APPROPRIATED GROWTH*

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17 February 2023

Abstract

We build a novel structural growth model that features a dynamic agency conflict and knowledge spillovers to assess how labor mobility affects economic growth. Our calibration to US data targets responses of employee turnover and firms' intangible investment rates to variation in workers' outside option values that are identified by state-level changes in degrees of non-compete enforcement. Counterfactual analysis finds that the current degree of restrictions across states on labor mobility are close to being growth maximizing.

*Chen, Thakor, and Ward are with the University of Minnesota. Li is with the University of South Carolina. For helpful comments we thank Stathi Avdis, Alan Benson, Yasser Boualam, Alex Corhay, Michael Fishman, Murray Frank, Mark Huson, Erik Loualiche, Gordon Phillips, Joel Waldfogel, and Mindy Xiaolan and participants at Alberta's School of Business, Midwest Macro, Minnesota (Carlson), Minnesota Corporate Finance Conference, UMN applied economics workshop, and UNC Junior Finance Roundtable.

INTRODUCTION

Intangible capital plays an ever-larger role in the operation of the modern firm and economic growth. While known to enhance the productivity of labor and physical capital, the best allocation of its reward among a firm's owners and employees remains debated. An established view argues that, because its investment generates knowledge spillovers which preclude owners from fully capturing the reward, it will be underprovided (Arrow (1962)). To shield owners' investment, then, is to maximize growth. A widespread mechanism by which firms attempt to achieve this is through non-compete agreements that restrict employees from moving to competing firms and taking knowledge capital with them.

This view, however, ignores the effect on workers' behavior, especially those whose effort is crucial to the creation of knowledge and new intangible assets. If this investment creates know-how that becomes inalienable to these key employees, then restricting their mobility will alter their prospects and worth—and thus their very motive to exert effort. Therefore, an important channel overlooked by the established view is the effect that agents' mobility has on their incentives and its implications for growth.

In this paper, we investigate this channel both theoretically and empirically. And we further lever our theory to ask a deeper question: what degree of mobility restrictions is growth maximizing? An answer to this question could not be more timely, as the Federal Trade Commission (FTC) recently put forward an expansive proposal to prohibit companies from limiting workers' ability to work for rivals.[1]

We answer in three steps. First, we build a structural growth model to understand mechanisms. It is based on a dynamic agency problem where both owners' and workers' incentives are affected by and respond to changes in mobility. It co-determines intangible investment with the allocation of rents. Investment raises firm profits but also bolsters the marketability of agents, and we allow them to leave their firm.

Second, we present new evidence of the impact of workers' incentives on growth. We establish causally that stricter enforcement of non-compete agreements reduces employee turnover and raises firms' investment rate in intangible capital. That we find significant effects casts doubt on the established view that ignores the impact of mobility restrictions on agents' incentives.

Third and finally, we calibrate our model's salient, unobserved parameters to the data's informative, reduced-form estimates. We use our calibrated framework to evaluate how different counterfactual enforcement policies would impact long-term growth. Our main result is that the current set of restrictions across states is near growth-optimal and adequately balances the interests of owners and employees.

[1] https://www.nytimes.com/2023/01/05/business/economy/ftc-noncompete.html

In Section I we lay out the elements of our structural model. It features a distribution of heterogenous firms making decisions on intangible capital accumulation and agents' compensation in the presence of knowledge spillovers. In the model, investment in intangible capital is financed by the firm's investors, enhances firm value, and grows the economy. Yet it ultimately becomes embedded in the firm through the effort of agents who have their own self-interest. During the process of investment, agents appropriate a part of it, in the sense that their private knowledge or marketability improves concurrently, akin to a knowledge spillover. This appropriation raises the value of their outside option and the probability of their leaving the firm, an event which is costly to investors. This tension locates the heart of our model.

We characterize the model's solution in Section II. We show that to solve the dynamic agency problem, the firm's owners write a contract that encourages agents to exert effort at all times by prescribing policies of investment, termination, and a mix of current and deferred compensation. Common to other dynamic agency models (for example, DeMarzo, Fishman, He and Wang (2012)), sequences of beneficial shocks to the firm's intangible capital raise profits, investment, and the agents' stock of deferred compensation, ensuring their commitment to exert effort.

