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The Macro Impact of Noncompete Contracts

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The Macro Impact of Noncompete Contracts*

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Abstract

This paper studies the macro impact of noncompete employment contracts, assessing the trade-off between restricting worker mobility and encouraging firm investment. I develop an on-the-job search model in which firms and workers sign dynamic wage contracts with noncompete clauses and firms invest in their worker's general human capital. The incumbent employers use noncompete clauses to enforce buyout payments when their workers depart, ultimately extracting rent from future employers. The model implies that this rent extraction is socially excessive and restrictions on these clauses can improve efficiency. I quantitatively evaluate the model in the managerial labor market, using a novel dataset of executive employment contracts. I find that the optimal restriction on noncompete duration is close to a ban.

Keywords: On-the-job search, noncompete contract, dynamic contract, labor reallocation, investment holdup

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1 Introduction

Noncompete employment contracts, agreements that prohibit employees from joining competing firms for some duration, are prevalent in the U.S. labor market. About 64% of executives employed in publicly listed firms have signed noncompete contracts. These arrangements have permeated into broader labor markets. A survey conducted by Prescott, Bishara, and Starr (2016) indicates that about 30 million (roughly 18% of the country's workforce) are subject to such constraints. The anticompetitive effects of such contracts are concerning: restricted labor mobility precludes reallocation of workers to more productive employment and inhibits the entry of new firms.[1] Employers, conversely, argue that noncompete contracts offer the protection they need to carry out investments. The disagreement over the merits of noncompete contracts has manifested itself in the disparate legal landscape across the country: many states take a permissive stance; others, notably California, ban noncompete contracts altogether. Recent attempts at legal reform, modeled after the California noncompete law, have been unsuccessful.[2]

This paper assesses the macro impact of noncompete contracts, considering the beneficial effects of encouraging firm investments and the harmful effects of restricting worker mobility. Despite the two opposing effects being well documented in empirical studies, their overall effect is unexamined.[3] While many theoretical inquiries investigate similar issues (Acemoglu (1997), Moen and Rosen (2004), Marimon and Quadrini (2011), Heggedal, Moen, and Preugschat (2017), and Cooley, Marimon, and Quadrini (2018)), they are unfit for understanding the incentives of noncompete contracts and, if private parties willingly enter into these contracts, whether there are social gains from interfering in them. Further, the lack of comprehensive contract data poses a challenge to disciplining quantitative assessment.

To this end, I develop an on-the-job search model in which firms optimally design dynamic wage contracts with noncompete clauses. As in the model by Postel-Vinay and Robin (2002) concerning labor mobility, workers search on the job and form matches with potential new employers who attempt to poach them from their incumbent employers. While adopting

[1] The White House (2016) and The U.S. Department of Treasury (2016) identify noncompete contracts as a likely cause for the declining labor market fluidity, stagnant wage growth, and declining business dynamism observed in the U.S. (see Davis and Haltiwanger (2014)).

[2] These attempts include perennial legislative proposals in Massachusetts to restrict the use of noncompete contracts. For example, the state filed a bill in 2017 that proposed to cap noncompete duration at one year. Details can be found at https://malegislature.gov/Bills/190/SD1578. In addition, the Obama Administration proposed a nationwide ban. Details can be found at https://obamawhitehouse.archives.gov/sites/default/files/competition/noncompetes-calltoaction-final.pdf.

[3] Many empirical papers document both effects. These include Garmaise (2009), Marx, Strumsky, and Fleming (2009), Starr, Balasubramanian, and Sakakibara (2017), Jeffers (2018), and Lavetti, Simon, and White (2019).

their dynamic wage contract as an important way for firms to retain workers, I expand the contract to include (1) a *noncompete clause* restricting the worker's outside employment, and (2) a *buyout payment* from the worker to be released from the clause. While the buyout payment arrangement is similar to the damage payment contract in Aghion and Bolton (1987), the noncompete arrangement arises naturally here: since workers would renege on the buyout payment, the noncompete clause is essential for firms to enforce the payment.

To understand the efficiency implications, I first show that the contract between the incumbent firm and the worker is *bilateral efficient*: given the firm's commitment to the contract and risk-neutral preferences, the firm aligns the worker's incentive by costlessly backloading the wage to retain the worker. However, the additional clauses adversely affect future employers that subsequently contract with the worker, resulting in a *contracting externality*. Together, the incumbent firm and the worker act like a monopolist toward entrant employers. The buyout payment, in addition to the wage payment, allows them to charge a monopoly price to new firms poaching the worker. Crucially, assuming that the new match quality is private information to the poaching firms, the buyout payment cannot be contingent on it. Hence, noncompete buyouts distort the allocation of workers and inhibit the entry of new firms.

I also introduce endogenous investment in the worker's human capital, which is transferable to future employment. To understand the investment incentive, notice that the presence of a search friction breaks the insights of the classical analysis by Becker (1962) in a perfectly competitive labor market. There, because human capital is perfectly priced externally, the problem reduces to bilateral bargaining between the firm and the worker about who pays for the investment. In contrast, in my model, since they are facing an imperfectly competitive external labor market, the problem is one among three parties. Future employers also have some monopsony power and can partially appropriate the payoff; therefore, a positive *investment externality* on entrants appears. While the incumbent firm pays for the cost, investment is prone to holdup. Consequently, noncompete buyouts allow the incumbent employers to partially capture the external payoff and undertake more investment.

Noncompete contracts generate what I call an *investment-reallocation trade-off*: a longer noncompete duration alleviates the holdup problem due to the investment externality but aggravates the distortion in the allocation of workers due to the contracting externality. The private-optimal contract, despite being bilaterally efficient, is socially inefficient along this trade-off. Recall that the incumbent firm and the worker maximize their bilateral joint value, disregarding the value of new entrants. Compared to a planner who aims to maximize social value, including that of new entrants, the private parties set an excessively long duration and overextract rent, even after accounting for the investment benefits. Theoretically, restricting the duration of noncompete contracts can improve efficiency. In fact, the social optimum can be implemented by capping the noncompete duration.

To fit the institutional environment and the data, the model is augmented structurally by (1) the noncompete legal regime in the form of an enforcement probability, and (2) a fixed noncompete contracting cost. Together, they generate binary choices of whether to use a noncompete clause. Further, the more likely the enforcement, the larger the proportion of firms and workers signing noncompete clauses.

To assess the theoretical results, I assembled a novel dataset on noncompete arrangements for executives in U.S. public-listed firms. I scrapped the data from contracts disclosed in company filings using machine-learning and textual-analysis tools; I merged this data with a rich array of datasets on executives and firms. Applying the model to the managerial labor market, I find that the empirical patterns confirm the model's predictions. Overall, 64% of the executives in the data are subject to noncompete clauses. There is substantial cross-state variation: the percentage of executives with noncompete contracts is 38% higher in Florida compared to California.

The data suggests that noncompete arrangements generate sizable distortion in executive mobility and relatively mild effects on firm investment. First, executives with a noncompete clause are around 0.9% annually less likely to separate from their firms. Second, when the percentage of executives subject to noncompete clauses increases by 1%, investment in intangible capital increases by 0.012% annually. The same effect is absent for physical capital investment. The magnitudes of mobility restriction and investment encouragement are higher in states with stronger enforcement.

I also provide new evidence on how noncompete clauses interact with wage backloading. In the model, when workers sign a noncompete contract, their wage is less backloaded because their employers need to bid less against outside offers for retention in the future. To be precise, the worker starts with a higher wage but experiences lower wage growth. I find that the starting wage for executives with a noncompete clause is 13% (or $130k in 2010 prices) higher than for executives without such a clause, but their wage grows 1% less annually over the first ten years of tenure.

In the quantitative analysis, I calibrate the model to match the aforementioned moments and others. In particular, I identify the parameters crucial to tracing out the investment-reallocation trade-off directly from moments related to mobility restriction and investment response. Quantitatively, the optimal cap on noncompete duration is 0.6 years, much lower than the private-optimal level of 1.6 years found in the data. In a full-enforcement regime that resembles Florida and Massachusetts, the optimal cap and a ban result in welfare gains measured in steady-state output of 4.8% and 2.3%, respectively, relative to the laissez-faire equilibrium outcome. In low-enforcement states like California, the optimal cap and a ban results in welfare gains of within 1%. If noncompete arrangements were banned altogether, the outcome would be fairly close to the social optimum.

1.1 Related Literature

This paper extends the on-the-job search literature along the lines of Postel-Vinay and Robin (2002), Cahuc, Postel-Vinay, and Robin (2006), and Postel-Vinay and Turon (2010) in several dimensions. First, I modify their perfect-information assumption regarding match quality to asymmetric information. To preserve the Bertrand competition outcome for workers, I use an English auction instead of their take-it-or-leave-it offers. Second, I enrich their dynamic wage contract with noncompete clauses. This extension generates the effect of damage payments as barriers to entry as in Aghion and Bolton (1987). Third, I introduce endogenous investment in human capital while maintaining the tractability of the model.

This paper contributes to the theoretical literature on contract design under worker limited commitment (Diamond and Maskin (1979), Marimon and Quadrini (2011), and Cooley et al. (2018)), in particular concerning the spillover effects of on-the-job general human capital accumulation (Acemoglu (1997), Acemoglu and Pischke (1999), Moen and Rosen (2004), Lentz and Roys (2015), and Heggedal et al. (2017)). This is the first paper to rationalize the design of noncompete clauses as an optimal contract among private parties and to study the aggregate welfare of regulating these contracts. The theoretical insight here departs from the classical analysis by Becker (1962) in a perfectly competitive labor market, yet it recasts the optimal patent duration going back to Nordhaus (1967) in a monopsonistic labor contract setting.

Relating to empirical studies on noncompete contracts, this paper is the first to use a large dataset of actual contracts with information on both whether a noncompete clause is included and the duration. Existing studies have relied on exploring exogenous variations in the legal enforceability over time (Garmaise (2009), Marx et al. (2009), Starr (2016), Starr et al. (2017), and Jeffers (2018)), except for Lavetti et al. (2019), who surveyed whether the physicians they study are subject to noncompete clauses. Using the contract data, I provide new evidence on the use and effects of noncompete contracts, on how the effects depend on legal enforceability, and on the effects on wage dynamics.

Finally, this paper is related to studies on competitive market forces in determining executive compensation. Frydman (2019) documents that the increasing importance of general managerial human capital has led to higher executive mobility and compensation over time. My empirical findings suggest that outside competition affects also the structure of executive compensation, confirming concerns about retention in dynamic compensation design (Clementi, Cooley, and Wang (2006)).

The rest of the paper is organized as follows. Section 2 introduces the model. Section 3 characterizes the equilibrium and studies the optimal noncompete policy. Section 4 presents empirical evidence in the managerial labor market. In Section 5, I calibrate the model and conduct policy evaluations. Section 6 concludes.

2 Model

This section lays out an on-the-job search model built on Postel-Vinay and Robin (2002), in which firms and workers design dynamic wage contracts with noncompete clauses and the firms invest in their worker's general human capital. The goal is to capture the trade-off between labor mobility and firm investment.

2.1 Environment

Time is continuous and infinite, $t \in [0,\infty)$. The economy is populated by a measure-one of over-lapping generations of workers with an exponential lifetime. The workers are employed by a corresponding continuum of firms.[4] Each worker dies with Poisson intensity δ, upon which the firm also exits, and is replaced by a newborn worker matched to a newborn firm. Agents are risk-neutral. Hence, risk-sharing concerns between firms and workers are absent. Agents discount the future at rate ρ. Therefore, the effective discount rate is $r = \rho + \delta$.

The firm-worker matches are heterogeneous in their match productivity, z_t, at time t. A firm-worker match produces a flow output equal to its productivity, $y_t = z_t$.[5] The initial productivity of a newborn match is drawn according to the cumulative distribution function $H(\cdot)$. The productivity evolves according to

$$d\log(z_t) = \mu_t dt + \sigma dB_t,$$

where B_t is a standard Brownian motion. The drift μ_t is an endogenous investment variable chosen by the firm at a cost of $c(\mu_t)$.[6] The cost function $c(\cdot)$ is strictly increasing, twice

[4] Firms in the model are single-worker firms. When mapping the model to firm-level data, I define a firm as a collection of linearly additive firm-worker matches.

