Economic Inquiry

OPTIMAL ENFORCEMENT OF NONCOMPETE COVENANTS

SUMAN GHOSH and KAMESHWARI SHANKAR

Noncompete covenants or covenant not to compete (CNC) are clauses in employment contracts in which the employee agrees not to gain employment with a competitor firm. In this article, we study the efficiency aspects of such contracts by incorporating the effect of labor mobility restrictions on knowledge transfer across firms, investment decisions by firms, and investment by workers. Following research that shows state-wise variations in the degree of CNC enforcement, we allow the strength of CNC enforcement to vary as a matter of regulatory policy and derive the optimal strength of enforcement. We also look at how regulations around CNCs should be optimally designed when employers can use collusive agreements, such as "no poaching" agreements, as an alternative to noncompete clauses. Given recent allegations of employer collusion among large Silicon Valley firms, we argue for a cautious approach in designing policies on CNC enforcement. (*JEL* J24, J41, J63, K31)

I. INTRODUCTION

As knowledge-intensive industries have grown in importance in the last few decades, several recent studies have focused on the role of worker mobility as an important conduit through which knowledge is transferred across firms (Franco and Filson 2006; Franco and Mitchell 2008; Moen 2005). In a recent paper, Tambe and Hitt (2014) show that over the last two decades, productivity spillovers through worker mobility across IT firms have contributed 20%–30% as much to productivity growth as the firms' own IT investments. Shankar and Ghosh (2013) explain how worker turnover plays a unique role in optimally allocating worker knowledge in high-technology industries where firm-specific technological shocks create a continuous cross-section of expanding and contracting firms.

Given the apparent benefits of worker turnover among knowledge-intensive firms, many researchers have argued in favor of the free flow of ideas facilitated through employee mobility in these industries (Gilson 1999; Hyde 2003; Saxenian 1994). Employers, on the other hand, have generally attempted to restrict such transfer of knowledge via exiting workers. One such contractual restriction that firms and workers often enter into is a noncompete agreement, or covenant not to compete (CNC) clause. These agreements prevent employees from accepting employment in a competing firm for a specified period of time after they leave the current employer. Hence, by restricting worker mobility, they limit the flow of knowledge to competitors.

There are widespread differences from state to state within the United States in the extent to which CNCs can be legally enforced. Some states such as California have made such contracts completely unenforceable. At the other extreme, Texas and Massachusetts are known for being very permissive in their enforcement of such contractual employment restrictions. State-wise variation in the enforcement of CNCs has provided fertile ground for researchers to analyze the effects of labor mobility restrictions. Not surprisingly, several papers, such as Fallick, Fleischman, and Rebitzer (2006) and Marx, Strumsky, and Fleming (2009), show that more permissive legal enforcement of CNCs reduces worker mobility among firms. To the extent that labor turnover plays a positive role in the efficient allocation of worker knowledge and ideas across firms, these studies would suggest that CNCs have a negative

Ghosh: Professor, Department of Economics, Florida Atlantic University, Boca Raton, FL 33131. Phone 561-297-2948, Fax 561-297-2542, E-mail sghosh@fau.edu
Shankar: Associate Professor, Department of Economics and Business, Colin Powell School of Civic and Global Leadership, City College of New York, New York, NY 10031. Phone 212-650-6213, E-mail kshankar@ccny.cuny.edu

ABBREVIATION

CNC: Covenant Not to Compete

Economic Inquiry
(ISSN 0095-2583)
Vol. 55, No. 1, January 2017, 305–318

doi:10.1111/ecin.12357
Online Early publication May 5, 2016

effect on growth and productivity. Gilson (1999) and Hyde (2003), for example, attribute the success of Silicon Valley firms in California and correspondingly the failure of technology firms in the Route 128 cluster of Massachusetts to differences in CNC enforcement across the two states. Samila and Sorenson (2011) find that permissive enforcement of CNCs has an adverse effect on innovation. The research we have described thus far highlights the negative effect of CNCs on the incentive for workers to invest in developing new ideas and on the optimal transfer of such ideas through worker mobility.

On the other hand, it is arguable that CNCs can also have positive output effects by limiting turnover and allowing firms to protect their human capital investments and intellectual property, thereby enhancing such investments by firms. Kim and Marschke (2005) show that turnover of scientists reduces research and development expenditures by the firm. Starr (2015) shows that noncompete enforcement improves firm-sponsored training in certain occupations. Lavetti, Simon, and White (2015) find that noncompetes have a positive effect on wage and revenue generated by physicians. The hold-up of firms' investments in training and general human capital accumulation caused by labor market competition has been studied extensively in the literature.[1] However, the role of CNCs in mitigating this investment hold-up has received very little attention. Thus, our first objective in this article is to provide an integrated theoretical framework to explore all efficiency aspects of CNCs, namely, the efficient transfer of knowledge through worker mobility and optimal investment decisions by firms as well as workers.

Secondly, our analysis of this investment trade-off allows us to take a more nuanced approach to the issue of how CNCs should be enforced by law. A key drawback of the current debate over enforcement of CNCs is that regulation has been treated as a binary choice. In contrast, the actual strength of CNC enforcement under state law varies greatly across states. Yet, much of the research on CNCs has focused only on states that fall at either end of the enforcement spectrum—states such as California with no enforcement and states like Massachusetts with extremely permissive enforcement—leaving out the vast majority of states in the middle.[2] Bishara (2011) gives a detailed account of the variation in enforcement policy across the 50 states. He rightly points out that researchers have been using a simplistic analysis of CNCs by cherry-picking certain states for analysis while not acknowledging that the strength of enforcement varies across states. In line with Bishara's critique, we argue that posing the problem in this binary fashion in terms of existence or absence of CNC enforcement severely limits the analysis and ignores the role that policies surrounding CNC enforcement can play in balancing the investment trade-off between firms and workers.[3] Further, restricting the policy analysis to two extremes—to enforce or not to enforce CNCs—is even more problematic when we recognize that firms often tailor CNCs in their employment contract to balance the trade-offs. Thus, we adopt a unique approach to this issue by characterizing the choice of CNCs in the employment contract as a continuous variable that balances the investment trade-off rather than as a discrete decision process. Thus, we account for differences in the strength of CNCs in the firm's employment contract. Similarly, by allowing the strength of regulatory enforcement to vary continuously we derive an optimal enforcement level that maximizes surplus. This provides more nuanced policy prescriptions about how CNC enforcement can be optimally designed. Hence, we argue, contrary to some researchers, that zero enforcement of noncompetes is sometimes suboptimal.[4]

Specifically, we argue the following. Output from a worker depends on (1) human capital investments made by the firm and the workers themselves, and (2) the quality of the firm-worker match. When human capital investments are general, they make the worker more productive not just in the current firm but in a new firm as well. At the same time, a low match quality with the current firm can make the worker and her investments more valuable in a new firm. Worker turnover then facilitates the

1. Acemoglu and Pischke (1998, 1999a, 1999b) are seminal papers on this issue.

2. Marx et al. (2009) looks at Michigan which reversed its ban on noncompete agreements and hence established a highly permissive environment for CNCs.

3. Bishara, Martin, and Thomas's (2012) study is a recent attempt in this direction to study CEO compensation by incorporating "degree of enforcement" of CNCs.

4. Hyde (2010–2011), for example, argues that these clauses should be banned across the United States, as they are in California.

efficient transfer of knowledge and investment across firms in the industry.

The increase in worker wages and the possibility of turnover following investment leads firms to underinvest as they cannot appropriate all gains from their investment. At the other end, looking at workers' investment incentives, outside wages for workers grow more slowly than output as the match quality with a new firm is uncertain for a new worker. This leads workers also to underinvest in human capital.

In this situation, CNCs that restrict the worker from joining a competing firm effectively convert general human capital acquired by workers into firm-specific human capital. Consequently, the market wage falls and worker incentives to invest are further dampened. Moreover, by restricting worker turnover CNCs also limit the efficient transfer of worker investments in the event of a low quality match. Firm investments, however, improve as CNCs allow firms to appropriate more of the returns from their investment. This investment trade-off is present in both profits to the firm and overall surplus although the adverse worker investment effect is relatively weaker for profits than for surplus. Hence, the optimal employment contract entails a weakly less restrictive CNC than that chosen by the firm. At the same time, we find that zero enforcement of CNCs is efficient if and only if the marginal product of worker investment is sufficiently higher than the marginal product of firm investment. In all other cases, the optimal employment contract includes a CNC. Further if firm investment is productive enough relative to worker investment, the firm always chooses the optimal employment contract eliminating any need for regulation.

The only other paper that explores the investment trade-off, to our knowledge, is Garmaise (2011). He also shows that CNC enforcement encourages firm investment in its managers, but lowers managers' own investment in human capital. However, unlike our article, he treats the existence of CNCs as an exogenous variable, whereas we allow the decision to use CNCs in employment contracts to be determined in equilibrium. Further, as with other papers on CNC enforcement, Garmaise also treats CNC enforcement as a binary variable and hence he does not address the question of optimal CNC enforcement as we do here.