Novel to our model is the introduction of appropriability on the structure of the optimal contract. Knowledge spillovers can enhance the value of agents' outside options, and their options becoming more valuable make it harder to motivate them to work. Appropriation in effect broadens agents' prospects and, all else equal, exacerbates the agency conflict. We show that it is optimal to sometimes pay bonus-like payments to retain skilled employees, even at low values of deferred compensation.

In Section III, we devise an empirical environment to test and ground these model predictions. Informed by labor market search theory, we construct a novel metric of the value of agents' outside options that depends on the compensation structure and mobility across different industries and states. We take a stand empirically and identify agents to be i) chief executives or ii) employees who work in high-skilled industries. We call these actors that are crucial for the development of intangible capital *specialists*.

We explore how the value of specialists' outside options are impacted in response to an exogenous change in their mobility. Specifically, we use variation in states' enforcement of non-compete agreements to establish causally that stricter enforcement lowers the value of outside options, prolongs tenure, and raises the investment rate in intangible capital. Our identifying assumption is that the degree of enforcement only affects turnover and firm investment through its impact on specialists' outside options. We run a host of robustness tests to confirm the validity of our empirical setup.

We calibrate and analyze our model in Section IV. Our calibration centers on setting the model's key parameters that govern the appropriation process by targeting the identified coefficients of our empirical sample. The model's predictions match what we see in the data well, including some that distinguish our dynamic contracting environment.

Finally, we run counterfactual experiments in Section V. They center on assessing how different levels of knowledge appropriability, a factor that non-compete agreements likely influence, determine the economy-wide growth rate.

Our analysis produces a hump-shape in expected growth rates with respect to appropriability, with our current data placing us just right of the maximum. It points towards potential gains to growth of up to 10 basis points per year by a modest strengthening of restrictions on specialists' mobility. Generally speaking however, the current set of mobility restriction are close to optimal. The hump-shape underscores the importance of studying model counterfactuals that jointly account for the equilibrium forces of appropriability, turnover, agency conflicts, and the return of investment rather than relying on extrapolations of local average treatment effects to inform policy.

LITERATURE

Work in applied theory studies the role of intangible capital and worker characteristics on firms' risk profiles, investment, and production functions.[2] Donangelo (2014) argues how firms' limited control over their most important factor, labor, represents a risk source to owners. Belo, Li, Lin and Zhao (2017) show this risk is amplified in industries that rely heavily on high-skilled labor. In this vein, Eisfeldt and Papanikolaou (2013) look at the organizational capital created by skilled labor and its implications for the cross-section of expected returns. A key systemic risk source they identify relates to the likelihood of key personnel leaving the firm. Eisfeldt, Falato and Xiaolan (2019) structurally estimate a production function that includes high-skilled labor who earn a substantial part of their income in the form of equity-like claims and find strong complementarity with physical capital. None of these papers model an agency conflict that is integral to understand how mobility affects agents' incentives. Nor do they seek to understand how these forces impact growth.

Complementary to these theories is a growing empirical literature on the determinants of labor mobility and its impact on firm outcomes. For example, Jeffers (2020) uses detailed employee-employer matched data to examine how the enforceability of non-compete agreements impacts firms' *physical* investment. Babina and Howell (2022) show that increases in corporate research and development spur employee departures to join startups. Fedyk and Hodson (2022) explore the career migration of employees and find that technical skill sets of individuals negatively forecast the financial and operational performance of the firm. None of these papers, however, use an

[2]A short list is Ai, Croce and Li (2013), Sun and Xiaolan (2019), Donangelo, Gourio, Kehrig and Palacios (2019), Kogan, Papanikolaou and Stoffman (2020), Crouzet and Eberly (Forthcoming), and Crouzet, Eberly, Eisfeldt and Papanikolaou (2022).

equilibrium model to study counterfactuals on worker mobility and investment.

Our theoretical environment builds upon previous work on dynamic agency models.[3] In the class of models that feature limited commitment, for example Bolton, Wang and Yang (2019) and Ai, Kiku, Li and Tong (2021), contract separation does not occur in equilibrium, as it is optimal to readjust the contract so that both parties' participation constraints remain satisfied. That is, (almost surely) *all* separation in these models is exogenous. In contrast, because our economy features moral hazard in which agents can shirk, the dynamic contracting environment prescribes separation in equilibrium. Specialists' probability of leaving the firm and exercising their outside option is thus a choice influenced by their ability to appropriate knowledge.