[5] I retain a simple production structure to focus on the contracting problem. In addition, I eliminate the possibilities of unemployment for workers and replacement of workers by firms.

[6] Bilal, Engbom, Mongey, and Violante (2019) also develop a continuous-time version of the on-the-job model by Postel-Vinay and Robin (2002), where the match productivity follows a Brownian motion. One difference here is that the drift representing the firm's investment is endogenous.

continuously differentiable, and convex.

The labor market is frictional. Workers are matched to an entrant firm at Poisson intensity λ. The entrant match has productivity $z'_t = z_t\theta_t$, which is multiplicative of the incumbent productivity z_t and the entrant match quality θ_t.[7] The entrant match quality, θ_t, is drawn according to the cumulative distribution function $F(\cdot)$, defined over $[\theta_m,\infty)$. The function $F(\cdot)$ is continuous, with $\theta_m < 1$ and $1 - F(1) > 0$. The investment is embodied in the worker's general human capital. When workers moves to new jobs, they take the accumulated human capital to the new employers and their incumbent employers exit. This implies that the investment undertaken by incumbent employers has a positive *investment externality* on future employers.

2.2 Information and Contract

Information. Information is asymmetric: firms do not observe each other's productivity.[8] This information friction is crucial for noncompete clauses to reduce labor mobility. Otherwise, under perfect information, agents could always engage in efficient ex post renegotiation given any ex ante contract, resulting in reallocation of workers to more productive firms.

Contract. Firms and workers enter into bilateral long-term contracts. The contract specifies the process through which employment and the corresponding transfers are determined ex post. While adopting the dynamic wage contract in Postel-Vinay and Robin (2002) as a way for firms to retain workers, I expand the contract to include: (1) a *noncompete clause* restricting the worker's outside employment; and (2) a *buyout payment* from the worker to be released from the clause.

Firms are deep-pocketed while workers are hand-to-mouth. Absent an outside offer, the transfer from the firm to the worker, i.e., the wage payment, has to be positive. However, when the worker takes a new job, he or she can make a payment to the current employer, which could be financed by the new employer. Further, firms can commit to the contract but workers cannot. In particular, workers can renege on their buyout payment obligation. To circumvent the problem of reneging, the firm uses a noncompete treat, excluding the worker from outside employment for a duration of π_t units of time. The worker together with the

[7] Alternatively, I can keep track of the workers. The worker productivity evolves according to a jump-diffusion process, $d\log(z_t) = \mu_t dt + \sigma dB_t + \theta_t I_t dN_t$, where B_t is a standard Brownian motion and N_t is a Poisson process with intensity λ. Further, θ_t is drawn from the distribution $F(\cdot)$ and I_t is an indicator function equal to 1 if the worker moves to the entrant firm and 0 otherwise.

[8] I assume two-sided information asymmetry here. However, only one-sided information asymmetry is needed as in Aghion and Bolton (1987): the entrant productivity z'_t (or, equivalently, the entrant match quality θ_t) is private information. The results do not change when the incumbent productivity z_t is also private information. A one-period example in Section C of the online appendix clarifies this point.

new employer can pay the incumbent firm to avoid the exclusion. From a property-rights perspective, the incumbent firm owns the property right to the worker's future employment during the noncompete period, which it can sell back to the worker or resell to new employers. Given that firms contract with the same worker sequentially, the poaching firms take as given the existing contract between the worker and the incumbent firm. The additional clauses adversely affect subsequent employers, resulting in a *contracting externality*.

Motivated by the institutional details, I model firms resorting to noncompete clauses as a means to achieve buyout payments. In practice, a noncompete clause quite often comes with a buyout option, either ex ante stipulated or ex post bargained, that grants the employee an option to buy out the clause.[9] Buyouts are also reflected in law.[10] Finally, noncompete arrangements avoid the controversy of enticement payment, which existed historically in the postbellum American South before the enactment of anti-enticement laws.[11]

The firm decides whether to include a noncompete clause. If it decides to include one, it incurs a fixed cost at match formation, κz, proportional to its initial match productivity with the worker z. Each worker draws a fixed, observable κ from a cumulative distribution function $\Phi(\cdot)$.[12] This cost includes legal fees and disutility that the worker suffers due to perceived restricted opportunity. It allows me to capture binary noncompete contract choice.

Noncompete law. The legal regime is represented by an enforcement probability. Namely, if a worker is bound by a noncompete clause, after an entrant firm arrives to poach the worker, with probability p the noncompete clause turns out to be enforceable and would subsequently require some buyout payment.[13]

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[9] Similar contractual arrangements exist in the market for professional soccer players. To poach a player under contract, the acquiring club needs to pay the current club a transfer fee.

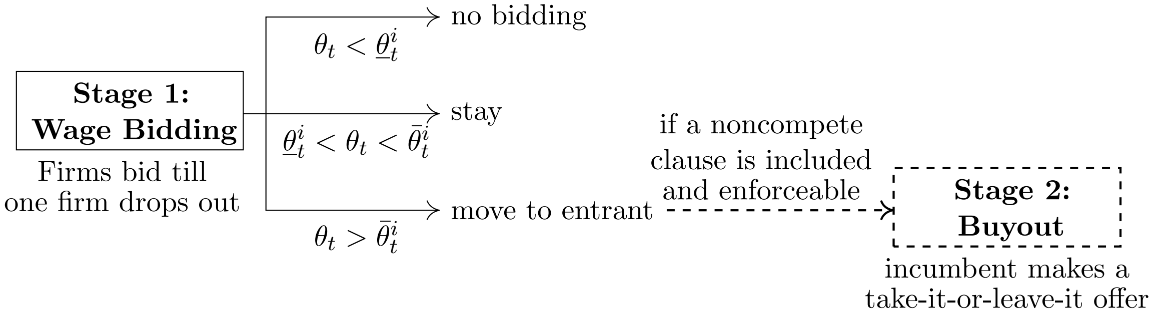
[10] Texas law requires that a noncompete contract must contain a buyout option for certain occupations. The state of New York follows the "employee choice doctrine"—the employee chooses to either have the noncompete clause enforced or have some previous compensation clawed back. For this reason, a buyout clause is sometimes called a "forfeiture-for-competition" clause. Buyouts are preferable to enforcement: the former involves a zero-sum transfer between the parties, while the latter is mere "money burning."

[11] Naidu (2010) finds that recruitment restrictions in the form of "enticement" fines in the postbellum South lowered the mobility of sharecroppers. While enticement fines have long been vestigial due to anti-enticement laws, noncompete buyouts effectively achieve the same outcome.

[12] This contracting cost structure has three useful implications. First, the cost being proportional to productivity implies that the use of noncompete clauses has no correlation with productivity, consistent with the empirical pattern in the data. Second, a contract signed at match formation will remain optimal later, simplifying the analysis. Third, given that κ is fixed for a given worker, the contract choice is persistent among job-changers. Some extent of persistence is found in the data.

[13] One could think of the enforcement probability as follows. In a state more permissive toward noncompete contracts, it is more likely that a judge will rule in favor of enforcing them.

Figure 1: Competition for workers in a two-stage game



A two-stage game. At subsequent employment time t, when a poaching firm arrives, the competition for the worker occurs in a two-stage game depicted in Figure 1. In the first stage, the incumbent and entrant firm bid for the worker in an ascending (English) auction. Firms have limited liability, implying that they can only commit to delivering to their workers a promised utility up to the entire match value. The resulting wage is denoted by $\mathcal{W} = \{w_t\}_{t\geq 0}$, where $w_t \geq 0$. If the worker is poached by the entrant firm and there is an enforceable noncompete clause, a second buyout stage ensues. The incumbent firm makes a take-it-or-leave-it offer of a buyout menu $\{\tau_t(\tilde{\pi}) : \tilde{\pi} \in [0,\pi_t]\}$, where $\tau_t(\tilde{\pi})$ is the payment required for reducing the noncompete duration from π_t to $\tilde{\pi}$.

Taken together, the contract includes the wage, as well as the noncompete clause and the corresponding buyout menu

$$\mathcal{C} = (\mathcal{W},\mathcal{M}), \text{ where } \mathcal{W} = \{w_t\}_{t\geq 0} \text{ and } \mathcal{M} = \{\pi_t,\{\tau_t(\tilde{\pi}) : \tilde{\pi} \in [0,\pi_t]\}\}_{t\geq 0}.$$

The noncompete contract choice is denoted by $i \in \{c,n\}$. If a noncompete clause is not included, $i = c$ and the extra clause is null, $\mathcal{M} = \emptyset$. Otherwise, $i = n$.

2.3 Firm's Problem

Consider the problem of a firm contracting with its worker at match formation at time 0. At time t, when a poaching firm arrives, the wage bidding outcome can be characterized by a poaching threshold: if the entrant match quality is above the threshold, the worker moves to the entrant. When a noncompete clause is not included or not enforced, the poaching threshold is denoted by $\bar{\theta}_t^c$; otherwise, it is denoted by $\bar{\theta}_t^n$. Correspondingly, depending on whether a noncompete clause is used, the worker has a job-to-job transition rate

$$\begin{aligned}\eta_t^c &= \lambda\big(1 - F\big(\bar{\theta}_t^c\big)\big)\\ \eta_t^n &= \lambda p\big(1 - F\big(\bar{\theta}_t^n\big)\big) + \lambda(1-p)\big(1 - F\big(\bar{\theta}_t^c\big)\big).\end{aligned}$$

The match has a stopping time T, which occurs when an entrant with a match quality above the poaching threshold arrives for the first time, $\theta_T > \bar{\theta}_T^i$.

Following the long-term contract approach, the cost of a contract to the firm can be summarized by the level of utility promised to the worker. When bidding for the worker, the incumbent firm and the entrant firm compete in utility terms. Notice that, given the bidding protocol, the incumbent will bid up to its match value. Therefore, in order to poach the worker, the entrant firm needs to deliver to the worker a promised utility fully compensating the value of the current match destroyed. Let $J^i(z)$ denote the joint value of a firm-worker match with productivity z and noncompete contract choice i. At employment termination time T, the worker receives a promised utility of $J^i(z_T)$ from the entrant firm. To deliver the initial promised utility U_0, the firm faces the following promise-keeping (PK) constraint:

$$\mathbb{E}\left[\int_0^T e^{-rt} w_t dt + e^{-rT} J^i(z_T)\right] \geq U_0. \tag{1}$$

The firm chooses whether to include a noncompete clause, taking into account the contracting cost

$$\max\{V^c(z_0,U_0), V^n(z_0,U_0) - \kappa z_0\},$$

where $V^i(z,U)$ is the value function of the firm with productivity z, promised utility U to the worker, and contract choice i. If a noncompete clause is not included, the firm chooses the streams of wage payments $\mathcal{W}$ and the investments $\boldsymbol{\mu} = \{\mu_t\}_{t\geq 0}$ to maximize its value

$$V^c(z_0,U_0) = \max_{\mathcal{W},\boldsymbol{\mu}} \mathbb{E}\left[\int_0^T e^{-rt}(z_t - c(\mu_t)z_t - w_t)dt\right], \tag{2}$$

subject to the PK constraint (1).