Finally, we also examine some unintended consequences of regulating CNCs, namely the use of "no poaching" agreements between firms. Recently, a number of high-tech companies in Silicon Valley including Apple, Google, Intel, Adobe, and eBay were accused of colluding to not hire each others' employees.[5] While the conspiracy was clearly illegal, as we argue in this article, restrictions on labor turnover can improve efficiency. When an alleged anticompetitive act also has potentially positive effects on surplus, the legal process should examine whether there are other less egregious ways of limiting turnover. One such alternative is a noncompete agreement between the firm and its employees. Because the strength of CNCs in the employment contract can be tailored in a continuous manner to achieve more optimal labor mobility restrictions, it is clearly preferable to no poaching agreements that severely restrict turnover possibilities for the employee. We show that regulations around CNC enforcement can, in some cases, facilitate collusion and further that the relative productivity of human capital investments by firms and workers can affect the firm's choice between no poaching agreements and CNCs when regulation limits the enforceability of CNCs. To the extent that strict regulations around CNCs in states such as California make it difficult for firms to utilize such employment contracts to protect their investments, we argue that firms may have had a greater incentive to use no poaching agreements. As a result, regulatory restrictions on CNCs may have had the opposite effect of reducing labor mobility rather than enhancing it.

The article is structured as follows. Section II describes the basic model for our follow-up analysis. In Section III, we solve the equilibrium employment contract and compare it with the optimal contract. Section IV analyzes the impact of CNC regulations when the firm can enter into no poaching agreements with its competitors. Section V discusses some of the policy implications of our analysis. Section VI concludes. All proofs are in the Appendix.

II. MODEL

We consider a two period model of production. At the beginning of Period 1, a single firm hires a worker of unknown match quality. The Period 1 employment contract includes a hiring wage and a CNC which places restrictions on the worker's future employment in a new firm. We assume that

5. "Justice Department Requires eBay to End Anticompetitive 'No Poach' Hiring Agreements," US Department of Justice Release, May 1, 2014

the worker is liquidity constrained so that upfront payments from the worker to the firm in Period 1 are not feasible.[6]

The strength of restrictions in the CNC is captured by the parameter $z \in [0, 1]$. There is significant variation in the terms of the CNC that firms can adopt. For example, a noncompete agreement typically specifies the duration and geographic scope for which the contract is valid. The duration can range from a few months to several years. Similarly, the geographic scope may also vary across employment contracts. In some cases, the worker's mobility may be restricted within the county where the firm operates, or, as in the case of many CEO contracts, the scope may be as broad as any global region where the firm has headquarters. In our model, a lower z represents fewer restrictions in the employment contract. At the two extremes, $z = 0$ is equivalent to no CNCs in the contract, while $z = 1$ effectively prevents the worker from using any of her human capital investments in a new firm and hence eliminates the possibility of turnover. Production occurs after the worker is hired in Period 1. At the end of Period 1, the worker and the firm simultaneously invest in human capital.[7] We assume that both worker and firm make investments independently. The cost of making the investment is $c(I)$ for both worker and firm but the marginal return from the two types of investment differs. In order to obtain closed form solutions, we assume a quadratic cost function, $c(I) = \frac{1}{2}I^2$. We denote the investment levels chosen by the worker and the firm as I_w and I_f, respectively.

In Period 2, the match quality between the current firm i and the worker k is revealed. Let us denote this match quality between worker k and firm i by r_{ki} which is uniformly distributed over the unit interval, that is, $r_{ki} \sim U[0, 1]$. The worker's match quality with a new firm is still unknown. Period 2 output is determined by the investment levels of both workers and firms, as well as the firm-worker match. There are two raiding firms that make competitive wage offers to the worker based on unknown match quality and human capital investment conditional on the CNC agreement between the worker and her current employer. We assume that, in the absence of any contractual restrictions on worker mobility, these raiding firms can utilize the worker's human capital investment as productively as the current firm given the same match quality.

The output from worker k in the current firm i in Period t is

$$y_{tki} = y + \left(v_w I_w + v_f I_f\right) r_{ki}.$$

In the above production function, $y > 0$ represents the baseline productivity of the worker in the labor market in a firm that cannot utilize the worker's human capital investments. Because this is the minimum output that the worker produces in any employment, it becomes the de facto reservation wage that must be paid to employ the worker in any period. The marginal returns to worker and firm investments are given by $v_w > 0$ and $v_f > 0$, respectively. Note that in Period 1, because investments have not yet occurred, worker output is simply y, that is, $y_{1ki} = y$.

If worker k moves to a competitor firm j in Period 2, her expected output there is given by

$$y_{2kj} = y + \left({}^{(1-z)}\!/_{2}\right) \left(v_w I_w + v_f I_f\right).$$

The timing of the game is as follows. In Period 1, the firm hires a worker with an employment contract that specifies a hiring wage and a noncompete clause. Production occurs and firms and workers make human capital investments. At the beginning of Period 2, the firm-worker match quality is realized. Two raiding firms simultaneously make wage offers to the worker. The current firm decides to either match the raiding offer and retain the worker or let the worker move to a new firm. We assume that when indifferent the firm and worker continue the current employment relationship.

In the following sections, we first describe the equilibrium investment and Period 2 wages given the turnover restrictions agreed to at the time of hire in the CNC and then we derive the first period employment contract chosen by the firm.

III. INVESTMENT, TURNOVER, AND CNC AGREEMENTS

In this section, we describe the equilibrium investment levels chosen by the firm and the worker given the turnover restrictions imposed by the CNC agreed to at the time of hire. Because firms invest to maximize profits and workers invest to maximize their wages, neither worker nor firm investments are optimal for maximizing surplus. However, as the CNC agreement in

6. The importance of this assumption is discussed when we compare the equilibrium and optimal employment contracts in Section III.B.

7. Firm investments in employee human capital may take the form of training while worker investments may take the form of learning a new skill or a new computing language. See Garmaise (2011) for a distinction between such investments. Related to this, see Almeida and Carneiro (2009) on firm investments in human capital.

the employment contract becomes more restrictive, the firm can appropriate more of its investment, and this improves firm investment levels. At the same time, greater restrictions on worker mobility distort turnover outcomes and depress worker incentives to invest. This trade-off suggests that the strength of restriction in CNCs can play a role in improving overall surplus by balancing investment incentives for firms and workers. In what follows, we first describe the equilibrium investment choice by the firm and workers and the wage and turnover outcomes for a CNC of given strength, z. We then derive the optimal CNC strength, z^o, that maximizes surplus conditional on the equilibrium investment and turnover outcomes following the CNC. Finally, we look at how the profit maximizing choice of CNC strength, z^*, deviates from this optimal. This allows us to address the role that regulation can play in improving surplus.

A. *Period 2 Investment and Turnover*

Let us start by taking the CNC enforcement strength, z, as given and describe the incentives facing firms and workers to invest in Period 2. We assume that all investments are general except for the firm-specificity introduced by the CNC contract.

Given z, I_f, and I_w, the worker's outside wage is her expected output in a raiding firm, that is, $w_2 = y + \frac{1}{2}(1-z)\left(v_w I_w + v_f I_f\right)$. Output in the current firm given match quality r is $y + (v_w I_w + v_f I_f) r$. So turnover occurs if and only if $r < \frac{1}{2}(1-z)$. If there is turnover, then firm profits are zero. If $r \geq {}^{(1-z)}\!/_2$ and there is no turnover, then profits are $\left(v_w I_w + v_f I_f\right)(r - ({}^{(1-z)}\!/_2))$. So expected Period 2 profits, wages, and output are, respectively, the following:

$$\pi_2 = \left(v_w I_w + v_f I_f\right) \int_{\frac{1-z}{2}}^{1} (r - ({}^{(1-z)}\!/_2))\, \mathrm{d}r - c\left(I_f\right),$$

$$w_2 = y + \frac{1}{2}(1-z)\left(v_w I_w + v_f I_f\right),$$

$$Y_2 = y + \left(v_w I_w + v_f I_f\right) \times \left(\int_0^{\frac{(1-z)}{2}} \frac{1}{2}(1-z)\, \mathrm{d}r + \int_{\frac{(1-z)}{2}}^{1} r \mathrm{d}r \right).$$

Equilibrium firm investment, I_f^*, equates the marginal effect of investment on profit to the marginal cost of investment. So I_f^* solves,

$$c'\left(I_f^*\right) = ({}^{v_f}\!/_8)(1+z)^2. \tag{1}$$

The worker's equilibrium investment level, I_w^*, equates the marginal increase in wages from worker investment to the marginal cost of investment.

$$c'\left(I_w^*\right) = \frac{1}{2}(1-z)\, v_w. \tag{2}$$

On the other hand, surplus-maximizing investment levels for the firm and worker, respectively, are I_f^o and I_w^o which solve

$$c'\left(I_f^o\right) = \frac{v_f}{8}\left(4 + (1-z)^2\right), \tag{3}$$

$$c'\left(I_w^o\right) = \frac{v_w}{8}\left(4 + (1-z)^2\right). \tag{4}$$

Looking at Equations (3) and (4), the surplus-maximizing investment level for the worker is greater than the firm's if and only if $v_w > v_f$. However, comparing equilibrium investment levels in Equations (1) and (2), we see that this is not the case. Since $\frac{1}{2}(1-z) < (2-(1-z))^2$, even if $v_w > v_f$, worker investment levels can be lower than the firm's in equilibrium. The proposition below describes the equilibrium investments and turnover in Period 2 and compares it to the surplus-maximizing outcome.