In contrast to much of the dynamic contracting literature, we look at the implications of agency conflicts on the growth rate of the economy. Closely related papers are Dow, Gorton and Krishnamurthy (2005) and Albuquerque and Wang (2008), though their focuses are on asset prices and investment, not economic growth. Lustig, Syverson and Van Nieuwerburgh (2011) attribute the rise in the disparity across executive compensation since the 1970s to a compositional shift of productivity growth from vintage-specific to general growth, which impact the value of these executives' outside options, but they do not study how worker mobility affects economy-wide growth.

The literature on growth is expansive and seminal entries date back at least to Schumpeter (1942), Solow (1956), Arrow (1962), and more recently Romer (1990b).[4] Similar to Uzawa (1965) and Lucas (1988), we focus on the growth of an input into a firm's production function. In this sense, our notion of intangible capital is close to the spirit of Prescott and Visscher's (1980) organizational capital. As described in Crouzet, Eberly, Eisfeldt and Papanikolaou (Forthcoming), this capital is stored in employees, but we focus on their ability to leave the firm and its impact on investment.

Romer (1990a) distinguishes rivalry from excludability. Because intangible capital is in part knowledge, it is possible to talk about knowledge spillovers, that is, incomplete excludability. Specialists' outside options are the conduit through which intangible investment becomes partially nonexcludable. This is similar to Lucas (1988) where the production of a nonrival, nonexcludable good occurs as a side effect of production. This side effect, however, is internalized in our setup by the firm's owners. Moreover, adjustment costs on the investment of intangible capital creates quasi-rents that allow for intentional private investment, much like in Romer (1986). We further connect the growth in intangible capital to their creators' incentives and compensation.

Finally, our paper is close to Shi (2022) who, like us, studies the macroeconomic impact of

[3]A partial list is DeMarzo and Sannikov (2006), Biais, Mariotti, Plantin and Rochet (2007), Sannikov (2008), He (2009), DeMarzo et al. (2012), Xiaolan (2014), Ai and Li (2015), Ai and Bhandari (2021).

[4]Many contributions constitute this literature. An incomplete list is Grossman and Helpman (1991), Aghion and Howitt (1992), Comin and Gertler (2006), Atkeson and Kehoe (2007), Acemoglu (2009), Akcigit, Çelik and Greenwood (2015), Ward (2020), and Çelik and Tian (Forthcoming).

restrictions on workers' mobility. We share her idea that mobility is an important determinant of growth, but we differ from her analysis in a few ways. Most acutely, our model features an agency conflict that is absent in her setup. As a result, we have different predictions regarding the optimal restriction on mobility. Her two main assumptions are i) bilateral efficiency, so firm value is simply split between owners and agents according to fixed Nash bargaining weights and ii) incumbent firms with non-competes fully extract the implied rent from entrants, which are relatively more productive. Consequently, she argues for a complete ban on non-competes as they only affect entrants but not the split of firm value. In our model, the optimal contract makes firm value and investment dependent on agents' stake in the firm. High mobility reduces the investment return to the firm's owners, so a complete ban is also suboptimal. Our model instead prescribes an interior level of optimal enforcement relative to the extrema prescribed by Arrow (1962) and Shi (2022).

I. An Agency Model of Mobility and Intangible Investment

In this section, we develop dynamic agency model that co-determines investment in intangible capital with the allocation of its rents. Time is continuous and infinite. Firms are heterogeneous. Investors own the firms, have deep pockets, and hire specialists to exert effort towards developing the firm's intangible capital that complements physical capital and labor in the production of a final good. Specialists, which could be skilled employees but are best thought of as executives here, face limited liability. All economic agents are risk neutral but investors discount at rate $r > 0$ and specialists at rate $\gamma > r$ (see DeMarzo and Sannikov (2006) for details on this assumption).

A. Production Technology and Profits

The production technology uses intangible capital N, physical capital K, and (unskilled) labor L. Physical capital and labor are rented in competitive markets. At every instant the firm produces profits Π

$$\begin{aligned} \Pi_t &= \max_{K,L\geq 0} \left\{ \bar{A}(N_t^{\phi} K_t^{1-\phi})^{\alpha} L_t^{1-\alpha} - RK_t - W_L L_t - g_t N_t - C(g_t N_t, N_t) \right\} \\ &= ZN_t - g_t N_t - C(g_t N_t, N_t), \end{aligned} \tag{1}$$

where $Z > 0$ doubles as the marginal product of intangible capital and is a function of productivity $\bar{A}$, the capital share α, intangible capital's share of total capital ϕ, the wage W_L, and the rental rate R.