If a noncompete clause is included, apart from the wage payments and the investments, the firm chooses the noncompete duration and the buyout menu

$$V^n(z_0,U_0) = \max_{\mathcal{W},\mathcal{M},\boldsymbol{\mu}} \mathbb{E}\left[\int_0^T e^{-rt}(z_t - c(\mu_t)z_t - w_t)dt + e^{-rT}\tau_T(\tilde{\pi}_T(\theta_T))\right], \tag{3}$$

subject to the PK constraint (1), as well as the entrant firm's incentive-compatibility (IC) and individual-rationality (IR) constraints

$$\tilde{\pi}_t(\theta_t) = \underset{\tilde{\pi}\in[0,\pi_t]}{\operatorname{argmax}}\, e^{-r\tilde{\pi}} J^n(z_t\theta_t) - \tau_t(\tilde{\pi}),\, \forall \theta_t \geq \bar{\theta}_t^n \tag{4}$$

$$e^{-r\tilde{\pi}_t(\theta_t)} J^n(z_t\theta_t) - J^n(z_t) - \tau_t(\tilde{\pi}_t(\theta_t)) \geq 0,\, \forall \theta_t \geq \bar{\theta}_t^n. \tag{5}$$

In equation (2), the flow payoff to the firm is output net of investment cost and wage payment. If investment $\boldsymbol{\mu}$ were exogenous, the wage setting $\mathcal{W}$ is identical to the one in Postel-Vinay and Robin (2002). Compared to equation (2), equation (3) includes an extra term: the buyout payment at match termination. The IC constraint (4) captures that, in the buyout stage, the entrant firm chooses optimally from the buyout menu to reduce the noncompete duration from π_t to $\tilde{\pi}_t(\theta_t)$. Note that, with a production delay of duration $\tilde{\pi}$, its match value reduces to $e^{-r\tilde{\pi}_t(\theta_t)}$ fraction.[14] Moreover, it is without loss of generality to assume that the entrant match also includes a noncompete clause. Combining the buyout payment $\tau_t(\tilde{\pi}_t(\theta_t))$ and the promised utility $J^n(z_t)$ to the worker, I obtain the IR constraint (5) for the entrant firm.

2.4 Bilateral Joint Maximization Problem

The structure of the economy allows me to simplify the firm's problem. Due to the firm's commitment and the risk-neutral preferences, the firm is able to align the worker's incentive by costlessly backloading the wage payment to retain the worker when an outside opportunity arrives. One can incorporate the PK constraint (1) into the firm's objective in (2) and (3). The bilateral joint value is obtained by discounting the joint flow payoff.[15] Formally, in the following lemma, the firm's optimal policies always maximize its joint value with the worker.

Lemma 1 (Bilateral Efficiency)**.** *The contract maximizes the bilateral joint value between the firm and the worker.*

The bilateral efficiency result implies that the firm's problem can be separated into two parts. First, the firm-worker match chooses the clause $\mathcal{M}$ and investment $\boldsymbol{\mu}$ to maximize the joint value. It does not matter whether the firm or the worker designs the contract and has to pay any associated cost, because they would make the same choice. This argument also applies for the investment decision. Second, the firm chooses wage $\mathcal{W}$ to align the worker's incentive and split the maximized joint value. The first part is a static rent-extraction problem and the second part is a dynamic wage-setting problem.

[14] Details for this calculation are provided in the online appendix B.1.

[15] One restriction on the parameters is needed: the arrival rate of outside opportunity λ is small such that the wage non-negativity constraint, $w_t \geq 0$, never binds. Offsetting forces such as upward movement in productivity help to ensure that the wage non-negativity constraint is slack.

Recursive formulation. I state the joint maximization problem recursively for convenience. The firm-worker match decides whether to include a noncompete clause,

$$\max\{J^c(z),J^n(z)-\kappa z\}, \tag{6}$$

where the noncompete contract choice is denoted by $\mathbb{I}(z,\kappa)\in\{c,n\}$.

Without a noncompete clause, the joint value function $J^c(z)$ follows the Hamilton-Jacobi-Bellman (HJB) equation

$$rJ^c(z)=\max_{\mu}\; z-c(\mu)z+\mu zJ^c_z(z)+\frac{1}{2}\sigma^2z^2J^c_{zz}(z). \tag{7}$$

The poaching threshold rule and investment decision are denoted by $\bar{\theta}^c(z)$ and $\mu^c(z)$.

While with a noncompete clause, the joint value function $J^n(z)$ follows the HJB equation

$$rJ^n(z)=\max_{\mathcal{M},\mu}\; z-c(\mu)z+\mu zJ^n_z(z)+\frac{1}{2}\sigma^2z^2J^n_{zz}(z)+\lambda p\int_{\bar{\theta}^n}^{\infty}\tau(\tilde{\pi}(\theta)|z)dF(\theta), \tag{8}$$

subject to the entrant firm's IC and IR constraints (4) and (5). The clause is denoted recursively by $\mathcal{M}(z)=\{\pi(z),\{\tau(\tilde{\pi}|z):\tilde{\pi}\in[0,\pi(z)]\}\}$. The poaching threshold rule and investment decision are denoted by $\bar{\theta}^n(z)$ and $\mu^n(z)$.

In equation (7), the first two terms on the right-hand side are the flow of output net of investment cost. The next two terms capture the change in the joint value due to productivity innovations. In equation (8), the last extra term reveals the incentive for noncompete contract design: the incumbent firm and the worker together act like a monopolist toward future entrants. They choose the noncompete buyout to maximize the expected rent extracted from future entrants. The arrangement allows the firm to claim ownership in the worker's future employment during the noncompete period and resell it to entrants.

2.5 Dynamic Wage Setting

Since the agents are risk neutral, the wage can be indeterminate. To uniquely pin the wage down, I assume a constant wage contract following Postel-Vinay and Robin (2002). Namely, the wage stays constant unless the incumbent firm needs to bid it up to retain the worker.[16] When newborn workers and firms enter the economy, they engage in Nash bargaining to determine the initial promised utility, where the worker's bargaining weight is β. Given that

[16] A constant wage contract can be justified by arbitrarily small amount of risk aversion on the worker side. Any amount of worker risk aversion implies that the optimal contract offers constant wage to insure worker's risk. When risk aversion vanishes, the constant wage contract still obtains.

the outside option for both parties is zero, the firm and the worker split the maximized joint value according to their bargaining weights. Let $U^i(z,w)$ denote the value function of a worker employed at productivity z, wage w, and contract i. To deliver the initial promised utility, the starting wage w_0^i, $\forall i \in \{c,n\}$, satisfies

$$U^i\big(z_0,w_0^i\big) = U_0 = \beta \max\{J^c(z),J^n(z) - \kappa z\}. \tag{9}$$

To set the wage, the firm accounts for three possible outcomes of wage bidding. First, if the entrant match value is below the current promised utility, no bidding takes place. Second, if the entrant can offer more than the current promised utility but fails to poach the worker, the incumbent firm increases the wage to match the outside offer. Third, if the entrant is able to poach the worker, the incumbent match is destroyed. I obtain a wage bidding threshold denoted by $\theta^c(z,w)$ if without a noncompete clause, $\theta^n(z,w)$ if a noncompete clause exists and is enforced, and $\theta^u(z,w)$ if the clause is not enforced. The thresholds satisfy

$$U^c(z,w) = J^c(z\underline{\theta}^c(z,w)) \quad \text{and} \quad U^n(z,w) = J^n(z\underline{\theta}^u(z,w)) = e^{-r\pi}J^n(z\underline{\theta}^n(z,w)). \tag{10}$$

Given the firm's limited liability, the contract optimally embeds firm-initiated wage renegotiation.[17] Specifically, when a large negative productivity shock occurs, the promised utility to the worker may exceed the joint match value, resulting in negative firm value. Under such circumstances, the firm reduces the promised utility just to the level of the joint match value by resetting the wage. Hence I obtain an upper bound on wage, $\bar{w}^i(z)$, $\forall i \in \{c,n\}$, characterized by the following boundary conditions:

$$U^i\big(z,\bar{w}^i(z)\big) = J^i(z) \quad \text{and} \quad U_z^i\big(z,\bar{w}^i(z)\big) = J_z^i(z). \tag{11}$$

Without a noncompete clause, the worker's value function $U^c(z,w)$ follows the HJB equation: $\forall w \in [0,\bar{w}^c(z)]$,

$$\begin{aligned}(r+\lambda)U^c(z,w) = {} & w + \mu^c z U_z^c(z,w) + \frac{1}{2}\sigma^2 z^2 U_{zz}^c(z,w) \\ & + \lambda\left\{F(\underline{\theta}^c(z,w))U^c(z,w) + \int_{\underline{\theta}^c(z,w)}^{\bar{\theta}^c} J^c(z\theta)dF(\theta) + \big(1 - F\big(\bar{\theta}^c\big)\big)J^c(z)\right\}.\end{aligned} \tag{12}$$

While with a noncompete clause, the worker's value function $U^n(z,w)$ follows the HJB equa-

[17] The wage renegotiation mechanism follows Postel-Vinay and Turon (2010).Worker-initiated wage renegotiation is unnecessary here, since the worker's value never falls below their zero.

tion: $\forall w \in [0,\bar{w}^n(z)]$,

$$(r+\lambda)U^n(z,w) = w + \mu^n z U^n_z(z,w) + \frac{1}{2}\sigma^2 z^2 U^n_{zz}(z,w) \tag{13}$$
$$+ \lambda p\left\{ F(\underline{\theta}^n(z,w))U^n(z,w) + \int_{\underline{\theta}^n(z,w)}^{\bar{\theta}^n} e^{-r\pi} J^n(z\theta)dF(\theta) + \big(1 - F\big(\bar{\theta}^n\big)\big)J^n(z) \right\}$$
$$+ \lambda(1-p)\left\{ F(\underline{\theta}^u(z,w))U^n(z,w) + \int_{\underline{\theta}^u(z,w)}^{\bar{\theta}^c} J^n(z\theta)dF(\theta) + \big(1 - F\big(\bar{\theta}^c\big)\big)J^n(z) \right\}.$$

In equation (12), the first term on the right-hand side is the wage flow. The second and third terms capture the change in the value function due to match productivity innovations. The terms inside the large bracket specify revised utility under the three possible outcomes of wage bidding: no bidding, bidding up wage, and match separation, respectively. In equation (13), the terms involving wage bidding distinguish two cases depending on whether the noncompete clause turns out to be enforceable.

2.6 Equilibrium Definition

The measure of firm-worker matches with productivity $z_t \le z$ and contract $i \in \{c,n\}$ at time t is denoted by $G(z,i,t)$. The corresponding density function, $g(z,i,t) \equiv G_z(z,i,t)$, follows the Kolmogorov Forward (KF) equation:

$$g_t(z,i,t) = -\mu^i z g_z(z,i,t) + \frac{1}{2}\sigma^2 z^2 g_{zz}(z,i,t) + \delta\left[h(z)\int \mathbb{1}_{\{\mathbb{I}(z,\kappa)=i\}} d\Psi(\kappa) - g(z,i,t)\right] \tag{14}$$
$$+ \lambda(1-p)\int_{\bar{\theta}^c}^{\infty}\left[g\Big(\frac{z}{\theta},i,t\Big) - g(z,i,t)\right]dF(\theta) + \lambda p\int_{\bar{\theta}^i}^{\infty}\left[g\Big(\frac{z}{\theta},i,t\Big) - g(z,i,t)\right]dF(\theta).$$

The first two terms on the right-hand side capture the match productivity process. The third term is due to exogenous entry and exit. The second line describes the job-to-job transitions depending on whether a noncompete clause is included and enforced.

Definition 1 (Equilibrium)**.** An equilibrium consists of contract choice $\{\mathbb{I}(z,\kappa),\mathcal{M}(z)\}$, for contract choice $i \in \{c,n\}$, the respective joint value function $J^i(z)$, investment and poaching threshold rules $\{\mu^i(z),\bar{\theta}^i(z)\}$, worker's value function $\{U^i(z,w) : \forall w \in [0,\bar{w}^i(z)]\}$, and initial wage rule w^i_0, wage-bidding threshold rules $\{\underline{\theta}^i(z,w) : i \in \{c,n,u\}\}$, and distribution $G(z,i,t)$, such that, given the initial distribution $G(z,i,0)$,

(i) the contract choice and the corresponding investment and poaching threshold rules, together with the joint value functions, solve problem (6);

(ii) the initial wage and wage-bidding threshold rules, together with the worker's value functions, satisfy the initial wage setting (9) and equations (12) and (13); and

(iii) the distribution follows the KF equation (14) .

3 Equilibrium Characterization

In this section, I first characterize the equilibrium, including the use of noncompete clauses and the effects of such clauses on worker mobility, firms investment, and wage backloading. I then derive some comparative statics with respect to the noncompete legal regime, corresponding to the cross-state pattern in the empirical and quantitative sections. Finally, I study the optimal noncompete policy.