PROPOSITION 1. *If firms use CNCs to restrict the transfer of human capital and CNC strength is z, then the following is true in the Period 2 equilibrium.*

(a) Turnover occurs if and only if $r < {}^{(1-z)}\!/_2$.

(b) $I_w^* < I_w^o$ *and the underinvestment by workers increases as z increases.*

(c) $I_f^* < I_f^o$ *and the underinvestment by firms decreases as z increases.*

The proposition highlights inefficiencies in both firm and worker investment levels in the presence of CNCs. Both the firm and the worker underinvest. The worker underinvests because retention wages rise slower than output with investment. Further as z increases, the retention wage becomes less sensitive to investment so that I_w^* decreases as z increases. Looking at optimal investment in (4), we see that I_w^o is also decreasing in z. However, the rate at which I_w^o falls is lower than the fall in I_w^*. This is because a higher z makes profits more sensitive to worker investment and this partially offsets the negative effect on retention wages in total surplus.

Part (c) shows that the firm also invests less than the surplus-maximizing level because the retention wage, $({}^{(1-z)}\!/_{2})\left(v_w I_w + v_f I_f\right)$, increases with investment and hence firms cannot appropriate all gains in output from their investment. But a higher z alleviates this investment hold-up. From (1) and (3), we see that whereas I_f^* increases with z, the optimal investment falls as z increases, thus bringing the two investment levels closer. This result conforms to previous research on the effects of turnover on firms' incentives to provide general training to its workers. For example, Moen and Rosen (2004) show that firms underinvest in training when they cannot write long-term wage contracts with their employees. Similarly, Stevens (1996, 2001) argues that the possibility of workers being poached by competing firms leads to lower than efficient levels of worker training. Our result extends this well-established finding by allowing the employment contract between the worker and the firm to influence the extent of the underinvestment.

B. Equilibrium and Optimal Employment Contracts

As the analysis in the previous section shows, a higher level of z implying greater restrictions on worker mobility enhances firm investment, but depresses worker investment. This affects both firm profits as well as surplus. Further z also affects worker turnover as the cut-off match quality for retaining a worker $\frac{1}{2}(1-z)$ is decreasing in z. Because the firm only earns positive profits on the workers it retains, the turnover effect of CNCs on profits is always favorable. By contrast, CNCs distort the allocation of firms with workers based on match quality. Comparing actual output across the two firms in Period 2, we see that a worker is on average more productive in the other firm if and only if $y + r\left(v_w I_w + v_f I_f\right) < y + \frac{1}{2}\left(v_w I_w + v_f I_f\right)$, that is, $r < \frac{1}{2}$. For $z > 0$, $\frac{1}{2}(1-z) > \frac{1}{2}$ and hence CNCs produce less than optimal turnover and this distortion worsens as z increases.

As long as the worker faces liquidity constraints, she cannot elicit the surplus-maximizing level of CNC restrictions by making ex ante payments to the hiring firm in Period 1 to compensate for the higher Period 2 wages following firm investments. It then follows that the trade-off in profits faced by the firm differs from the trade-off in total surplus, so that the firm's choice of z in the Period 1 employment contract deviates from the second-best efficient level that maximizes total surplus. Below, we first describe the equilibrium, z^*. We then show the conditions under which regulatory policies on the enforcement of CNCs can impact total surplus.

First let us look at how the firm chooses z to maximize its own profits. The derivative of $\pi_2(z)$ with respect to z, given that I_f^* is subsequently chosen to maximize profits is

$$({}^{\mathrm{d}}\!/_{\mathrm{d}z})\,\pi_2(z) = v_w\,{}^{\mathrm{d}I_w^*}\!/_{\mathrm{d}z}\int_{\frac{1-z}{2}}^{1}\left(r - \frac{(1-z)}{2}\right)\mathrm{d}r + \left(v_w I_w^* + v_f I_f^*\right)\frac{(1+z)}{4}.$$

Since ${}^{\mathrm{d}I_w^*}\!/_{\mathrm{d}z} < 0$, the firm loses profits through lower worker investment. However, as the second term in the above derivative shows, a higher z lowers worker turnover and hence increases the range of match quality where the firm can earn positive profits on the worker. Thus, the firm chooses z^* to balance out the worker investment effect and the turnover effect. The following proposition describes the equilibrium employment contract chosen by the firm in Period 1. We define $\lambda = {}^{v_w}\!/_{v_f}$ which represents the marginal rate of technical substitution between worker and firm investment.

PROPOSITION 2. *The firm always chooses a CNC with strength, $z^* > 0$ in its employment contract. There exists $\widehat{\lambda}$ such that $z^* = 1$ if and only if $\lambda \leq \widehat{\lambda}$. For every $\lambda > \widehat{\lambda}$, $z^* \in (0, 1)$ and it solves* $({}^{\mathrm{d}\pi_2(z)}\!/_{\mathrm{d}z})\,|_{z^*} = 0.$

The above proposition describes the effect of λ on how restrictive the firm's choice of CNC is. If worker investment is relatively less important, the firm chooses the strongest possible restrictions on worker mobility through its CNC.

We now turn to the optimal CNC strength that maximizes total surplus. The derivative of total surplus, $S_2(z) = Y_2(z) - c\left(I_f^*\right) - c\left(I_w^*\right)$ with respect to z is:

$$({}^{\mathrm{d}S_2(z)}\!/_{\mathrm{d}z}) = \left({}^{\mathrm{d}I_w^*}\!/_{\mathrm{d}z}\right)\left\{v_w\left(\int_0^{\frac{(1-z)}{2}}\frac{1}{2}(1-z)\,\mathrm{d}r + \int_{\frac{(1-z)}{2}}^{1} r\mathrm{d}r\right) - c'\left(I_w^*\right)\right\} - \left\{\frac{1}{4}\left(v_w I_w^* + v_f I_f^*\right)(1-z)\right\}$$

$$+ {}^{\mathrm{d}I_f^*}\!/_{\mathrm{d}z} \left\{ v_f \left(\int_0^{\frac{(1-z)}{2}} \frac{1}{2}(1-z)\,\mathrm{d}r + \int_{\frac{(1-z)}{2}}^{1} r\mathrm{d}r \right) - c'\left(I_f^*\right) \right\}.$$

As the above expression shows, there are three effects of a higher z on total surplus. First as with profits, lower worker investment decreases output and hence lowers surplus. However, lower worker investment affects every worker's output, while lower investment only affects the profits from retained workers (i.e., workers with $r \in \left[{}^{1-z}\!/_2, 1\right]$). Hence, this effect is stronger on surplus than on profits. Second, turnover efficiency is worsened as workers are misallocated across firms with respect to match quality. In contrast, the turnover effect of a higher z is positive on profits. Finally, surplus is improved as firms invest more in the presence of stronger CNCs. This effect is absent in profits because the firm optimizes its investment decision to maximize profits. Overall, comparing the effects of z on surplus and profits, $({}^{\mathrm{d}S_2(z)}\!/_{\mathrm{d}z}) \leq ({}^{\mathrm{d}\pi_2(z)}\!/_{\mathrm{d}z})$, so that the profit maximizing choice of labor mobility restrictions is greater than the surplus-maximizing level.

PROPOSITION 3. *Let* z^o *represent the optimal CNC strength. There exist* $\widehat{\lambda}_1^o$ *and* $\widehat{\lambda}_2^o$ *where* $\widehat{\lambda}_1^o < \widehat{\lambda}_2^o < \widehat{\lambda}$ *such that the following is true in the optimal employment contract in Period 1:*

(a) If $\lambda \leq \widehat{\lambda}_1^o$, *then* $z^o = z^* = 1$.

(b) If $\widehat{\lambda}_1^o < \lambda < \widehat{\lambda}_2^o$, *then* $0 < z^o < 1$, *where* z^o *solves* $({}^{\mathrm{d}}\!/_{\mathrm{d}z})\, S_2(z^o) = 0$ *and* $z^o < z^*$.

(c) If $\lambda \geq \widehat{\lambda}_2^o$, *then* $z^o = 0$, *that is, CNCs are not optimal.*

Comparing Propositions 2 and 3 we see that, when $\lambda \geq \widehat{\lambda}_2^o$, the firm chooses a CNC contract even though employment restrictions are never optimal. Further, even if the existence of CNCs may be optimal as shown in part (b) of Proposition 3, the firm places inefficiently high employment restrictions. This provides a justification for regulatory restrictions on the enforcement of CNCs observed in various states across the United States. At the same time, the results also demonstrate the importance of a nuanced approach to regulation rather than an outright prohibition on enforcing such agreements. Because labor mobility restrictions can serve an efficient role by enhancing firm investments, states should allow firms to negotiate CNCs with their employees. Further, as part (a) of the above Proposition shows, if firm investment is productive enough relative to worker investment, regulatory restrictions around what is permitted in employment contracts may be altogether unnecessary. Section V discusses specific policy implications that arise from this result in greater detail.