The profit function features a form of "AK" technology, common to growth models (see Jones and Manuelli (2005)). The rate of accumulation of intangible capital will be a firm's primary choice that affects the economy's endogenous growth. Jorgenson (2005) attributes the lion's share of the US growth experience to the accumulation of (quality-adjusted) capital rather than technical change, especially in regards to the accumulation of information technology over the period 1995–2002.

Because investments in knowledge-intensive activities are often of long duration and require sustained expense to succeed, we place a variable adjustment cost $C(\cdot)$ on the investment rate of intangible capital g. We assume that it is homogeneous of degree one in both arguments and takes a quadratic form

$$gN + C(gN, N) = Nc(g) \equiv N\left(g + \frac{\theta}{2}(g - \delta_N - x)^2\right),$$

where θ is the adjustment cost parameter and x locates the average investment rate. The adjustment cost creates value in the form of accruable rents, captured by (intangible) marginal q, that can be allocated to the firm's investors and specialists.

B. Intangible Capital and Agency Conflict

Intangible capital comprises information technology, research and development design, business processes, and human and brand capital. It is because part of this knowledge is inalienable to employees that it differs from physical capital. Its inalienability affects their outside options and their incentive compatibility constraints on remaining with the firm. There is no such meaningful inalienability or potential appropriation with physical capital—you simply cannot take it with you.

Intangible capital is created by the hands of specialists. Its development is gradual: for example, the term research and development reflects the difficulty in creating something truly new and useful, which takes time; advertisements that build brand capital often take the form of campaigns. We posit that specialists' collective effort $e_t \in \{0, 1\}$ determines the growth of intangible capital that evolves as

$$dN_t = (g_t e_t - \delta_N)N_t dt + \sigma_N N_t dB_t. \tag{2}$$

Realized growth is hindered by obsolescence $\delta_N > 0$ and varies with a Brownian motion B_t with volatility $\sigma_N > 0$. Volatility here measures its inherent riskiness, which could be stochastic obsolescence driven by competitive forces, or variation in the quality of intangible capital (see Ward (2022) for perspective on this modeling assumption). Thus, σ_N summarizes the uncertainty over the quality of the firm's intangible capital and the degree to which specialists can hide their effort.

When specialists shirk ($e_t = 0$) they receive private benefits commensurate to the magnitude of intangible investment, $\lambda g_t N_t dt$, where the parameter $\lambda > 0$ measures the severity of the agency friction. Larger flows, $g_t N_t$, make it easier to waste resources. Because specialists have their own private interest and because their effort choice is not observable, investors write a contract that gives specialists the incentive to exert effort and maximize firm value.

C. The Contracting Environment

We assume that the firm's traditional inputs, K and L, and the firm's (cumulative) cash flow process $\{\Pi_t : 0 \leq s \leq t\}$ are observable and contractible. Therefore from (1), cash flow realizations allow investors to write contracts on intangible capital's growth. Investors thus monitor physical capital, employment, and cash flows to discover the firm's level of intangible capital N.

The contract, represented by $\mathcal{C} = (g, U, \tau)$, specifies intangible investment g_t, specialists' cumulative current compensation U_t which must be nondecreasing by limited liability, and a termination time τ, all of which depend on the stock of intangible capital N_t. As we will show, a novelty of our model relative to DeMarzo et al.'s (2012) is that U_t will account for the history of retention payments made to agents to keep them in the firm.

C.1. Appropriation, Specialists' Skill, and Outside Option

The contract can be terminated at any time. In this event, investors recover $0 \leq l < 1$ per unit of intangible capital and specialists receive the value of their outside option. We assume that specialists' skills are always in demand and we do not take a stand on whether the specialist leaves for an existing firm or to start a new one. Thus their outside option is to leave the current firm and join a different firm with $a_t N_t$ units of intangible capital, where $a_t > 0$ captures their appropriation of the current firm's capital that we succinctly refer to as *skill*. Because it is transferable, we view this skill as a general trait and not a firm-specific one.