To characterize the equilibrium, I first solve the joint maximization problem concerning the noncompete contract choice and investment. Second, I solve for the dynamic wage setting problem. Before proceeding, to simplify the problem, I show that the joint value functions are linear in productivity.

Lemma 2 (Linearity)**.** *The joint value functions* $J^i(z) = j^i z$, $\forall i \in \{c,n\}$, *where*

$$j^c = \frac{1 - c(\mu^c)}{r - \mu^c} \quad \textit{and} \quad j^n = \frac{1 - c(\mu^n)}{r - \mu^n - \lambda p\big(\bar{\theta}^n - 1\big)\big(1 - F\big(\bar{\theta}^n\big)\big)}. \tag{15}$$

Inspecting the HJB equations (7) and (8), one can see that the production output and the investment cost are scaled by z and the outside match quality θ is independent of z. It follows that all quantity variables are independent of z while all price variables are linear in z. That is, $\pi(z) = \pi$, $\bar{\theta}^i(z) = \bar{\theta}^i$, and $\mu^i(z) = \mu^i$, $\forall i \in \{c,n\}$. Hence, the joint value function $J^i(z)$ is linear in z.

3.1 Use of Noncompete Clauses

Assumption 1 (Monotone Hazard Rate)**.** *The hazard rate* $\frac{f(\theta)}{1-F(\theta)}$ *is increasing in* θ*.*

This assumption plays the standard role in monopoly pricing. It ensures that, when designing the noncompete clause, a unique poaching threshold (or, equivalently, a unique noncompete duration) exists.

Proposition 1 (Private-Optimal Contract)**.** *Under Assumption 1, the firm-worker match* *includes a noncompete clause if the contracting cost is below* $\bar{\kappa} = j^n - j^c$*:*

$$\mathbb{I}(z,\kappa) = \begin{cases} c, & \text{if } \kappa > \bar{\kappa} \\ n, & \text{if } \kappa \leq \bar{\kappa} \end{cases}.$$

If a noncompete clause is not included or enforced, the poaching threshold is

$$\bar{\theta}^c = 1. \tag{16}$$

Otherwise, the poaching threshold is characterized by

$$\bar{\theta}^n = 1 + \frac{1 - F\big(\bar{\theta}^n\big)}{f\big(\bar{\theta}^n\big)}; \tag{17}$$

the noncompete duration and buyout menu are

$$\pi = \frac{1}{r}\log\big(\bar{\theta}^n\big) \quad \text{and} \quad \tau\big(0|z\big) = j^n z\big(\bar{\theta}^n - 1\big). \tag{18}$$

The proposition first states that firm-worker matches with a low contracting cost include a noncompete clause. This result captures the observed binary contract choice. The poaching threshold in equation (16) suggests that, when a noncompete clause is not included or enforced, the wage bidding process results in workers moving to firms with better match quality. Although the outcome is identical to the one in Postel-Vinay and Robin (2002), the bargaining protocol is modified. In their setup with perfect information, firms each make a take-it-or-leave-it offer to the worker; here, under asymmetric information, firms engage in wage bidding through an ascending (English) auction.

If a noncompete clause is enforced, the poaching threshold in equation (17) is distorted upward. To understand this expression, recall the intuition that the incumbent match acts like a monopolist toward potential entrants. Indeed, the expression is a monopoly markup pricing formula: the monopolist sets a markup of $\big(1 - F\big(\bar{\theta}^n\big)\big)/f\big(\bar{\theta}^n\big)$ over the efficient level.[18] Further, given the linearity of the joint value functions, the monopolist charges a constant markup independent of realized productivity z. Correspondingly, the contract specifies a fixed noncompete duration π in equation (18).

The bidding process reveals the entrant match quality θ only up to the poaching threshold. If the entrant match quality is below the threshold, its value is perfectly revealed; otherwise,

[18] Given the information asymmetry, the maximum payoff the incumbent can achieve is by charging entrant firms a monopoly price to poach the worker. The wage bidding and the noncompete buyouts implement this monopoly pricing.

the incumbent learns only that it is above the threshold. Given that no information revelation occurs to allow screening in the buyout stage, the buyout menu bunches to a single price. That is, the incumbent charges a nondiscriminating price that fully extracts the rent from entrants at the poaching threshold; all entrants that can poach the worker fully buy out the noncompete clause.

To sum up, non-compete buyouts create barriers to entry as in Aghion and Bolton (1987), with an additional appeal. The incumbent firm doesn't necessarily need to specify or commit to the buyout payment ex ante, since it would ask the same amount ex post in the buyout stage. This finding aligns well with the observation that some contracts specify buyout payments while others are bargained ex post.

3.2 Effects of Noncompete Clauses

Given the contract choice in Proposition 1, the investment decision follows immediately. The optimality condition with respect to μ in equations (7) and (8) is

$$c'\big(\mu^i\big) = j^i,\ \forall i \in \{c,n\}. \tag{19}$$

The investment incentive is such that the marginal cost of investment is equal to the marginal joint value. The buyout extracts rent of amount $\lambda p\big(\bar{\theta}^n - 1\big)\big(1 - F\big(\bar{\theta}^n\big)\big)$, translating into a higher marginal joint value. Indeed, rent extraction allows the incumbent match to partially capture the external payoff to its investment, thus alleviating investment holdup by exactly the amount of extracted rent. Formally, the effect of noncompete clauses is stated in the following proposition.

Proposition 2 (Investment-Reallocation Trade-off). *Firm-worker matches with a noncompete clause experience a lower job-to-job transition rate but invest more:*

$$\eta^c - \eta^n = \lambda p\big(F\big(\bar{\theta}^n\big) - F(1)\big) \tag{20}$$

$$\frac{\mu^n - \mu^c}{\mu^c} \approx \frac{c'(\mu^c)}{c''(\mu^c)\mu^c}\frac{\lambda p\big(\bar{\theta}^n - 1\big)\big(1 - F\big(\bar{\theta}^n\big)\big)}{r - \mu^c}. \tag{21}$$

The interaction between the contracting externality and the investment externality generates an *investment-reallocation trade-off*: the noncompete clause alleviates the holdup problem due to the investment externality but aggravates the distortion in the allocation of workers due to the contracting externality. The investment response in equation (21) depends on the investment elasticity $c'(\mu^c)/(c''(\mu^c)\mu^c)$.

The presence of a search friction breaks the insights of the classical analysis by Becker

(1962) in a perfectly competitive labor market. There, because human capital is perfectly priced externally, the problem reduces to bilateral bargaining between the firm and the worker about who pays for the investment. In contrast, in my model, since they are facing an imperfectly competitive external labor market, the problem is one among three parties. Future employers also have some monopsony power and can partially appropriate the payoff; therefore, a positive *investment externality* on entrants appears. While the incumbent firm-worker match pays for the cost, investment is prone to holdup. Consequently, it undertakes more investment in response to rent extraction from the noncompete clause buyout.

Since movement of workers across firms is an important form of knowledge diffusion, these insights connect to the literature on innovation and knowledge diffusion. In particular, the distinction between rivalry and excludability in the use of knowledge, emphasized by Romer (1990) among others, has relevance here. Rivalry refers to the use of knowledge by one firm precluding the use by others; excludability refers to preventing others from using the knowledge. The key tension here is not the extent of rivalry but rather the extent of excludability. Precisely, the incumbent's ability to exclude entrants from employing the workers alters the appropriation of surplus from knowledge diffusion.[19]

3.3 Wage Backloading

The presence of noncompete clauses tends to reduce the extent of wage backloading. For example consider the wage of newborn matches. Workers with a noncompete clause tend to have higher starting wage, $w_0^n > w_0^c$, but experience slower wage growth.

The mechanism is straightforward: the noncompete clause reduces the extent of outside competitive pressure and in turn the amount of wage backloaded for retention. For a worker with a noncompete clause, the reservation value of entrants that are unable to poach the worker is reduced. The incumbent needs to bid up the wage less to retain the worker. Specifically, in the HJB equation (13), for $\theta \in \left[\underline{\theta}^n(z,w),\bar{\theta}^n\right]$, wage bidding raises the promised utility to $e^{-r\pi}J^n(z\theta)$ only. In anticipation of less wage bidding, to deliver the initial promised utility, the worker starts with a higher wage but experiences lower wage growth. Although it is hard to prove this result in general, I show that numerically it is the case.

[19] The model setup that incumbent firms exit after losing their workers is innocuous for efficiency analysis: it only sets the incumbent's outside option to zero and simplifies accounting. One could extend the model to a general setting where the incumbent retains some productive knowledge. Consider, for example, the other extreme where the incumbent fully retains the productive knowledge, as in models of knowledge diffusion (Perla and Tonetti (2014)). Or there could be costs of replacing the worker, as in Heggedal et al. (2017). Further, firms might engage in duopolistic competition in the product market, as in Franco and Mitchell (2008). As long as there are gains from labor reallocation and entrant firms capture some of the gains due to labor market monopsony, incumbent firms have an incentive to extract rent. The contract design and the resulting externality are unchanged

I can simplify the wage-setting problem by looking at the wage-productivity ratio $x \equiv w/z$. The HJB equations (12) and (13) can be transformed into equations with a single state variable. The newborn matches have an initial wage-productivity ratio $x_0^i = w_0^i/z_0$ satisfying the Nash bargained result. Section B.2 of the online appendix presents the details.

3.4 Comparative Statics

Following Propositions 1 and 2, I obtain some useful comparative statics.

Lemma 3 (Cross-Regime Variation)**.** *In a higher-enforcement regime p, a higher proportion of firm-worker matches $F(\bar{k})$ use a noncompete clause. Noncompete clauses reduce the job-to-job transition rate η^n and increase investment μ^n by a larger magnitude.*

When it is more likely that a noncompete clause can be enforced, the benefit of including the clause increases and hence a higher proportion of matches use it. Moreover, such contracts allow firms to extract more rent, resulting in a larger reduction in worker mobility and hence spurring more investment. The comparative statics are useful when mapping the model to the data in the cross-state variation.

3.5 Optimal Noncompete Policy

Consider a planner who can cap the noncompete duration. Without loss of generality, suppose that the cap is between zero and the private-optimal level, $\pi^* \in [0,\pi]$. Since the rent extracted peaks at the private-optimal duration, the planner would not want to increase the duration beyond that level. Given a duration cap π^*, there is a corresponding poaching threshold, $\bar{\theta}^n = e^{r\pi^*}$, according to equation (18). Hence, I consider that the planner chooses the poaching threshold $\bar{\theta}^n$ directly. Formally, the planner maximizes social welfare, defined as the sum of the discounted stream of aggregate net output,

$$\max_{\bar{\theta}^c,\bar{\theta}^n} \int_0^\infty e^{-\rho t}\left[\sum_{i\in\{c,n\}}\int \left(z - c\left(\mu^i\right)z\right)dG(z,i,t) - \delta \iint \mathbb{1}_{\{\mathbb{I}(z,\kappa)=n\}} kz dH(z) d\Psi(\kappa)\right]dt,$$

subject to the KF equation (14) and the investment incentive constraint (19).

Proposition 3 (Optimal Duration Cap)**.** *The optimal cap on noncompete duration is below the private-optimal level, i.e., $\pi^* \leq \pi$.*

This proposition states that the private-optimal contract, despite being bilaterally efficient, is socially inefficient along the investment-reallocation trade-off. Recall that the incumbent firm-worker match maximizes their joint value and disregards the value of future entrants. From the aggregate welfare perspective, accounting for the value of entrants, the private parties set an excessively long duration and overextract rent. Hence, a planner can improve efficiency by capping the duration.

Recall that, in Proposition 2, the investment benefit depends crucially on the investment elasticity $c'(\mu)/(c''(\mu)\mu)$. So does the optimal duration cap. The lower the investment elasticity, the closer the optimal cap is to zero. At the extreme when investment is perfectly inelastic, the investment holdup problem disappears, the optimal cap is exactly zero.

The insight behind the optimal noncompete duration resembles the literature on optimal patent duration going back to Nordhaus (1967), where an analogous trade-off between the static and dynamic considerations exists. A longer patent duration encourages more investment at the expense of static distortion due to additional incumbent monopoly power. Here, the static distortion is due to the monopoly power of incumbent over future employers.