Notwithstanding the regulations on the terms of CNCs between workers and firms, employers may be able to use other means of restricting worker mobility. One such alternative is a no poaching agreement between competing employers. In the following section, we describe how the likelihood of such collusion is impacted by CNC regulations.

IV. NO POACHING AGREEMENTS AND EMPLOYER COLLUSION

Over the last few years, the Antitrust Division of the U.S. Department of Justice has investigated claims of employer collusion in the recruiting practices of several high-technology firms. The investigation led to a series of civil lawsuits and most recently a class action lawsuit against large Silicon Valley firms including Apple, Google, Intel, eBay, and Adobe. Although explicitly illegal, these firms allegedly used no poaching agreements to reduce labor market competition and hence drive down worker wages. In this section, we analyze the firm's decision to collude with raiding firms in the presence of regulatory restrictions on CNCs.

Although a no poaching agreement, as with any firm-level collusion, is illegal and can never be enforced in court, in our view it is much more difficult to enforce laws against such practices relative to CNCs. There are several reasons for this. First, many collusive agreements are likely to be tacit and even if there is explicit communication between the parties, it is often difficult to establish a paper trail to prove collusion.[8] Second, lawsuits based on noncompete agreements are usually initiated by firms against workers, whereas litigation on no poaching agreements typically involves class action lawsuits brought on by employees. The latter is procedurally much more difficult because common harm needs to

8. The class action lawsuit against Apple, Google, Intel, eBay, and Adobe sought billions of dollars in damages under antitrust law. Yet, the companies settled for an estimated $300 million and denied violating any laws (Streitfeld 2014).

be proved first. Thus, with this presumption, we show that regulatory restrictions on CNCs can have unintended consequences of incentivizing no poaching agreements which may hurt labor mobility and surplus.

Suppose the firm can enter into a no poaching agreement with the raiding firms in Period 2. This is effectively the same as the firm choosing $z = 1$ in Period 1 because it completely eliminates any possibility of turnover and drives worker wages to $w_2 = y$. Because worker wages under collusion do not depend on investment, workers do not invest at all, that is, $I_w^*(1) = 0$. In this section, we consider two questions concerning the existence of such collusive agreements between firms. First, we look at how regulations on CNCs can incentivize no poaching agreements. Second, we describe how optimal CNC enforcement changes when no poaching agreements are taken into account.

We begin by taking the regulatory constraint as given in order to analyze how it affects the incidence of no poaching agreements. Let z^R denote the maximum CNC strength enforceable under state law. Then firms are constrained to choose $z < z^R$. Note that under perfect CNC enforcement, that is, if $z^R = 1$, the firm always weakly prefers CNCs over no poaching agreements because CNCs offer a better tool to balance out the positive and negative effects of employment restrictions on profits.[9] Similarly, if regulations are weak so that the regulatory constraint does not bind, that is, if $z^* \le z^R$, the firm never chooses to collude with its competitors.

In order to analyze the collusive agreement, we frame the problem as a repeated game where the three firms—the investing firm and the two raiding firms—carry out the collusive strategy across infinite periods.[10] For simplicity, let us call the investing firm, i and denote the raiding firms by j. Let $\delta \in (0, 1)$ be the discount rate for future profits. In a collusive agreement, firm i shares a portion of its gains from the no poaching agreement with each of the two raiding firms. So a necessary condition for collusion to occur is that the profits to firm i from colluding must be greater than its profits from not colluding and instead using a noncompete agreement under the regulatory restriction, that is, $\pi_{2i}(z^R) \le \pi_{2i}(1)$. From Proposition 2, we know that for $\lambda \le \widehat{\lambda}$, $z^* = 1$, which means that $\pi_{2i}(1) \ge \pi_{2i}(z^R)$ for all z^R. Now let us see what happens to $\pi_{2i}(z^R) - \pi_{2i}(1)$ as λ increases above $\widehat{\lambda}$. Here, the firm's profits are concave in z^R. Note that after applying the envelope theorem, a higher λ affects $\pi_{2i}(z^R)$ only through an increase in the value of worker investment. Because the firm chooses its investment to maximize profits, any effect of λ on firm investment is internalized through profit maximization. Thus, $\left({}^{d\pi_{2i}(z^R)}/_{d\lambda}\right) > 0$ for all $z^R < 1$. As worker investment is zero under collusion, $\pi_{2i}(1)$ is independent of λ. As a result, for every $z^R < 1$, as λ increases above $\widehat{\lambda}$, the difference $\pi_{2i}(z^R) - \pi_{2i}(1)$ increases. When λ is sufficiently high, the difference is positive for all z^R making a no poaching agreement unprofitable despite CNC regulations. We define this cut-off level of λ as $\widetilde{\lambda}^c$. Similarly, when $\widehat{\lambda} < \lambda < \widetilde{\lambda}^c$, collusion is not profitable if enforcement is very permissive, that is, if z^R is high. Let us define this cut-off as $\widehat{z}^R$. Figure 1(A)–1(C) elucidates the above reasoning more clearly and the lemma below states this result.

LEMMA 1. *There exists $\widetilde{\lambda}^c > \widehat{\lambda}$ such that the following is true:*

(a) If $\lambda \le \widehat{\lambda}$, then $\pi_{2i}(1) \ge \pi_{2i}(z^R)$ for all $z^R > 0$.

(b) If $\widehat{\lambda} < \lambda \le \widetilde{\lambda}^c$, there exists $\widehat{z}^R < z^*$ such that $\pi_{2i}(1) \ge \pi_{2i}(z^R)$ if and only if $z^R \le \widehat{z}^R$, where $\widehat{z}^R$ solves $\pi_2(\widehat{z}^R) = \pi_2(1)$.

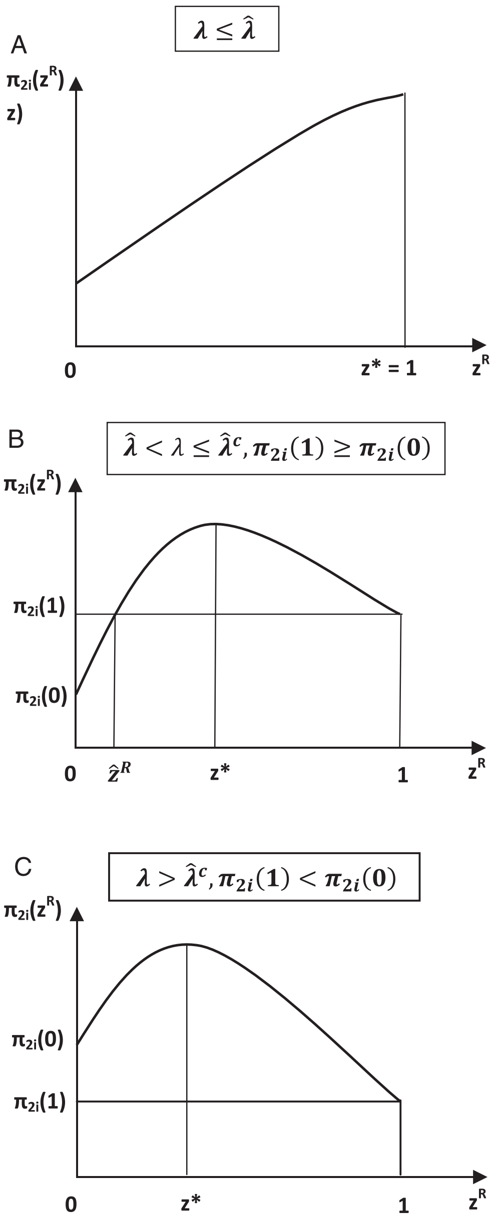
(c) If $\lambda > \widetilde{\lambda}^c$, $\pi_{2i}(1) < \pi_{2i}(z^R)$ for all $z^R \ge 0$ and hence the firm never chooses a no poaching agreement.

Lemma 1 shows that if worker investment is very important to output, then regulation does not affect the incentives to collude. This is because very high restrictions on employee mobility depress worker incentives for investment which has a significant negative impact on output and profits. When this is the case, the firm always finds it more profitable to allow some degree of worker mobility. Moreover, from Lemma 1, we see that firm i makes higher profits with collusion if $\lambda \le \widehat{\lambda}$ or if $\widehat{\lambda} < \lambda \le \widetilde{\lambda}^c$ and $z^R \le \widehat{z}^R$, suggesting the possibility of collusion between the employers. This is however not sufficient to guarantee the existence of a collusive equilibrium as firm i may not be able to prevent a deviation by raiding firms from the collusive agreement. In other words, firm i must be able to share a large

9. The assumption here is that as long as CNCs are legal, firms can negotiate the CNC contract in a transparent way with their employees. On the other hand, the illegality of no poaching agreements inherently makes it difficult to negotiate worker turnover in a continuous manner without increasing the visibility of the collusive act.