We emphasize that this skill, however, is independent of their ability to add value to the current firm at which they are working and instead measures the market's assessment of the value of knowledge they could potentially bring to a new firm. For example, a head marketer discovers that a particular branding strategy or campaign tends to attract more demand; this skill could be useful to another firm. As another example, research and development that has led to a seminal insight could be useful in forming a new firm. In the language of Crouzet et al. (2022), skill measures the fraction of the current firm's capital that is stored and can be potentially be appropriated by specialists.

There are two properties of appropriation that we aim to capture. First, it should grow with the firm's investment in intangible capital. Bell, Chetty, Jaravel, Petkova and Reenen (2019) show that the majority of inventors are a product of their environment ("nurture") rather than possess innate ability ("nature"). The process of investment creates more knowledge that, through inalienability, leads to some value being appropriated by specialists. Second, there should be variation in specialists' skill, whether it be induced by market-driven fluctuations in the value of that skill or government policies on competition among firms and workers.

Altogether, we specify the dynamics of their skill of appropriation as

$$da_t = \kappa(g_t - \delta_N)a_t dt + \sigma_a a_t dB_{a,t}, \tag{3}$$

where $\kappa > 0$ is a rate of learning from investment and where specialists' skill fluctuates with an independent Brownian motion, B_a, with volatility $\sigma_a > 0$. We also call κ the appropriation parameter. It interacts with the firm's *net* growth rate of intangible capital and, therefore, an agent's skill could depreciate. While specialists' skill could potentially become very large, we will show that the incentive compatible contract bounds this process by optimally giving retention payments.

Specialists will leave their current firm when their wealth falls below what they could have in a new firm, $W_0(a_t, a_t N_t)$—the value of their outside option—which depends on their skill, how much capital the new firm will have, as well as their bargaining power. Specialists and investors bargain when the contract is initiated to determine specialists' initial wealth. If investors had all bargaining power, then $W_0 = W_0^I \equiv \text{argmax}_{W \geq 0} P(a_0, N_0, W)$; conversely, if specialists had all power, then $W_0 = W_0^S \equiv \max\{W : P(a_0, N_0, W) \geq 0\}$. More generally, we blend the two extremes with a parameter $\psi \in (0, 1)$ by setting $W_0 = \psi W_0^S + (1 - \psi) W_0^I$.

To summarize termination, investors recover intangible capital worth lN_t and specialists leave. Specialists then join a new firm with $a_t N_t$ units of intangible capital, skill level a_t, and initial wealth $W_0(a_t, a_t N_t)$. Investors finance the new capital in part with the proceeds of their recovered capital. If $a_t > l$, managers have effectively used appropriation to dilute investors. Alternatively, this can be interpreted as specialists exercising their ability to leave and instead receiving a retention payment to keep them in the firm (although this would not result in separation). If $a_t \leq l$, then $l - a_t$ represents a net liquidating payout to investors.

C.2. The Contracting Problem

Given the contract, $\mathcal{C} = (g, U, \tau)$, specialists choose their action process to maximize the present value of current compensation, their consumption of private benefits, and the value of their outside option,

$$W(\mathcal{C}) = \max_{e_t \in \{0,1\}: 0 \leq t < \tau} \mathbb{E}^e \left[\int_0^\tau e^{-\gamma t} (dU_t + (1 - e_t)\lambda g_t N_t dt) + e^{-\gamma \tau} W_0(a_\tau, a_\tau N_\tau) \right],$$

where the expectation $\mathbb{E}^e[\cdot]$ is taken under the probability measure conditional on specialists' effort process.

When the contract is written, the firm has N_0 units of intangible capital and specialists have skill a_0. Investors write a contract to maximize firm value, the present value of cash flows less current compensation paid to specialists plus recovery in contract termination,

$$P(a_0, N_0, W_0) = \max_{\mathcal{C}} \mathbb{E}\left[\int_0^\tau e^{-rt}(\Pi_t dt - dU_t) + e^{-r\tau} l N_\tau\right]$$
$$\text{s.t. } \mathcal{C} \text{ is incentive compatible and } W(\mathcal{C}) = W_0. \tag{4}$$

A novelty of our model is the co-dependence of specialists' and investors' value functions on $W_0(\cdot)$. As we will see, this co-dependence impacts the maximum values that could be attained by both parties and, more broadly, the implementation of the optimal contract. This, in turn, affects mobility, investment, and the overall growth rate of the economy.