4 Empirical Evidence in the Managerial Labor Market

I apply the model to the managerial labor market where noncompete arrangements are prevalent. Using the new contract data I collected, I provide the empirical patterns of noncompete contract usage across states and the effects of noncompete contracts on executive mobility, firm investments, and wage backloading.

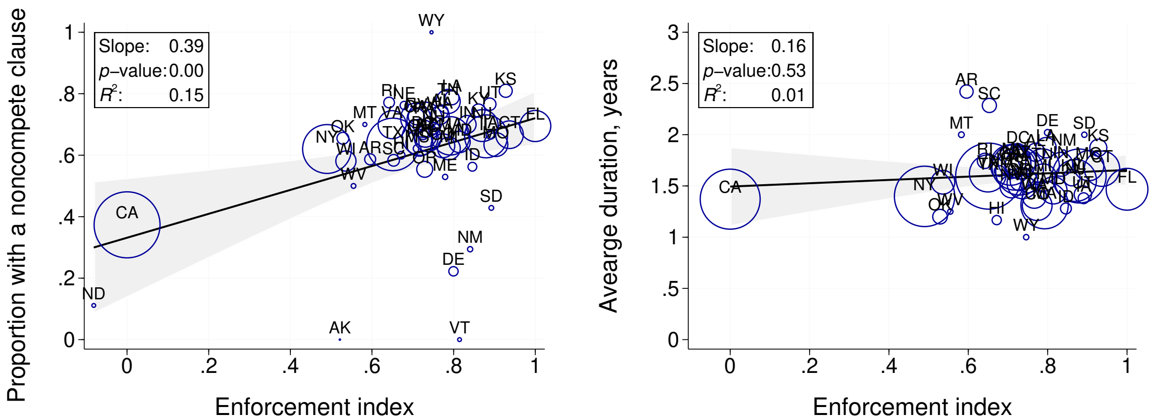
4.1 Data

I assembled a novel dataset of noncompete contracts for executives in U.S. public-listed firms. The data is constructed from around 68,000 actual contracts scraped from company filings in the SEC's EDGAR database, using machine-learning and textual-analysis tools. The details of my data collection procedure appear in Section D of the online appendix. Next, I merged the contract data with Compustat firm-level data and with ExecuComp and BoardEx data, including executive compensation and employment history.[20] After filtering the data, I obtained my final sample: 12,679 executives, 2,157 firms, and 13,363 firm-executive matches from 1992 to 2015. The summary statistics appear in Table D.1. Overall, 64% of the executives are subject to noncompete restrictions.

[20] The employment history information in ExecuComp is incomplete; therefore, I supplement it with the BoardEx data to improve measurement.

Figure 2: Noncompete law and contracts across states

(a) Whether a noncompete clause is included (b) Duration of noncompete clause



Notes: Panel (a) plots the proportion of executives with a noncompete clause against the normalized Bishara enforcement index in 2009. Panel (b) plots the average duration of noncompete clauses against the normalized Bishara enforcement index in 2009. The size of the circles represents the total number of firm-executive matches in the headquarter's state.

4.2 State Laws and Use of Noncompete Contracts

To measure noncompete laws across states, I use the Bishara enforcement index following previous empirical studies (Prescott et al. (2016), Lavetti et al. (2019)). To briefly explain the index, Bishara (2011) scores the enforceability of noncompete contracts based on legislation and case law.[21] Building on that, Starr (2016) constructs state-level weighted indices for the years 1991 and 2009, which I borrow. The raw indices are plotted in Figure D.5 in the online appendix. Given that the noncompete law is stable in a given state over the time period, I focus on the cross-state variation.

Figure 2 shows the relation between the noncompete law and the use of noncompete clauses across states. Panel (a) plots the proportion of executives with a noncompete clause against the enforcement index normalized to California at 0 and Florida at 1. As expected, the proportion increases as the enforcement index increases. Panel (b) plots the average duration of noncompete clauses against the normalized enforcement index. There is no significant correlation between the duration and the enforcement index. These patterns are consistent with the model's prediction of the private-optimal contract in Proposition 1 and the comparative statics in Lemma 3.

[21] Bishara (2011) looks at the following dimensions across jurisdictions: whether a state statute of general enforceability exists, scope of employer's protectable interest, plaintiff's burden of proof, consideration provisions, modification of overly broad contracts, and enforceability upon firing.

Table 1: Use of noncompete clauses

	Noncompete (Y/N)					Duration
	Baseline	Job-Changers		Cross-State Enforce		
	(1)	(2)	(3)	(4)	(5)	(6)
Enforce (State)	0.380***	0.267***	0.265***	0.368***		0.017
	(0.038)	(0.071)	(0.045)	(0.037)		(0.059)
Enforce (Industry)				0.471***	0.405***	
				(0.140)	(0.152)	
Noncompete (Previous Job)			0.131**			
			(0.054)			
Year FEs	√	√	√	√	√	√
Industry FEs	√			√		√
Firm FEs					√	
Executive FEs		√				
Observations	11,092	11,092	540	10,794	10,794	5,914

Notes: Standard errors clustered by state in columns 1, 2, 3, and 6, by industry in column 5, and by state and industry in column 4 are in parentheses. Four-digit SIC codes are used in all specifications. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

The formal econometric analysis is based on regressions of the form

$$NC_{ijst} = \beta \cdot Enforce_s + \gamma Z_{ijt} + \varepsilon_{ijst},$$

where whether executive i who starts working at firm j in state s in year t signs a noncompete contract, $NC_{ijst} \in \{0,1\}$, depends on the enforcement index in state s, $Enforce_s$, and other observable characteristics of the executive and the firm, Z_{ijt}. For the subsample of executives with a noncompete clause, I also look at their noncompete duration as the dependent variable. The control variables Z_{ijt} include age of the executive, whether the executive is the CEO, and the firm's asset.

Column 1 of Table 1 reports the baseline result on the incidence of noncompete contracts controlling for year and industry fixed effects. As expected, it shows that, moving from the enforceability level in California to the level in Florida, the percentage of executives subject to noncompete clauses increases by 38%. Column 6 shows that the same kind of correlation is absent for noncompete duration.

To mitigate concerns of unobserved executive heterogeneity, I take advantage of the information regarding the job-changers, namely, the executives who held multiple jobs. Column 2 shows that, after controlling for year and executive fixed effects, when an executive moves from a state with the enforceability level of California to a state with the level of Florida, he or she is 27% more likely to sign a noncompete contract. Column 3 uses the subsample of job-changers with nonmissing contract data in two consecutive jobs. The result that the state enforcement index is still significantly positive provides confirming evidence. Moreover, the executive's contract in the previous job is predictive of his or her contract in the current job, suggesting some persistence in the noncompete contract choice.

Cross-state enforcement. One puzzling fact is that, despite the ban in California, there are still firms there using noncompete contracts. One potential explanation is jurisdictional arbitrage: these firms might be able to enforce the clause when their employees move to other states. If more industry peers are located in higher-enforcement states, it is more likely that the clause can be enforced. To examine this possibility, I construct a location-weighted enforceability measure at the industry level,

$$Enforce_{jt} = \frac{\sum_s Enforce_s N_{jst}}{\sum_s N_{jst}},$$

where N_{jst} is the number of firms in industry j in state s in year t. I define this index according to three-digit SIC industry code.

The regression results in columns 2 and 3 suggest that cross-state enforcement does explain the contract choice: in a given industry, increases in the industry enforcement index are associated with increases in the prevalence of noncompete contracts. Column 2 shows that, controlling for year and industry fixed effects, the industry enforcement index is significant on top of the state one. Column 3 shows that the industry enforcement index is significant after controlling for year and firm fixed effects.

4.3 Mobility

To examine the restrictive effect of noncompete clauses on executive mobility, motivated by Proposition 2, I use the following specification:

$$SEP_{ijst} = \beta NC_{ij} + \gamma Z_{ijt} + \varepsilon_{ijt},$$

where the separation event for executive i at firm j in state s in period t, SEP_{ijst}, depends on whether the executive signed a noncompete contract with the firm, NC_{ij}, and other observable characteristics of the executive and the firm, Z_{ijt}. I also look at the job-to-job transition event as the dependent variable. The control variables Z_{ijt} include age of the executive, gender of the executive, whether the executive is the CEO, the firm's asset, and

Table 2: Effect of noncompete clauses on executive mobility

	Separation (Y/N)			Job-to-Job Transition (Y/N)		
	(1)	(2)	(3)	(4)	(5)	(6)
Noncompete	-0.009*			-0.004**		
	(0.005)			(0.002)		
Noncompete × Enforce (State)		-0.018***			-0.006**	
		(0.005)			(0.003)	
Noncompete × Enforce (Industry)			-0.098**			-0.056***
			(0.047)			(0.017)
Year FEs	√	√	√	√	√	√
Firm FEs	√	√		√	√	
Firm-Executive FEs			√			√
Observations	107,986	107,986	106,294	107,986	107,986	106,294

Notes: Standard errors clustered by state in columns 1, 2, 4, and 5 and by industry in columns 3 and 6 are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

return on asset.

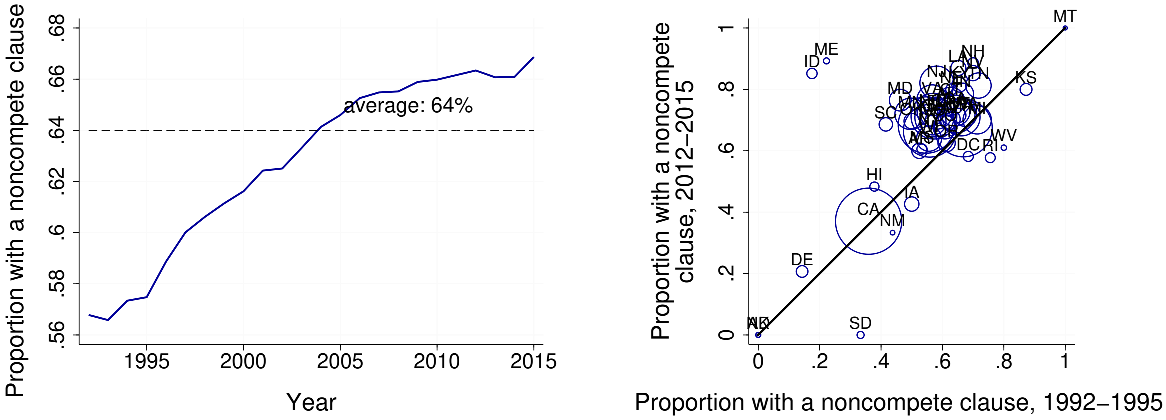
Table 2 reports the regression results for separation events and job-to-job transition events. Column 1 shows that executives with a noncompete clause are associated with a 0.9% lower separation rate annually than those without such clauses. Column 2 shows this magnitude is larger in higher-enforcement states. For example, in a high-enforcement state like Florida, the magnitude of mobility decline amounts to 1.8% annually. Both regressions control for year and firm fixed effects. Cross-state enforcement also reduces executive mobility. Column 3 shows that increases in industry-level enforceability also result in decreases in separation probability, after controlling for firm-executive fixed effects.

Column 4 shows that executive mobility also declines when I look at the job-to-job transition rates. Columns 5 and 6 show that this magnitude is larger in states and industries with higher enforcement. While job-to-job transition is usually the appropriate measure of mobility, in this case it is less reliable. The sample includes only top executive jobs in Compustat firms satisfying regulatory disclosure requirements; therefore, the job-to-job transition rate is systematically undermeasured due to executives moving out of the sample. For this reason, in the quantitative assessment, I rely on the separation rate to measure mobility distortion.

Accounting for declining labor market fluidity. The rise of noncompete arrangements is a likely culprit for the declining U.S. labor market fluidity. I perform a simple back-of-the-envelope calculation to assess how much this argument. Panel (a) of Figure 3 shows

Figure 3: Increasing noncompete prevalence over time

(a) Nationwide (b) By state



Notes: The size of the circles in panel (b) represents the total number of firm-executive matches in the headquarter's state.

that the prevalence of noncompete contracts has been on the rise in the past two decades. Overall, the percentage of executives under noncompete clauses increased from 57% in the early 1990s to 67% in the mid 2010s. Panel (b) shows that this increase is across-the-board in most states. Given that each noncompete contract causes a 0.9% decline in the separation rate, a 10% increase in noncompete contracts could result in a 0.09% decline in the aggregate separation rate.