10. See Mukherjee and Vasconcelos (2012).

FIGURE 1
CNC Regulation and Firm Profits



enough portion of its profits with the raiders to prevent them from hiring the worker after investment has occurred. Below, we describe the conditions under which collusion is profitable for firm i and the raiding firms under the parameter restrictions laid in part (a) of Lemma 1.[11]

11. The basic logic follows for part (b) as well.

Suppose, in the collusive agreement, firm i keeps a share $\alpha \in (0, 1)$ of the profits for itself and splits the remaining $(1 - \alpha)$ share equally among the two raiding firms. This means that given a discount rate of δ, the continuation payoff to each raiding firm in the collusive strategy is $\left|\left({}^{(1-\alpha)}/_{2}\right)\right| \pi_{2i}(1)\left({}^{\delta}/_{1-\delta}\right)$. In order for this strategy to be profitable for firm i, $\alpha\pi_{2i}(1) > \pi_{2i}(z^R)$ or

$$(5) \qquad \alpha > \left({}^{\pi_{2i}(z^R)}/_{\pi_{2i}(1)}\right).$$

Let us assume a punishment strategy that dissolves the collusion if a deviation occurs. This means that the raiding firms earn zero profits in every period following a deviation. If firm i follows its collusive strategy and invests $I_f^*(1)$, the worker's output in a raiding firm is $y + \left(1 - z^R\right) v_f I_f^*(1)$. So if a raiding firm deviates and poaches the worker at wage y, given that the other raiding firm and firm i follow the collusive strategy, it earns a one-time profit of $\left(1 - z^R\right) v_f I_f^*(1)$. Hence, given the discount rate δ, a deviation is not profitable if and only if $\left({}^{(1-\alpha)}/_{2}\right) \pi_{2i}(1)\left({}^{\delta}/_{1-\delta}\right) > \left(1 - z^R\right) v_f I_f^*(1)$, or

$$(6) \qquad \alpha < 1 - {}^{2(1-\delta)}/_{\delta}\left(1 - z^R\right) {}^{v_f I_f^*(1)}/_{\pi_{2i}(1)}.$$

Thus, in order for collusion to be possible in equilibrium, both (5) and (6) must simultaneously hold, that is, ${}^{\pi_{2i}(z^R)}/_{\pi_{2i}(1)} < 1 - \left({}^{2(1-\delta)}/_{\delta}\right)\left(1 - z^R\right) {}^{v_f I_f^*(1)}/_{\pi_{2i}(1)}$, or

$$(7) \qquad \Omega\left(z^R\right) = \left[\pi_{2i}(1) - \pi_{2i}\left(z^R\right)\right] - \left(2(1-\delta)/\delta\right)\left(1 - z^R\right) v_f I_f^*(1) > 0.$$

In (7) above, the function $\Omega(z^R)$ represents the likelihood of collusion among employers. The first term in square brackets represents the total profit gained through collusion, while the second term denotes the deviation profits to the raiding firm. It is clear that the likelihood of collusion depends on CNC regulations, z^R, the discount rate, δ, and the relative worker investment productivity, λ. Moreover, the marginal effect of z^R, ${}^{d}/_{dz^R}\Omega\left(z^R\right)$, also depends on λ.

Let us begin by looking at how z^R affects $\Omega(z^R)$. There are two effects of weakening noncompete enforcement. First a decrease in z^R decreases the baseline profit of firm i without collusion, (i.e., ${}^{d\pi_{2i}(z^R)}/_{dz^R} > 0$). This increases the profitability of collusion. However, there is also a counteracting effect as deviations by the raiding firm become more profitable with weaker CNC enforcement. Because the baseline profits are sensitive to worker investment, while the raiding firm's deviation profits are not, the strength of the two effects depends on λ. In general, we find that when λ is high, weak enforcement of CNCs (i.e., low z^R) makes collusion more likely to occur. In contrast, when λ is low, both very permissive CNC enforcement (or high z^R) and very weak enforcement may favor collusion.

To see why this is the case, let us look at how collusion is affected at the two extremes of z^R. First look at a situation where we have perfect CNC enforcement (i.e., $z^R = 1$). From (7), $\Omega(1) = 0$ implying that firm i is indifferent between colluding and not colluding. Now consider a small decrease in CNC enforcement. Because z^R is high, worker investment is insignificant even in the absence of collusion, while firm i's investment is substantial. Hence, a high λ makes the firm's baseline profits less sensitive to z^R. Thus, the increase in collusive profits is smaller than the increase in deviation gains, and the overall effect makes collusion undesirable when z^R is lowered slightly below 1. On the other hand, when λ is low implying that firm investment is relatively very productive, there is a big decrease in profits from weaker CNC enforcement at high levels of z^R. The increase in the collusion profits outweighs the increase in deviation incentive making collusion possible.

At the other end, when there is zero enforcement, that is, $z^R = 0$, worker investment is high in the absence of collusion. So a small increase in z^R has a larger impact on firm i's baseline profits when λ is high so as to outweigh the decrease in deviation incentive. In this case, we see that as enforcement increases, collusion becomes more difficult. By the reverse logic, when λ is low, the impact of lower enforcement on the raiders' deviation profits is greater than the reduction in collusion gains. As a result, collusion becomes more likely as enforcement increases.

Proposition 4 below explains how λ and δ determine the impact of z^R on collusion. In order to restrict the number of cases to consider, we assume that δ is high enough to ensure that collusion is possible under zero enforcement (i.e., $\Omega(0) \geq 0$). Let $\underline{\delta}$ denote the cut-off where $\Omega\left(0; \underline{\delta}\right) = 0$, then we assume $\delta \geq \underline{\delta}$.

PROPOSITION 4. *There exists* $\widehat{\lambda}^L < \widehat{\lambda}$ *and for every* $\lambda < \widehat{\lambda}^L$ *there exists* $\overline{\delta} \in \left[\underline{\delta}, 1\right]$ *such that collusion always exists if* $\lambda < \widehat{\lambda}^L$ *or* $\delta > \overline{\delta}$. *Additionally, there exists* $\widehat{\lambda}_1$ *with* $\widehat{\lambda}^L < \widehat{\lambda}_1 < \widehat{\lambda}$ *such that a collusive equilibrium also exists in the following cases.*

(a) $\widehat{\lambda}^L \leq \lambda \leq \widehat{\lambda}_1$, $\delta \leq \overline{\delta}$ *and either* $z^R < \tilde{z}_1^R$ *or* $z^R > \tilde{z}_2^R$, *where* $\tilde{z}_1^R \in (0, 1)$ *and* $\tilde{z}_1^R \in \tilde{z}_2^R, 1)$.

(b) $\lambda \geq \widehat{\lambda}_1$, $\delta \leq \overline{\delta}$, *and* $z^R < \tilde{z}_1^R$.

Proposition 4 provides a number of interesting policy implications. First the result that weak enforcement of CNCs increases the likelihood of collusion speaks to the alleged no poaching agreements among Silicon Valley firms. The fact that California law makes noncompetes unenforceable may have made collusion more attractive to employers. At the same time, part (a) of the proposition suggests that very permissive enforcement of CNCs may also favor collusion but only if worker investment is relatively less productive. The large number of start-ups and spin-offs from employees in Silicon Valley may be indicative of a high λ. Our results suggest that collusion in Silicon Valley is less likely to have occurred if the California courts had enforced CNCs. At the same time, we should apply caution in designing CNC regulations in other situations where industry growth depends primarily on firm-level worker training. In those cases, both very permissive and very weak enforcement can facilitate employer collusion.

Finally, we derive optimal CNC regulation when we account for the possibility of employer collusion.

PROPOSITION 5. *When the firm can use a no poaching agreement to restrict turnover the following is true about optimal CNC regulation (denoted by* z^{co}*). If* $\lambda < \widehat{\lambda}^L$ *or* $\delta > \overline{\delta}$, *then CNC regulation has no affect on surplus. In every other case,* $z^{co} = \tilde{z}_1^R \geq z^o$.

Proposition 5 suggests that the optimal CNC contract entails weakly higher restrictions on labor mobility when firms can use no poaching agreements. Thus, we find that focusing regulation on employment contracts may incentivize other types of market conduct that have much worse impacts on social surplus than noncompete agreements.

V. DISCUSSION

There are a number of takeaways from the analysis presented in this article. First, our result in Proposition 3 that noncompete clauses are not efficient when worker investment is very important to output supports the widely accepted argument that the California law prohibiting CNCs in employment contracts played a role in the success of the high-technology industry in Silicon Valley. There is a general belief that much of the innovation in the high-technology industry is employee-driven as suggested by the proliferation of start-ups by former employees. To the extent that worker investment is more productive than firm investment implying a high λ in our model, our result would imply that California's prohibition on CNCs has some merit and may well have played an important role in the Silicon Valley success story.

However, a more general policy implication of Propositions 2 and 3 is that noncompete enforcement policy should take into account occupation or industry-specific differences in the type of human capital investment that occurs. In certain labor markets, such as healthcare, where firm-sponsored training for employees is widespread, allowing employers to negotiate mobility restrictions with their workers facilitates such investment which is surplus enhancing.[12] At the same time, if the growth of certain industries is strongly dependent on incentivizing workers to invest and productively use their human capital through a competitive wage setting process, it may be desirable to carve out exceptions to the enforceability of noncompetes in those cases rather than weaken enforcement across the board irrespective of industry specifics. An example is a recent legislation passed in Hawaii, which selectively bans noncompetes for employees in the technology sector.[13]

It is also important to recognize that the use of noncompetes is not the only way in which employers can restrict labor mobility and regulations that make it more difficult for CNCs to be enforced can have spillover effects. Tightening the rules around legal contractual arrangements between firms and their employees may incentivize employers to seek out less desirable and often unlawful alternatives such as no poaching agreements with other potential competitors in the labor market. Our findings in Propositions 4 and 5 thus suggest further caution in weakening noncompete enforcements when it increases the likelihood of collusion in the labor market. There has been an increasing trend among various state legislatures and courts to tighten the requirements under which noncompetes are enforceable. Massachusetts, Michigan, and Washington have proposed legislation that would severely restrict or ban noncompetes.[14] Recent court decisions in Illinois and New Hampshire have also made it harder for employers to enforce CNCs.[15] However, we argue that, unless the weakening of enforcement is accompanied by more aggressive prosecutorial vigilance toward employer collusion, it is likely to be ineffective and may even be counter-productive.

