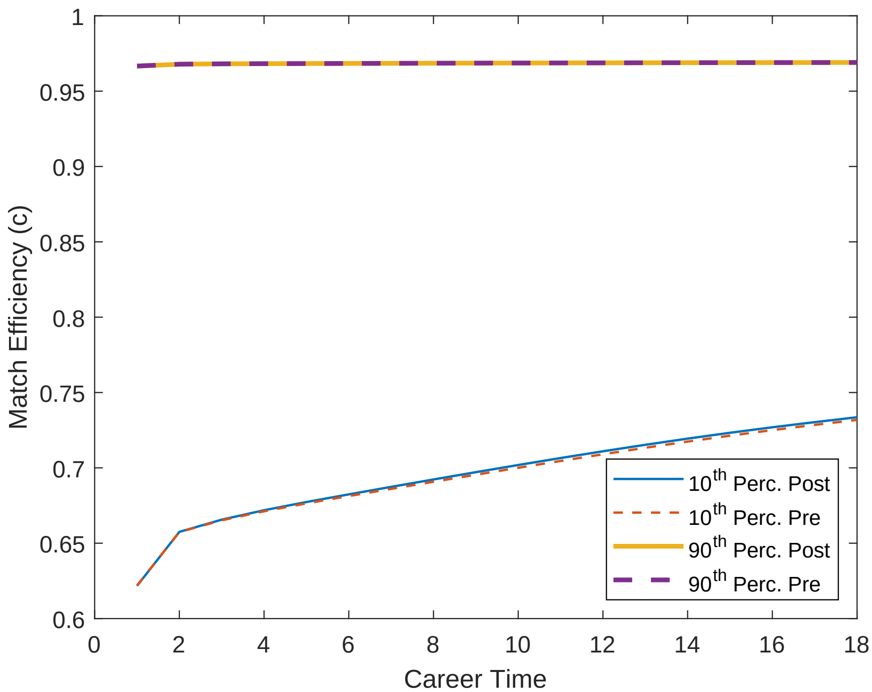
NOTES: Observed and fitted model wages (Panel a) and turnovers (Panel b). Observed data from RAIS. Average wages an turnovers in the data calculated for the years 1996 and 1997 (pre) and 1999 and 2000 (post). $t = 1$ corresponds to $age = 18$. Observed wages are adjusted for players' individual effects, i.e., they are the (exponentiated) residuals of a log earnings regression of wages on individuals' fixed effects. Turnover is calculated as the share of players moving clubs from career year $t-1$ to t. In the pre-act period, $\phi \approx 0.07$.

Figure A4: Average Match Efficiency: Alternative ϕ



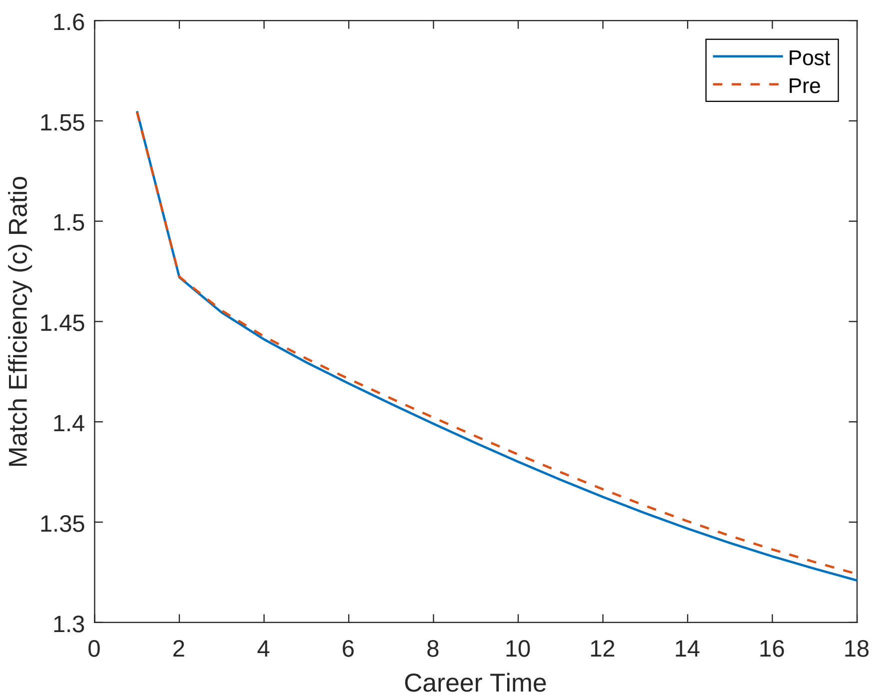
NOTES: Average match efficiency from the model in the pre- and post-act periods. $t = 1$ corresponds to $age = 18$. Average match efficiency is calculated as the average value of c at every point in time. In the pre-act period, $\phi \approx 0.07$

Figure A5: Match Efficiency Percentiles



NOTES: Figure displays the 10^{th} and the 90^{th} percentiles of the match efficiency distribution (c) in the pre- and post-act periods arising from the model. $t = 1$ corresponds to $age = 18$. In the pre-act period, $\phi \approx 0.10$.

Figure A6: Match Efficiency Percentile Ratios ($90^{th}/10^{th}$)



NOTES: Figure displays the ratio of the 90^{th} to the 10^{th} percentiles of the match efficiency distribution (c) in the pre- and post-act periods arising from the model. $t = 1$ corresponds to $age = 18$. In the pre-act period, $\phi \approx 0.10$.

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