4.4 Firm Investment

A firm's investment response to noncompete clauses in Proposition 2 motivates the following regression equation:

$$INV_{jt} = \beta \bar{N}C_j + \gamma Z_{jt} + \varepsilon_{jt},$$

where firm j's investment rate in period t, INV_{jt}, depends on the proportion of executives in the firm subject to noncompete clauses, $\bar{N}C_j$. This regression is at the firm level because investment is reported at the firm level. I look at both the physical capital investment rate and th intangible capital investment rate as the dependent variables.[22] I include the standard control variables for investment, such as Tobin's Q and cash.

Table 3 reports the investment regression results. Column 1 shows that, when the percentage of executives subject to noncompete clauses increases by 1%, the investment rate in

[22]Intangible capital investment is defined as R&D expenses plus 30% of selling, general, and administrative expenses. Intangible capital stock is the estimated replacement cost of the firm's intangible capital, calculated by Peters and Taylor (2017).

Table 3: Effect of noncompete clauses on firm investment

	Intangible Capital			Physical Capital		
	(1)	(2)	(3)	(4)	(5)	(6)
Noncompete	0.012***			-0.003		
	(0.003)			(0.003)		
Noncompete × Enforce (State)		0.017***			-0.001	
		(0.005)			(0.004)	
Noncompete × Enforce (Industry)			0.019***			-0.002
			(0.005)			(0.005)
Year FEs	√	√	√	√	√	√
Firm FEs	√	√	√	√	√	√
Observations	19,673	19,673	19,477	19,673	19,673	19,477

Notes: Standard errors clustered by state in columns 1, 2, 4, and 5 and by industry in columns 3 and 6 are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

intangible capital increases by 0.012% annually, controlling for year and firm fixed effects. For example, in a high-enforcement state like Florida, the magnitude of investment increase is 0.017% annually. Columns 2 and 3 show that the investment effect in intangible capital is stronger in states and industries with higher enforceability. Columns 4, 5, and 6 show that the same investment effect is absent for physical capital. This differential pattern suggests that the holdup problem indeed concerns investment activities such as R&D that relate to human capital.

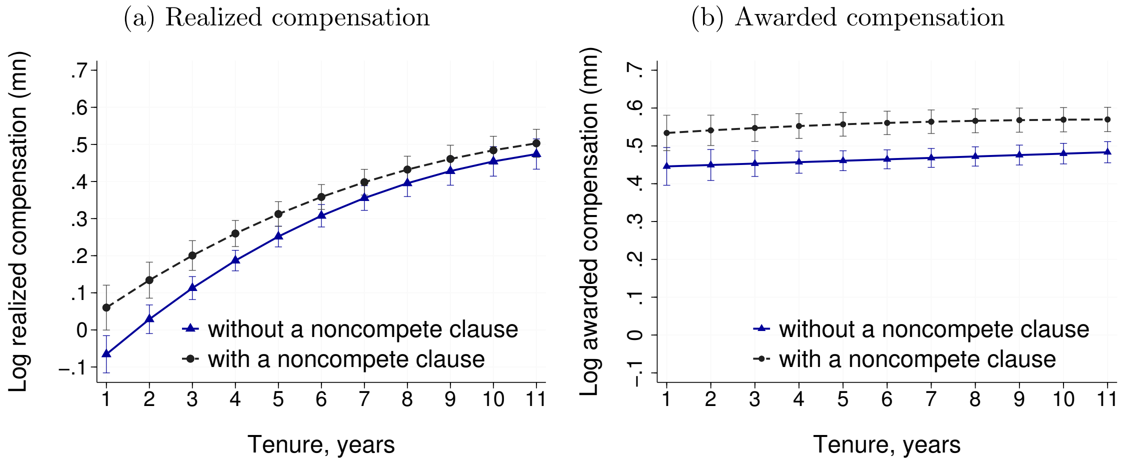
4.5 Wage Backloading

To examine how a noncompete contract interacts with wage backloading, I use the following wage regression equation:

$$W_{ijt} = \beta_1 NC_{ij} + \sum_{k=1}^{3} \beta_{2,k} T_{ijt}^k + \sum_{k=1}^{3} \beta_{3,k} \cdot T_{ijt}^k \times NC_{ij} + \gamma Z_{ijt} + \varepsilon_{ijt},$$

where the wage for executive i at firm j in period t, W_{ijt}, depends on whether the executive entered into a noncompete contract with the firm, NC_{ij}, the tenure of the executive at the firm, T_{ijt}, and other observable characteristics of the executive and the firm, Z_{ijt}. To allow for the tenure effect to depend on the contract, I include the interaction of tenure with the noncompete contract choice, $T_{ijt} \times NC_{ij}$. To allow for a nonlinear tenure effect due to the wage bidding, I also include higher-order polynomials of tenure, T_{ijt}^2 and T_{ijt}^3, and their

Figure 4: Noncompete contract and wage-tenure profile



Notes: Panel (a) is based on the marginal effects at means according to column 1 of Table D.2 in the online appendix. Panel (b) is based on the marginal effects at means according to column 3 of the same table. The bars display 95% confidence intervals.

interactions with the noncompete contract choice, $T^2_{ijt} \times NC_{ij}$ and $T^3_{ijt} \times NC_{ij}$. To allow for differential effects due to enforceability, I allow for the interaction between the noncompete contract status and the state-level enforcement index. The control variables Z_{ijt} contains the firm's asset, Tobin's Q, return on asset, whether the executive is the CEO, and gender of the executive.

The distinction between two measures of executive compensation—awarded compensation and realized compensation—are meaningful here. A large part of awarded compensation is in the form of restricted equity, which is deferred to future dates contingent on the executive staying with the firm. Deferred compensation is exactly how firms backload wage for retention purposes.[23] Therefore realized compensation is the appropriate wage definition for gauging the extent of wage backloading.

In Figure 4, panel (a) plots realized compensation over tenure by whether the executive is subject to a noncompete clause, according to the marginal effects at means in the baseline regression in column 1 of Table D.2 in the online appendix. First, an executive with a noncompete clause is associated with a starting wage that is 13% (or \$130k in 2010 prices) higher than executives who are not under such a clause. Second, an executive with a noncompete clause is associated with a 1% lower average annual wage growth over the first ten years of tenure than their counterparties.

Panel (b) shows that, in contrast the awarded compensation is very flat over tenure

[23]Much discussion in the executive compensation literature focuses on the moral hazard aspect of the agency problem, as opposed to retention due to limited commitment. My results suggest that retention is indeed an important consideration in contract and compensation design.

regardless of the type of contract. Indeed, awarded compensation reflects the executive's productive value during the period, which is much flatter than actual realized take-home wage, as the model suggests. Overall, the pattern of wage dynamics in the data confirms the incentives of wage backloading.

5 Quantitative Analysis

I now calibrate the model and use the calibrated model to carry out welfare analysis.

5.1 Calibration

To formulate the calibration strategy, I take advantage of the cross-state variation in the noncompete laws. First, I calibrate the model in a full-enforcement regime. For states such as Florida and Massachusetts, which are on the extreme high end of the enforcement index, I assume that the enforcement probability is one. Second, I map the model-implied variation in noncompete prevalence with respect to the enforcement probability to the data.

I specify the following functional forms. First, the entrant match quality follows a Pareto distribution, $F(\theta) = 1 - \left(\frac{\theta_m}{\theta}\right)^{\alpha}$, $\forall \theta \in [\theta_m, \infty)$. Second, the investment cost function is $c(\mu) = \frac{\phi}{1+1/\varphi}(\mu - \frac{1}{2}\sigma^2)^{1+\frac{1}{\varphi}}$. Third, the contract cost follows a log-normal distribution, $\log(\kappa) \sim N(\mu_\kappa, \sigma_\kappa^2)$. Lastly, the productivity distribution for newborn matches is a mass point at 1.

Two parameters, θ_m and β, are irrelevant for welfare analysis due to the bilateral efficiency result. These two parameters relate only to the dynamic wage setting in Section 2.5; they are not inputs in the investment-reallocation trade-off. The outside matches relevant for welfare improvement have match quality $\theta \geq 1$. Hence, while I calibrate all parameters, I discuss the welfare-relevant and welfare-irrelevant parameters separately.

5.1.1 Welfare-Relevant Parameters

I calibrate the model at an annual frequency. One unit of time in the model corresponds to one year in the data. Table 4 displays the calibrated parameters and the moments. The discount rate ρ is set to 0.05, following the literature, to match the interest rate.

Outside opportunity. The separation rate for executives without a noncompete clause is $\delta + \lambda(1 - F(1)) = 8.5\%$. In a full-enforcement regime, noncompete clauses results in a decline in the separation rate by $\lambda\big(F\big(\bar{\theta}^n\big) - F(1)\big) = 1.8\%$. Given the match quality distribution, the private-optimal noncompete duration in Proposition 1 is $\frac{1}{\rho+\delta}\log\big(\frac{\alpha}{\alpha-1}\big)$, which averages

Table 4: Calibrated parameters

Parameter	Symbol	Value	Moment	Data	Model
Discount rate	ρ	0.05	interest rate	5%	5%
Brownian motion std dev	σ	0.24	Pareto right tail	1.16	1.16
Bargaining weight	β	0.5	peak-to-initial wage ratio	1.8	4
Outside opportunity					
Exogenous death rate	δ	0.05	separation rate	8.5%	8.5%
Entrant arrival rate	λ	0.13	separation rate response	1.8%	1.8%
Dstribution shape	α	6.2	average noncompete duration	1.6	1.6
Distribution lower bound	θ_m	0.77	wage growth (first ten years)	5.4%	5.4%
Investment cost function					
Level	ϕ	45	intangible investment rate	13.8%	13.8%
Elasticity	φ	3.5	intangible investment response	1.7%	1.7%
Contract cost					
Distribution mean	μ_κ	-1.56	noncompete prevalence ($p = 1$)	70%	70%
Distribution std dev	σ_κ	1.03	variation in noncompete prevalence	38%	38%

1.6 years in the data. These three moments jointly identify the exogenous death rate δ, the arrival rate of better jobs $\lambda(1 - F(1))$, and the distribution shape parameter α.

Investment cost function. Given the investment elasticity $c'(\mu)/(c''(\mu)\mu) = \varphi$ and a full-enforcement regime, equation (21) in Proposition 2 becomes

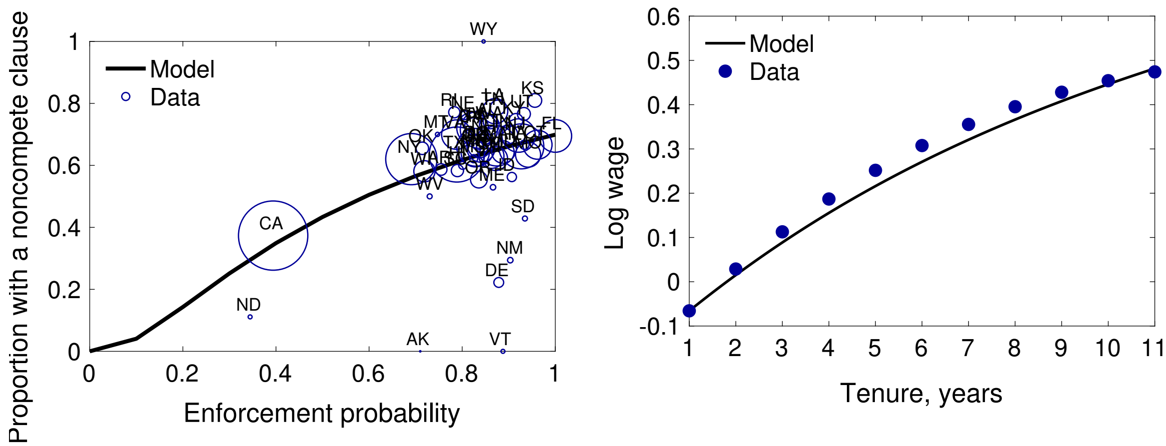
$$\frac{c(\mu^n) - c(\mu^c)}{c(\mu^c)} \approx \frac{\varphi + 1}{\varphi} \frac{\lambda\left(\bar{\theta}^n - 1\right)\left(1 - F\left(\bar{\theta}^n\right)\right)}{r - \mu^c},$$

which allows me to identify the investment elasticity φ directly from the data. Using the intangible capital investment rate, which increases by 1.7% annually in response to noncompete contracts, I obtain an investment elasticity of 3.2. Further, the level parameter ϕ maps to the average annual intangible capital investment of 13.8% in the firm-level panel data.