Finally, our results suggest clues as to where employer wage collusion is more likely to be present. A prosecutor looking to pursue antitrust litigation is most likely to find such collusion in industries where firm investment is very important and in states with weak noncompete enforcement. The employer collusion in Silicon Valley suggests a correlation between noncompete enforcement and the use of no poaching agreements. Employer wage collusion has also been observed in the healthcare sector. In one recent case, hospitals in Detroit were accused of agreeing to regularly exchange information on the compensation of Registered Nurse employees and to suppress their wages.[16] Michigan has famously permissive regulations when it comes to the enforcement of CNCs. Yet our findings in Proposition 4(a) would predict employer collusion in this case due to the presence of significant investments in general human capital by the firm. Many hospitals provide financial support to local nursing schools and also provide tuition assistance to nurses to enable them to become nurse practitioners. The need to protect these large human capital investments by hospitals creates incentives for collusion. At the same time, permissive noncompete enforcement strengthens the collusive mechanism by making it less profitable to deviate.

VI. CONCLUSION

Much of the previous research on CNCs has focused on their negative impact on labor mobility and the free flow of knowledge across firms. Under this reasoning, there has been a general consensus to restrict their enforcement under state laws. However, the literature on firm training has recognized the problem of investment hold-up created by worker turnover. Yet, the role of CNCs in alleviating this hold-up of

12. See Benson (2013), Lavetti et al. (2015), and Starr (2015).
13. See Zillman (2015).
14. See Benzoni (2015).
15. See Zappe (2013).
16. See Walsh (2014).

firm investment has not received much attention among researchers. In this article, we provide an integrated theoretical framework for analyzing the trade-offs presented by CNCs as they lower worker investment but improve firm investment.

By posing this problem in a wider framework than the current literature does, we first solve the equilibrium employment contract that firms sign with their workers. Unlike earlier papers that viewed the firms' CNC decision as binary choice of whether or not to use such contracts, we derive the strength of labor mobility restrictions chosen in the CNC in equilibrium. Similarly, given that regulatory restrictions surrounding CNC enforcement also vary considerably across jurisdictions, we also derive the socially optimal level of labor mobility restrictions. After comparing the equilibrium and optimal outcomes, we find that in some cases the firm restricts labor mobility more than is optimal, suggesting the need for regulation to serve as a corrective mechanism in those situations.

Finally, given recent events surrounding the use of no poaching agreements by important Silicon Valley firms such as Google and Apple, we further extend our inquiry to account for employer collusion in designing optimal CNC regulations. We find surprising lessons from a policy perspective given this possibility. We show that zero enforcement of CNCs, such as in California, may worsen labor mobility by incentivizing employer collusion through no poaching agreements. Thus, we argue for a cautious approach toward the enforcement of CNCs by taking all significant market ramifications of such regulations into account.

APPENDIX

Proof of Proposition 1

(a) Turnover occurs if and only if the expected output for a worker in a new firm is greater than her output in the current firm, that is, if and only if $y + \left({}^{(1-z)}\!/_2\right)\left(v_w I_w + v_f I_f\right) \geq y + r\left(v_w I_w + v_f I_f\right)$, or $r \leq \left({}^{(1-z)}\!/_2\right)$.

Without CNCs, the actual output of the worker in a new firm is $y + \frac{1}{2}\left(v_w I_w + v_f I_f\right)$, and hence turnover is efficient if and only if $r \leq \frac{1}{2}$. Since ${}^{(1-z)}\!/_2 \leq \frac{1}{2}$, turnover is suppressed even though it is efficient for ${}^{(1-z)}\!/_2 < r \leq \frac{1}{2}$.

(b) The worker's equilibrium investment level is $c'\left(I_w^*\right) = \frac{1}{2}(1-z)v_w$. The surplus is $S_2 = y + \frac{1}{8}\left(v_w I_w + v_f I_f\right)\left(4 + (1-z)^2\right) - c\left(I_f\right) - c\left(I_w\right)$. So the surplus-maximizing investment level for workers is $c'\left(I_w^o\right) = \frac{v_w}{8}\left(4 + (1-z)^2\right)$. $c'\left(I_w^o\right) - c'\left(I_w^*\right) = \frac{v_w}{8}(1+z)^2 > 0$. Hence, $I_w^o > I_w^*$. $({}^{d}\!/_{dz})\left[c'\left(I_w^o\right) - c'\left(I_w^*\right)\right] = ({}^{v_w}\!/_4)(1+z) > 0$. Hence, $I_w^o - I_w^*$ is increasing in z.

(c) The expected profits of the firm are $\pi_2 = \frac{1}{8}\left(v_w I_w + v_f I_f\right)(1+z)^2 - c\left(I_f\right)$. Hence, the equilibrium level of firm investment is $c'\left(I_f^*\right) = ({}^{v_f}\!/_8)(1+z)^2$ and the surplus-maximizing level firm investment is $c'\left(I_f^o\right) = ({}^{v_f}\!/_8)\left(4 + (1-z)^2\right)$. $c'\left(I_f^o\right) - c'\left(I_f^*\right) = ({}^{v_f}\!/_2)(1-z) > 0$, so $I_f^o > I_f^*$. $\frac{d}{dz}\left[c'\left(I_f^o\right) - c'\left(I_f^*\right)\right] = ({}^{-v_f}\!/_2) < 0$, so $I_f^o - I_f^*$ is decreasing in z. ■

Proof of Proposition 2

The expected Period 2 profits of the firm given equilibrium investment and its higher order derivatives with respect to z are as follows.

$$\pi_2^* = \left({}^{(1+z)^2}\!/_{128}\right) v_f^2 \left[8(1-z)\lambda^2 + (1+z)^2\right],$$

$$d\pi_2^*/dz = \left({}^{(1+z)v_f^2}\!/_{32}\right)\left[2(1-3z)\lambda^2 + (1+z)^2\right],$$

$$d^2\pi_2^*/dz^2 = \left({}^{v_f^2}\!/_{32}\right)\left\{-4(1+3z)\lambda^2 + 3(1+z)^2\right\},$$

$$d^3\pi_2^*/dz^3 = \left({}^{v_f^2}\!/_{32}\right)\left\{-12\lambda^2 + 6(1+z)\right\}.$$

First note that for $z \leq \frac{1}{3}$, profits are always increasing. So $z^* > \frac{1}{3}$. Let us look at $z > \frac{1}{3}$.

At $z = \frac{1}{3}$, $d^3\pi_2^*/dz^3 = \left({}^{v_f^2}\!/_{32}\right)\left\{-12\lambda^2 + 8\right\} > 0$ if and only if $\lambda^2 < \frac{2}{3}$. At $z = 1$, $d^3\pi_2^*/dz^3 = \left({}^{v_f^2}\!/_{32}\right)\left\{-12\lambda^2 + 12\right\} > 0$ if and only if $\lambda^2 < 1$.

(1) $\lambda^2 \leq \frac{2}{3}$, then $d^3\pi_2^*/dz^3 \geq 0$ so that $d^2\pi_2^*/dz^2$ is increasing in z. At $z = \frac{1}{3}$, $d^2\pi_2^*/dz^2 = \left({}^{v_f^2}\!/_{32}\right)\left\{-8\lambda^2 + \frac{16}{3}\right\} \geq 0$ if and only if $\lambda^2 \leq \frac{2}{3}$ which is true. This means that $d^2\pi_2^*/dz^2 \geq 0$ for all z and hence $d\pi_2^*/dz \geq 0$ for all z. So $z^* = 1$.

(2) $\frac{2}{3} < \lambda^2 \leq 1$, then $\left[d^3\pi_2^*/dz^3\right]_{z=\frac{1}{3}} < 0$ and $\left[d^3\pi_2^*/dz^3\right]_{z=1} \geq 0$. $d^2\pi_2^*/dz^2$ is convex in z with a minimum at $z = 2\lambda^2 - 1$. $\left[d^2\pi_2^*/dz^2\right]_{z=\frac{1}{3}} < 0$ for all $\lambda^2 > \frac{2}{3}$. $\left[d^2\pi_2^*/dz^2\right]_{z=1} < 0$ if and only if $\lambda^2 > \frac{3}{4}$.