Contract cost. I use the prevalence of noncompete contracts across states to pin down the contract cost distribution parameters. In states such as Florida and Massachusetts, which resemble a full-enforcement regime, the percentage of executives with a noncompete clause is 70%. In states with lower enforcement probability, the slope in the decline of noncompete arrangements is 0.38. Together, the two moments pin down the two cost parameters, μ_κ and σ_κ. Panel (a) of Figure 5 plots the model-generated variation in the proportion with a noncompete clause against the enforcement probability. In the linear range of the model-implied relation, I overlay the state-level data from panel (a) of Figure 2. To fit the noncompete

Figure 5: Model and data fit

(a) Cross-state variation (b) Wage without a noncompete clause



prevalence in California, the effective enforcement probability would be around 0.4.

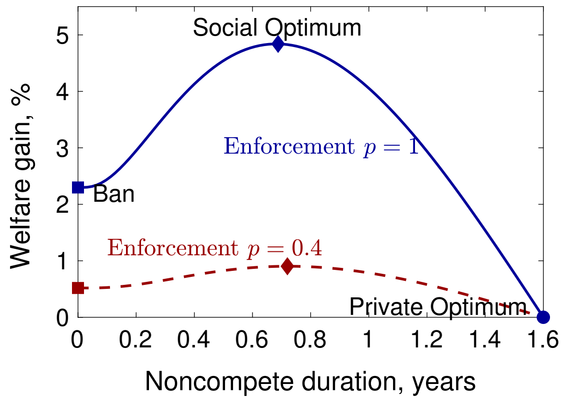
Productivity process. The endogenous stationary productivity distribution has a Pareto right tail, which is related to the standard deviation of the Brownian motion σ. This calibration strategy of identifying the stochastic component of the productivity process from the cross-sectional firm distribution follows Luttmer (2007) and Atkeson and Burstein (2010). I fit an empirical distribution of firm size measured in terms of employment in a given year and obtain an average right-tail index of 1.16 for the years 1992 through 2015. This data moment implies a standard deviation of 0.24.

5.1.2 Welfare-Irrelevant Parameters

I assume a bargaining weight β of 0.5. It is difficult to measure the value of an executive directly in the data. To check whether the bargaining parameter is reasonable, I use the peak-to-initial wage ratio. In the model, at the peak wage, a worker obtains a promised utility equal to the entire match value; at the initial wage, the worker has a promised utility equal to the bargained level. Hence the ratio of the peak wage to the initial wage ratio maps to the share of the match value the worker bargained for. The peak-to-initial wage ratio in the data is 1.8. The model-implied level is 4. While further improvement is useful, it does not affect the welfare analysis.

Since the wage-tenure profile is generated by bidding against job offers with match quality in the interval $[\theta_m,1]$, I use it to recover the lower bound θ_m. The average annual wage growth for executives without a noncompete clause in the first ten years of tenure is 5.4%. To fit this data moment, I obtain a lower bound of 0.82. Panel (b) of Figure 5 plots the wage-tenure

Figure 6: Welfare gain from capping noncompete duration



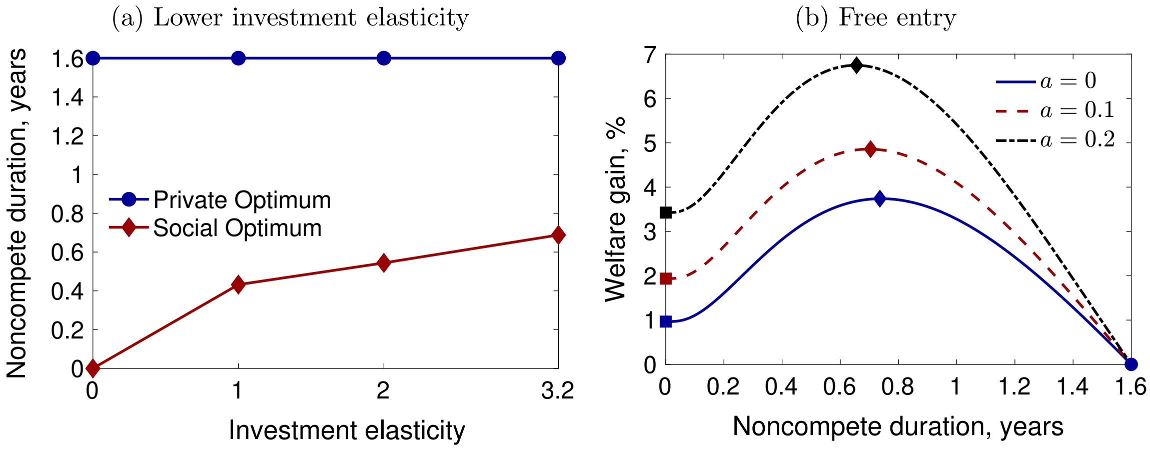
profile generated by the model and the one in the data. I then separates out the the instances of better jobs $1 - F(1)$ from the arrival rate of outside opportunity λ, which is 0.094.

Finally, the model implies that the average buyout payment is about ten times the starting wage, or around \$12 million in 2010 prices. Although there is no comprehensive buyout data available, as a sanity check, I cross-examine a few noncompete buyout cases. For example, in the case of Mark Hurd, the former CEO of Hewlett-Packard who moved to Oracle in 2010, the new employer paid \$14 million for a buyout. It suggests that the model-implied level lies in a reasonable range.

5.2 Policy Evaluation

Using the calibrated model, I quantitatively assess the optimal restriction on the noncompete duration in Proposition 3. The steady-state aggregate output is the appropriate welfare measure. Figure 6 plots the welfare gains from a cap ranging from zero to the private-optimal level. Quantitatively, the optimal cap is 0.6 years, much lower than the private-optimal level. To put this number in perspective, it is generally considered easy in many states to enforce a noncompete clause if its duration does not exceed two years. In addition, a legislative bill in Massachusetts in 2017 proposed to cap noncompete duration at one year. In a full-enforcement regime $p = 1$, the optimal cap and a ban result in welfare gains of 4.8% and 2.3%, respectively, relative to the laissez-faire equilibrium outcome. In a low-enforcement regime $p = 0.4$ that resembles California, the optimal cap and a ban result in welfare gains of 0.9% and 0.5%, respectively. If noncompete arrangements were banned altogether, the outcome would be fairly close to the social optimum.

Figure 7: Robustness check: optimal duration cap



5.3 Discussions

Investment elasticity. The welfare gains from restricting noncompete contracts depend crucially on the investment elasticity, that is, how responsive investment is to rent extraction. If investment is highly elastic, the investment holdup is severe and the benefit from alleviating holdup is large. Reducing the cap on noncompete duration leads to significant lost investment, which in turn implies a higher optimal cap. The calibrated investment elasticity parameter, $\varphi = 3.2$, is at the higher end of the range found in the literature, which centers around a unity.[24] Hence, my welfare calculation is conservative. As a sensitivity check, in a full-enforcement regime, I fix the investment elasticity at 0, 1, and 2, respectively, and recalibrate the model to match the data moments except for the investment response. Unsurprisingly, as shown in panel (a) of Figure 7, lower investment elasticity generates an even lower optimal duration cap. In particular, if investment is perfectly inelastic, i.e., $\varphi = 0$, the investment benefit disappears. In this case, the optimal duration cap is zero.

Free entry. Assuming an exogenous arrival rate of outside opportunities is innocuous for the welfare analysis. If one were to endogenize the arrival rate through free entry, given the information environment, random search would be the appropriate choice. Since agents do not internalize that the arrival rate is endogenous, the restrictive effect of noncompete contracts on worker mobility as observed in the data is preserved. Hence, capping noncompete duration improves welfare.

In fact, free entry amplifies the welfare gains due to the endogenous response of entry.[25] To illustrate, suppose that the arrival rate of outside opportunity is $\lambda(v) = \lambda_0 v^a$, where v is

[24] Akcigit, Celik, and Greenwood (2016) estimate an investment elasticity of 3 using patent resale data.
[25] Section B.6 of the online appendix provides more details.

the measure of entrants and $a \in [0,1]$ captures the extent of entry congestion. When entry is fully congested, i.e., $a = 0$, the arrival rate becomes exogenous. The holdup of investment is now two-sided: apart from the positive external effect of an incumbent's investment, there is also a positive external effect of new firms' investment to enter. The Hosios (1990) insight applies here. The constrained efficient outcome is obtained when the surplus division between the two sides equals their respective contributions to matching. Noncompete contracts shift that surplus division in favor of the incumbents. If entry is less congested, i.e., higher a, it is more desirable to restrict noncompete contracts and restore the surplus division.[26] Panel (b) of Figure 7 confirms this insight. Consider a full-enforcement regime $p = 1$. At a lower entry congestion (higher a), the optimal duration cap is lower and the welfare gain is larger. In the model with exogenous arrival rate, given that entry is fully congested while entrants appropriate the entire surplus, the welfare calculation is conservative.

6 Conclusion

The paper studies the aggregate impact of noncompete contracts and shows that there are sizable gains from restricting them. This quantitative evaluation based on the managerial labor market has broader relevance. Admittedly, one should be cautious when extrapolating the results to other segments of the labor market. For high-skilled labor, however, the same economic forces of similar magnitudes operate.

There are other potential channels that I have abstracted away from. One channel is risk-sharing between firms and workers, which is shut down given the risk-neutral assumption in the model. Noncompete contracts can improve risk-sharing by restricting the workers' outside opportunities. Another channel is the agglomeration effects of industry clusters. Noncompete contracts prevent the formation of industry clusters by limiting technology spillover and discouraging entrepreneurship. For instance, the noncompete ban in California is considered conducive to the rise of Silicon Valley and its surpassing Boston's Route 128 tech district (Gilson (1999)).[27] Incorporating these additional channels in future work would be useful. While the risk-sharing channel could attenuate my conclusion here, the agglomeration channel should further reinforce it.

[26] Diamond and Maskin (1979) is among the first papers to study damage payments in breach of contracts in a labor search model. Gautier, Teulings, and Van Vuuren (2010) argue that, with Bertrand competition and absent any entry congestion $\lambda(v) = \lambda_0 v$, there is excessive entry. In contrast, here there tends to be under-entry. This is because, unlike in their setting, moving to better jobs doesn't reduce opportunity for even better future jobs.

[27] Many studies point to job-hopping and spinoffs as instrumental in the formation of industry cluster, to which mobility restrictions bring adverse effects (Fallick, Fleischman, and Rebitzer (2006), Franco and Filson (2006), Franco and Mitchell (2008), Samila and Sorenson (2011), Rauch (2016), and Baslandze (2017)).