(2.1) $\frac{2}{3} < \lambda^2 \leq \frac{3}{4}$, then $\left[d\pi_2^*/dz\right]_{z=1} > 0$ and $\left[d^2\pi_2^*/dz^2\right]_{z=1} \geq 0$. Since $\left[d\pi_2^*/dz\right]_{z=\frac{1}{3}} > 0$ and $\left[d^2\pi_2^*/dz^2\right]_{z=\frac{1}{3}} < 0$, this means that $d\pi_2^*/dz$ reaches a minimum at $\left[d^2\pi_2^*/dz^2\right]_{z^{\min}} = 0$, that is, where $-4(1+3z^{\min})\lambda^2 + 3(1+z^{\min})^2 = 0$. $\min d\pi_2^*/dz = \left({}^{(1+z^{\min})v_f^2}\!/_{32}\right)\left[2\left(1-3z^{\min}\right)\lambda^2 + \left(1+z^{\min}\right)^2\right] = \left({}^{(1+z^{\min})v_f^2\lambda^2}\!/_{48}\right)\left[5 - 3z^{\min}\right] > 0$. Thus, $d\pi_2^*/dz > 0$ so that $z^* = 1$.

$2(1-3z)\lambda^2 + (1+z)^2 = 0$, $\left({}^{v_f^2\lambda^2}\!/_{16}\right)\{-5 + 5z\} < 0$. So the z^* that solves $d\pi_2^*/dz = 0$ is a maxima. This means that if at $z = 1$, $d\pi_2^*/dz > 0$, $z^* = 1$.

(2.2) $\frac{3}{4} < \lambda^2 \leq 1$, then $d^2\pi_2^*/dz^2 < 0$ and π is concave but $\left[d\pi_2^*/dz\right]_{z=1} \geq 0$. So again $z^* = 1$.

(3) $\lambda^2 > 1$, then π is concave in z and $\left[d\pi_2^*/dz\right]_{z=\frac{1}{3}} > 0$ and $\left[d\pi_2^*/dz\right]_{z=1} < 0$. Hence, z^* solves $\left[d\pi_2^*/dz\right]_{z^*} = 0$.

Hence let us define, $\widehat{\lambda} = 1$. ■

Proof of Proposition 3

The expected Period 2 surplus at I_w^* and I_f^* and its higher order derivatives with respect to z are as follows.

$$S_2(z) = y + \left({}^{v_f^2}\!/_{128}\right)\left[\left(8\lambda^2 + 1\right)\left(3 + z^2 - z^3 - 3z\right) + 5z\right],$$

$$^{\mathrm{d}}/_{\mathrm{d}z} S_2(z) = \left(^{v_f^2}/_{128}\right)\left[-\left(8\lambda^2+1\right)\left(3z^2-2z\right)-24\lambda^2+5\right],$$

$$\left(^{\mathrm{d}^2}/_{\mathrm{d}z^2}\right) S_2 = \left(^{v_f^2}/_{64}\right)(1-3z)\left[8\lambda^2+1\right].$$

Let us first look at the shape of $(^{\mathrm{d}}/_{\mathrm{d}z})S_2$. This is concave in z with a max at $z=\frac{1}{3}$. At $z=0$, $(^{\mathrm{d}}/_{\mathrm{d}z})S_2 = \left(^{v_f^2}/_{128}\right)\left[-24\lambda^2+5\right] > 0$ if and only if $\lambda^2 < \frac{5}{24}$. At $z=1$, $(^{\mathrm{d}}/_{\mathrm{d}z})S_2 = \left(^{v_f^2}/_{128}\right)\left[-32\lambda^2+4\right] > 0$ if and only if $\lambda^2 < \frac{1}{8}$. At $z=\frac{1}{3}$, $(^{\mathrm{d}}/_{\mathrm{d}z})S_2 = \left(^{v_f^2}/_{24}\right)\left[-4\lambda^2+1\right] > 0$ if and only if $\lambda^2 < \frac{1}{4}$.

(1) $\lambda^2 < \frac{1}{8}$, then $(^{\mathrm{d}}/_{\mathrm{d}z})S_2 > 0$ for all z. Hence, $z^o=1$. Define $\widehat{\lambda}_1^{o2} = \frac{1}{8}$.

(2) $\frac{1}{8} < \lambda^2 < \frac{5}{24}$, then $(^{\mathrm{d}}/_{\mathrm{d}z})S_2 < 0$ at $z=1$. So S_2 is increases first at an increasing rate, then at a decreasing rate, reaches a maximum and then falls. So, there is a z^o where it reaches a maximum which solves $\left[^{\mathrm{d}S_2}/_{\mathrm{d}z}\right]_{z^o} = 0$.

(3) $\frac{5}{24} < \lambda^2 < \frac{1}{4}$, then S_2 has a global maxima and a minima, that is, two stationary points. So we check the maximum value against the value of the surplus at $z=0$. At $z=0$, $S_2(0) = y + \left(^{3v_f^2}/_{128}\right)\left[8\lambda^2+1\right]$. To find the maximum value, we solve the quadratic equation, $2z^{\max}\left(8\lambda^2+1\right) - 3z^{\max^2}\left(8\lambda^2+1\right) - 24\lambda^2 + 5 = 0$. $^{\mathrm{d}}/_{\mathrm{d}\lambda^2}\left[S_2^{\max} - S_2(0)\right] = \left(^{v_f^2}/_{128}\right)\left[8(1-z)\left(3+z^2\right)\right] - \left(^{v_f^2}/_{128}\right)24 < 0$. At $\lambda^2 = \frac{5}{24}$, $S_2^{\max} > S_2(0)$. At $\lambda^2 = \frac{1}{4}$, $S_2^{\max} < S_2(0)$. Hence, there exists $\widehat{\lambda}_2^{o2} \in \left(\frac{5}{24}, \frac{1}{4}\right)$ such that $S_2^{\max} - S_2(0) > 0$ if and only if $\lambda < \widehat{\lambda}_2^o$. Then, for $\lambda < \widehat{\lambda}_2^o$, z^o solves $\left[^{\mathrm{d}S_2}/_{\mathrm{d}z}\right]_{z^o} = 0$ and for $\lambda > \widehat{\lambda}_2^o$, $z^o = 0$.

(4) $\lambda^2 > \frac{1}{4}$, then $(^{\mathrm{d}}/_{\mathrm{d}z})S_2 < 0$ for all z, so $z^o = 0$. ■

Proof of Lemma 1

From Proposition 2, if $\lambda \le 1$, then $z^* = 1$, so that the profits from collusion are always higher than baseline profits in the presence of any CNC regulation. Hence, $z^{c*} = 1$. If $\lambda > 1$, $\pi_{2i}(z)$ is concave in z. We check if $\pi_{2i}(1) \ge \pi_{2i}(0)$. This is true if and only if $\lambda^2 \le \frac{15}{8}$. Hence, for $1 < \lambda^2 \le \frac{15}{8}$, there exists $\widehat{z}^R$ such that if $z^R < \widehat{z}^R$, $\pi_{2i}(1) \ge \pi_{2i}(0)$. However, if $\lambda^2 > \frac{15}{8}$ or $z^R \ge \widehat{z}^R$, then $\pi_{2i}(z^R) > \pi_{2i}(1)$. $\widehat{z}^R$ solves $\pi_2(\widehat{z}^R) = \pi_2(1)$, that is, $(1+\widehat{z}^R)^2[8(1-\widehat{z}^R)\lambda^2 + (1+\widehat{z}^R)^2] - 16 = 0$. ■

Proof of Proposition 4

Looking at (7),

$$\Omega\left(z^R\right) = \left[\pi_{2i}(1) - \pi_{2i}\left(z^R\right)\right] - \left(^{2(1-\delta)}/_{\delta}\right)\left(1-z^R\right) v_f I_f^*(1)$$

$$= v_f^2\left\{\frac{1}{8} - \left(^{(1+z^R)^2}/_{128}\right)\left[8\left(1-z^R\right)\lambda^2 + \left(1+z^R\right)^2\right] - \left(^{(1-\delta)}/_{\delta}\right)\left(1-z^R\right)\right\}$$

$\Omega(0) \ge 0$ if and only if $\delta \ge (^{128}/_{143-8\lambda^2})$. We assume that $\delta \ge \frac{128}{143}$, so that $\Omega(0) \ge 0$ for all λ. So $\underline{\delta} = \frac{128}{143}$. Further, we also restrict $\lambda^2 < \widehat{\lambda} = 1$. We look at the slopes of $\Omega(z^R)$ at the two extremes, that is, $\left(^{\mathrm{d}\Omega(z^R)}/_{\mathrm{d}z^R}\right)\Big|_{z^R=0}$ and $\left(^{\mathrm{d}\Omega(z^R)}/_{\mathrm{d}z^R}\right)\Big|_{z^R=1}$. $\left(^{\mathrm{d}\Omega(z^R)}/_{\mathrm{d}z^R}\right)\Big|_{z^R=0} < 0$ if and only if $\delta > (^{32}/_{33+2\lambda^2})$ and $\left(^{\mathrm{d}\Omega(z^R)}/_{\mathrm{d}z^R}\right)\Big|_{z^R=1} < 0$ if and only if $\delta > (^{4}/_{5-\lambda^2})$. Following the shape of $\pi_2(z)$ derived in the Proof of Proposition 2, and comparing the various δ cut-offs, we get the following cases to consider.

(a) $\lambda^2 \le \frac{2}{3}$. Then, $^{\mathrm{d}^2\Omega(z^R)}/_{\mathrm{d}z^{R^2}} \le 0$. Since $\Omega(0) \ge 0$, this means that $\Omega(z^R) \ge 0$ for all z^R and hence collusion is always possible. So we define $\widehat{\lambda}^{L^2} = \frac{2}{3}$.

(b) $\frac{2}{3} < \lambda^2 < \frac{3}{4}$. Then $^{\mathrm{d}\Omega(z^R)}/_{\mathrm{d}z^R}$ first decreases, reaches a minimum, then increases reaches a maximum and then decreases again. So, we have to derive the sign of $^{\mathrm{d}\Omega(z^R)}/_{\mathrm{d}z^R}$ over the entire range of z^R.

In this case, $\left(\mathrm{d}\Omega\left(z^R\right)/\mathrm{d}z^R\right)|_{z^R=1} < 0$ and $^{\mathrm{d}\Omega(z^R)}/_{\mathrm{d}z^R}\Big|_{z^R=0} < 0$, whereas by assumption $\Omega(0) \ge 0$. This means that either $\Omega(z^R)$ is decreasing for all z^R so that collusion is always possible; or $\Omega(z^R)$ first decreases reaches a minimum and then increases. To see is the $\min\Omega(z^R) < 0$, note that $\min\Omega(z^R)$ is increasing in δ. At $\delta = 1$, we know that $\min\Omega(z^R) > 0$. At $\delta = \underline{\delta}$, $\Omega(0) = 0$, and hence, $\min\Omega(z^R) < 0$. So there exists $\overline{\delta}$ which solves $\left[\min\Omega\left(z^R\right)\right]_{\delta=\overline{\delta}} = 0$ such that if $\delta \le \overline{\delta}$ then $\Omega(z^R) > 0$ if and only if $z \notin \left(\widetilde{z}_1^R, \widetilde{z}_2^R\right)$ where $0 < \widetilde{z}_1^R < \widetilde{z}_2^R < 1$ are the roots of the equation $\Omega(z^R) = 0$. If $\delta > \overline{\delta}$, then collusion exists for all z^R.

(c) $\frac{3}{4} \le \lambda^2 < 1$. Then $^{\mathrm{d}^2\Omega(z^R)}/_{\mathrm{d}z^{R^2}} \ge 0$.

(i) If $\underline{\delta} \le \delta \le (^{4}/_{5-\lambda^2})$, then $\left(^{\mathrm{d}\Omega(z^R)}/_{\mathrm{d}z^R}\right)|_{z^R=1} \ge 0$. This means that there exists $\widetilde{z}_1^R \in (0,1)$ which solves $\Omega\left(\widetilde{z}_1^R\right) = 0$ such that $\Omega(z^R) > 0$ if and only if $z^R < \widetilde{z}_1^R$.

(ii) If $\delta > (^{4}/_{5-\lambda^2})$, then $\left.\frac{d\Omega(z^R)}{dz^R}\right|_{z^R=1} < 0$, then $\Omega(z^R) > 0$ for all z^R and hence collusion always exists.

Define $\widehat{\lambda}^L = \frac{2}{3}$ and $\widehat{\lambda}_1 = \frac{3}{4}$. ■

Proof of Proposition 5

From Proposition 4, for $\lambda \le \widehat{\lambda}^L$, collusion always exists and hence regulation has no effect on surplus which is always $S(1)$. $\widehat{\lambda}^L > \frac{1}{4}$, so $S(z^R)$ is decreasing in z^R. Hence, for $\lambda > \widehat{\lambda}^L$, $z^{co} = \widetilde{z}_1^R > z^o = 0$. ■

REFERENCES

Acemoglu, D., and J. Pischke. "Why Do Firms Train? Theory and Evidence." *Quarterly Journal of Economics*, 113(1), 1998, 79–119.

———. "The Structure of Wages and Investment in General Training." *Journal of Political Economy*, 107(3), 1999a, 539–72.

———. "Beyond Becker: Training in Imperfect Labour Markets." *Economic Journal*, 109(453), 1999b, 112–42.

Almeida, R., and P. Carneiro. "The Return to Firm Investments in Human Capital." *Labour Economics*, 16, 2009, 97–106.

Benson, A. "Firm-Sponsored General Education and Mobility Frictions: Evidence from Hospital Sponsorship of Nursing Schools and Faculty." *Journal of Health Economics*, 32(1), 2013, 149–59.

Benzoni, F. J. "State Legislatures Reconsider Non-competes," *www.smithlaw.com*, May 14, 2015.

Bishara, N. D. "Fifty Ways to Leave Your Employer: Relative Enforcement of Noncompete Agreements, Trends, and Implications for Employee Mobility Policy." *University of Pennsylvania Journal of Business Law.*, 13, 2011, 751–95.

Bishara, N., K. J. Martin, and R. S. Thomas. "When Do CEOs Have Covenants Not to Compete in their Employment Contracts?" Vanderbilt Law and Economics Research Paper No. 12-33, 2012.

Department of Justice Release. "Justice Department Requires eBay to End Anticompetitive 'No Poach' Hiring

Agreements." US Department of Justice Release, May 1, 2014.

Fallick, B., C. A. Fleischman, and J. B. Rebitzer. "Job-hopping in Silicon Valley: Some Evidence concerning the Microfoundations of a High-Technology Cluster." *Review of Economics and Statistics*, 88(3), 2006, 472–81.

Franco, A. M., and D. Filson. "Spin-outs: Knowledge Diffusion through Employee Mobility." *Rand Journal of Economics*, 37(4), 2006, 841–60.

Franco, A. M., and M. F. Mitchell. "Covenants Not to Compete, Labor Mobility, and Industry Dynamics." *Journal of Economics and Management Strategy*, 17(3), 2008, 581–606.

Garmaise, M. J. "Ties that Truly Bind: Noncompetition Agreements, Executive Compensation, and Firm Investment." *Journal of Law, Economics, and Organization*, 27(2), 2011, 376–425.

Gilson, R. J. "The Legal Infrastructure of High Technology Industrial Districts: Silicon Valley, Route 128 and Covenants Not to Compete." *New York University Law Review.*, 74(3), 1999, 575–629.

Hyde, A. *Working in Silicon Valley: Economic and Legal Analysis of a High Velocity Labor Market*. Armonk, NY: Sharpe, 2003.

———. "Should Noncompetes Be Enforced? New Empirical Evidence Reveals the Economic Harm of Non-compete Covenants." *Regulation*, 33(6), Winter 2010–2011, 6–11.

Kim, J., and G. Marschke. "Labor Mobility of Scientists, Technological Diffusion, and the Firm's Patenting Decision." *RAND Journal of Economics*, 36(2), 2005, 298–317.

Lavetti, K., C. Simon, and W. D. White. "Buying Loyalty: Theory and Evidence from Physicians." Unpublished manuscript, 2015.

Marx, M., D. Strumsky, and L. Fleming. "Mobility, Skills, and the Michigan Non-Compete Experiment." *Management Science*, 55(6), 2009, 875–89.

Moen, E., and A. Rosen. "Does Poaching Distort Training?" *Review of Economic Studies*, 71(4), 2004, 1143–62.

Moen, J. "Is Mobility of Technical Personnel a Source of R&D Spillovers?" *Journal of Labor Economics*, 23, 2005, 81–114.

Mukherjee, A., and L. Vasconcelos. "Star Wars: Exclusive Talent and Collusive Outcomes in Labor Markets." *Journal of Law Economics and Organization*, 28(4), 2012, 754–82.

Samila, S., and O. Sorenson. "Noncompete Covenants: Incentives to Innovate or Impediments to Growth." *Management Science*, 57(3), 2011, 425–38.

Saxenian, A. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press, 1994.

Shankar, K., and S. Ghosh. "A Theory of Worker Turnover and Knowledge Transfer in High-Technology Industries." *Journal of Human Capital*, 7(2), 2013, 107–29.

Starr, E. "Consider This: Firm-Sposored Training and the Enforceability of Covenants Not to Compete," Unpublished manuscript, 2015.

Stevens, M. "Transferable Training and Poaching Externalities," in *Acquiring Skills—Market Failures, Their Symptoms and Policy Responses*, edited by A. Booth and D. Snower. Cambridge: Cambridge University Press, 1996, 19–37.

———. "Should Firms Be Required to Pay for Vocational Training?" *Economic Journal*, 111(473), 2001, 485–505.

Streitfeld, D. "Tech Giants Settle Antitrust Hiring Suit." *New York Times*, April 24, 2014.

Tambe, P., and L. M. Hitt. "Job Hopping, Information Technology Spillovers, and Productivity Growth." *Management Science*, 60(2), 2014, 338–55.

Walsh, D. "Experts: Employ Caution before Agreeing Not to Hire Rival's Workers." *Crains Detroit Business,* August 24, 2014.

Zappe, J. "Your Non-Competes Just Got Weaker in Some Place." *Fordyce Letter,* September 12, 2013.

Zillman, C. "Hawaii Ban on Noncompetes Leaves Out a Huge Chunk of Workers." *Fortune*, July 8, 2015.