A Proofs

A.1 Proof of Lemma 1

I first define the discounting factors which adjust for the job-to-job transition rates

$$R^i(0,t) = \exp\Big(-\int_0^t \big(r + \eta_s^i\big) ds\Big),\ i \in \{c,n\}.$$

Next, using the adjusted discount factors, I obtain that the worker's continuation utility at time t is

$$\mathbb{E}\Big[\int_t^\infty R^i(t,s)\big(w_s + \eta_s^i J^i(z_s)\big) ds\Big] \geq U_t.$$

By the Martingale Representation Theorem, there exists a process $\{\sigma_t^U\}_{t\geq 0}$ such that $\{U_t\}_{t\geq 0}$ satisfies the following stochastic differential equation:

$$dU_t = \big((r + \eta_t^i)U_t - w_t - \eta_t^i J^i(z_t)\big)dt + \sigma_t^U dB_t.$$

I apply dynamic programming to the firm's problems and use the worker's continuation value as a state variable

$$\begin{aligned}
V^c(z_t,U_t) &= \max_{\mathcal{W},\boldsymbol{\mu}} \mathbb{E}\Big[\int_t^\infty R^c(t,s)(z_s - c(\mu_s)z_s - w_s)ds\Big]\\
V^n(z_t,U_t) &= \max_{\mathcal{W},\mathcal{M},\boldsymbol{\mu}} \mathbb{E}\Big[\int_t^\infty R^n(t,s)\Big(z_s - c(\mu_s)z_s - w_s + \lambda p\int_{\bar{\theta}_s^n} \tau_s(\tilde{\pi}_s(\theta_s))dF(\theta_s)\Big)ds\Big].
\end{aligned}$$

Without a noncompete clause, the firm's value function follows the HJB equation

$$\begin{aligned}
(r + \eta_t^c)V^c(z_t,U_t) = \max_{w_t,\mu_t,\sigma_t^U} &\Big\{ z_t - c(\mu_t)z_t - w_t + \mu_t z V_z^c(z_t,U_t) + \frac{1}{2}\sigma^2 z^2 V_{zz}^c(z_t,U_t) \\
+V_U^c(z_t,U_t)((r + \eta_t^c)U_t - w_t - \eta_t^c J^c(z_t)) &+ \frac{1}{2}\big(\sigma_t^U\big)^2 V_{UU}^c(z_t,U_t) + \sigma z \sigma_t^U V_{zU}^c(z_t,U_t)\Big\}.
\end{aligned} \tag{22}$$

With a noncompete clause, the firm's value function follows the HJB equation

$$\begin{aligned}
(r + \eta_t^n)V^n(z_t,U_t) = \max_{w_t,\pi_t,\tau_t(\cdot),\mu_t,\sigma_t^U} &\Big\{ z_t - c(\mu_t)z_t - w_t + \lambda p \int_{\bar{\theta}_t^n} \tau_t(\tilde{\pi}_t(\theta_t))dF(\theta_t) \\
+\mu_t z V_z^n(z_t,U_t) + \frac{1}{2}\sigma^2 z^2 V_{zz}^n(z_t,U_t) &+ V_U^n(z_t,U_t)((r + \eta_t^n)U_t - w_t - \eta_t^n J^n(z_t)) \\
&+ \frac{1}{2}\big(\sigma_t^U\big)^2 V_{UU}^n(z_t,U_t) + \sigma z \sigma_t^U V_{zU}^n(z_t,U_t)\Big\},
\end{aligned} \tag{23}$$

subject to the entrant firms' IC and IR constraints (4) and (5).

Taking the derivative with respect to w_t, I obtain

$$V_U^i(z_t,U_t) \geq -1 \text{ with } `` = " \text{ if } w_t > 0. \tag{24}$$

If λ is sufficiently small, the wage non-negativity constraint will never bind. That is, equation (24) becomes $V_U^i(z_t,U_t) = -1$. This in turn implies that

$$V_{UU}^i(z_t,U_t) = 0 \quad \text{and} \quad V_{zU}^i(z_t,U_t) = 0. \tag{25}$$

Since $J^i(z_t) = V^i(z_t,U_t) - V_U^i(z_t,U_t)U_t$, I also obtain

$$J^i(z_t) = V^i(z_t,U_t) + U_t. \tag{26}$$

Substituting equations (24), (25) and (26) into the HJB equations (22) and (23),

$$rJ^c(z_t) = \max_{\mu_t} z_t - c(\mu_t)z_t + \mu_t z J_z^c(z_t) + \frac{1}{2}\sigma^2 z^2 J_{zz}^c(z_t) \tag{27}$$

$$rJ^n(z_t) = \max_{\mathcal{M},\mu_t} z_t - c(\mu_t)z_t + \lambda p \int_{\bar{\theta}_t^n} \tau_t(\tilde{\pi}_t(\theta_t))dF(\theta_t) + \mu_t z J_z^n(z_t) + \frac{1}{2}\sigma^2 z^2 J_{zz}^n(z_t). \tag{28}$$

Dropping the time subscript, equations (27) and (28) become equations (7) and (8).

A.2 Proof of Lemma 2 and Proposition 1

First, I solve for the optimal buyout menu. The steps are similar to solving a second-degree price discrimination problem. I take advantage of the envelope condition for the IC constraint (4) and the binding IR constraint (5) at the poaching threshold. The buyout payment satisfies

$$\tau(\tilde{\pi}(\theta|z)|z) = e^{-r\tilde{\pi}(\theta|z)}J^n(z\theta) - \int_{\bar{\theta}^n}^{\theta} e^{-r\tilde{\pi}(\tilde{\theta}|z)} J_z^n\left(z\tilde{\theta}\right)dF\left(\tilde{\theta}\right) - J^n(z). \tag{29}$$

The problem becomes

$$\begin{aligned}
&\max_{\mathcal{M}} \int_{\bar{\theta}^n}^{\infty} \left[e^{-r\tilde{\pi}(\theta|z)}J^n(z\theta) - \int_{\bar{\theta}^n}^{\theta} e^{-r\tilde{\pi}(\tilde{\theta}|z)} J_z^n\left(z\tilde{\theta}\right)dF\left(\tilde{\theta}\right) - J^n(z)\right] F(\theta) \\
=&\max_{\mathcal{M}} \int_{\bar{\theta}^n}^{\infty} \left[e^{-r\tilde{\pi}(\theta|z)}\left(J^n(z\theta) - \frac{1-F(\theta)}{f(\theta)}J_z^n(z\theta)\right) - J^n(z)\right] F(\theta).
\end{aligned}$$

The first-order conditions with respect to $\tilde{\pi}(\theta|z)$ and $\bar{\theta}^n$ are, respectively,

$$J^n(z\theta) - \frac{1-F(\theta)}{f(\theta)} J^n_z(z\theta) \geq 0 \text{ with "} = \text{" if } \tilde{\pi}(\theta|z) > 0,\ \forall \theta \geq \bar{\theta}^n \tag{30}$$

$$e^{-r\tilde{\pi}\left(\bar{\theta}^n|z\right)}\left(J^n\left(z\bar{\theta}^n\right) - \frac{1-F\left(\bar{\theta}^n\right)}{f\left(\bar{\theta}^n\right)} J^n_z\left(z\bar{\theta}^n\right)\right) - J^n(z) = 0. \tag{31}$$

In equation (30), $J^n(z\theta) - \frac{1-F(\theta)}{f(\theta)} J^n_z(z\theta) > 0$ always holds. Therefore, the entrant chooses to fully buy out the noncompete clause after poaching the worker:

$$\tilde{\pi}(\theta|z) = 0,\ \forall \theta \geq \bar{\theta}^n. \tag{32}$$

Substituting the buyout level in equation (32) into equation (29), the payment is bunched to a single price:

$$\tau(\tilde{\pi}|z) = J^n\left(z\bar{\theta}^n\right) - J^n(z),\ \forall \tilde{\pi} \in [0,\pi].$$

Substituting the buyout level in equation (32) into equation (31), I obtain

$$L\left(\bar{\theta}^n|z\right) := J^n\left(z\bar{\theta}^n\right) - \frac{1-F\left(\bar{\theta}^n\right)}{f\left(\bar{\theta}^n\right)} J^n_z\left(z\bar{\theta}^n\right) - J^n(z) = 0. \tag{33}$$

I guess and verify that the joint value function is linear in z, i.e., $J^i(z) = j^i z$. The poaching threshold equation (33) reduces to

$$L\left(\bar{\theta}^n\right) := \bar{\theta}^n - \frac{1-F\left(\bar{\theta}^n\right)}{f\left(\bar{\theta}^n\right)} - 1 = 0.$$

The guess implies that, first, the poaching threshold $\bar{\theta}^i$ is constant and independent of productivity z. Second, the buyout payment is proportional to productivity, $\tau(\tilde{\pi}|z) = j^n z\left(\bar{\theta}^n - 1\right)$. Finally, the investment decision $\mu^i = (c')^{-1}(j^i)$ is also constant. Combining the three results above and replacing them in the HJB equations (7) and (8), I obtain the expression for j^i in equation (15). Assumption 1 guarantees that $L\left(\bar{\theta}^n\right)$ is strictly increasing in $\bar{\theta}^n$. In addition, $L(0) < 0$ and $L(\infty) > 0$. Hence there exists a unique solution $\bar{\theta}^n > 0$.

The poaching threshold also satisfies $e^{-r\pi} j^n z\bar{\theta}^n = j^n z\bar{\theta}^n - \tau(z) = j^n z$, which implies that the noncompete duration is $\pi = \frac{1}{r}\log\left(\bar{\theta}^n\right)$.

A.3 Proof of Proposition 2

It is straightforward to derive the differences in the job-to-job transition rates in equation (20). To derive the investment equation (21), I first take the log difference of the first-order condition (19),

$$\log(c'(\mu^n)) - \log(c'(\mu^c)) = \log(j^n) - \log(j^c) \approx \frac{\lambda p\left(\bar{\theta}^n - 1\right)\left(1 - F\left(\bar{\theta}^n\right)\right)}{r - \mu^c}.$$

Next, I adjust the left-hand side with the first-order derivative with respect to investment:

$$(\mu^n - \mu^c)\frac{c''(\mu^n)}{c'(\mu^n)} \approx \frac{\lambda p\left(\bar{\theta}^n - 1\right)\left(1 - F\left(\bar{\theta}^n\right)\right)}{r - \mu^c}.$$

A.4 Proof of Proposition 3

The social value associated with a worker employed at productivity z and contract i is denoted by $\Gamma^i(z)$. The social value functions follow the HJB equations:

$$r\Gamma^c(z) = \max_{\bar{\theta}^c,\mu^c}\left\{z - c(\mu^n)z + \mu^c z\Gamma^c_z(z) + \frac{1}{2}\sigma^2 z^2\Gamma^c_{zz}(z) + \lambda\int_{\bar{\theta}^c}^{\infty}[\Gamma^c(z\theta) - \Gamma^c(z)]dF(\theta)\right\} \quad (34)$$

$$\begin{aligned} r\Gamma^n(z) = \max_{\bar{\theta}^n,\mu^n}\Bigg\{& z - c(\mu^n)z + \mu^n z\Gamma^n_z(z) + \frac{1}{2}\sigma^2 z^2\Gamma^n_{zz}(z) \\ &+\lambda(1-p)\int_{\bar{\theta}^c}^{\infty}[\Gamma^n(z\theta) - \Gamma^n(z)]dF(\theta) + \lambda p\int_{\bar{\theta}^n}^{\infty}[\Gamma^n(z\theta) - \Gamma^n(z)]dF(\theta)\Bigg\}, \end{aligned} \quad (35)$$

subject to the investment incentive constraint (19). The details for the derivation are provided in the online appendix B.3.

Comparing equation (34) to (7), the planner also chooses the Bertrand competition outcome: $\left(\bar{\theta}^c\right)^* = \bar{\theta}^c = 1$. Comparing equation (35) to (8), they differ by the value of entrant firms. The planner chooses a different point along the investment-reallocation trade-off: $1 < \left(\bar{\theta}^n\right)^* < \bar{\theta}^n$ and $(\mu^n)^* < \mu^n$. The social optimum can be implemented by $\pi^* < \pi$. Following the same steps as in section A.2, I guess and verify that the social value functions are also linear in z, i.e., $\Gamma^i(z) = \gamma^i z$, where

$$\gamma^c = \frac{1 - c(\mu^c)}{r - \mu^c - \lambda\int_{\bar{\theta}^c}^{\infty}(\theta - 1)dF(\theta)} \quad (36)$$

$$\gamma^n = \frac{1 - c(\mu^n)}{r - \mu^n - \lambda(1-p)\int_{\bar{\theta}^c}^{\infty}(\theta - 1)dF(\theta) - \lambda p\int_{\bar{\theta}^n}^{\infty}(\theta - 1)dF(\theta)}. \quad (37)$$

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