Importantly, we do not impose a participation constraint on (4) as we allow for specialists to leave the firm. This assumption distinguishes our paper from limited commitment models of Ai et al. (2021) and Bolton et al. (2019), among others, as our model's contract will allow for endogenous separation of specialists from firms.

II. Model Solution

We first determine optimal investment in intangible capital without an agency problem. We then characterize the optimal contract in the presence of an agency conflict. We consider two model cases to clarify forces. We first solve for the optimal contract when a is constant to highlight appropriability's effect. We then allow a to vary according to (3), allowing the contract to account for investment feeding back into the value of specialists' outside option.

A. First-Best Benchmark

First-best is achieved when $\lambda = 0$ for then specialists always exert effort. Because the economic environment is iid and the model is homogeneous in intangible capital, there is a constant intangible investment rate that maximizes firm value per unit of intangible capital:

$$p^{FB} = \max_g \frac{Z - c(g)}{r - (g - \delta_N)}.$$

Because specialists are relatively more impatient ($\gamma > r$), it is optimal to pay them w immediately, so the payoff to investors per unit of intangible capital is $p^{FB} - w$.

Note these results hold true regardless if the agent can appropriate capital because appropriation only affects the value of their outside option, which they never exercise in first-best. That is, agency conflicts must exist for appropriation to have an economic effect.

B. THE OPTIMAL CONTRACT WITH AGENCY

We now solve for the optimal contract and the solution to (4). Recall that the contract is a triplet, $\mathcal{C} = (g, U, \tau)$, that specifies investment, compensation, and termination. Specialists' continuation payoff W_t is a state variable which summarizes their current incentives and reflects their expected path of current compensation and the likelihood of contract termination; intangible capital captures the history of investment via (2); and specialists' outside option is influenced by a. Altogether, whatever the history of the firm up until date t, the only relevant state variables are a_t, N_t, and W_t and, therefore, investors' value function at time t, $P(a_t, N_t, W_t)$, can be solved with a Hamilton-Jacobi-Bellman (HJB) equation.

B.1. Incentive Compatible Contract

We focus on the incentive compatible contract that implements $e_t = 1$ for all t. Given this contract and the firm's history up until time t, specialists's continuation payoff is

$$W_t(\mathcal{C}) = \mathbb{E}_t \left[\int_t^{\tau} e^{-\gamma(s-t)} dU_s + e^{-\gamma(\tau-t)} W_0(a_\tau, a_\tau N_\tau) \right].$$

Standard theory in dynamic contracting decomposes managers' incremental total compensation into incremental payments dU_t and incremental continuation payoff dW_t (Spear and Srivastava 1987). When intangible capital can be contracted upon, we formulate managers' incremental total compensation with a martingale representation (see Sannikov (2008) for details):

$$dW_t + dU_t = \gamma W_t dt + \beta_t N_t \left(\frac{dN_t}{N_t} - (g_t - \delta_N) dt \right) = \gamma W_t dt + \beta_t N_t \sigma_N dB_t. \tag{5}$$

The incentive coefficient $\beta_t > 0$ serves to expose specialists' compensation to the realizations of intangible capital and is key to maintaining incentive compatibility. Managers who deviate reduce their compensation by $\beta_t g_t N_t dt$ and receive private benefits $\lambda g_t N_t dt$; incentive compatibility is thus implemented with $\beta_t \geq \lambda$ for all t. Because termination is ex post inefficient and therefore costly to enforce, the optimal contract minimizes the likelihood of this event and sets

$$\beta_t = \lambda \text{ for all } t. \tag{6}$$

The incentive coefficient, β_t, is thus set to minimize the necessary level of incentive provision.

Once specialists' current wealth hits this lower bound they are better off shirking and consuming private benefits, and because investors know this, they will optimally terminate the contract at this threshold. Since this decision holds continuously, specialists' departure satisfies an indifference condition

$$\underline{W}(a_t, N_t) = W_0(a_t, a_t N_t), \tag{7}$$

where $\underline{W}(a_t, N_t)$ is a lower bound on specialists' wealth that is dependent on the level of intangible capital and their skill where it is optimal to terminate the contract.

Homogeneity further allows us to write $p(a, w) = P(a, N, W)/N$ and reduce the problem to two state variables: specialists' skill a and stake $w = W/N$ (their scaled continuation payoff), which evolves, by Ito's lemma, as

$$dw_t = d(W_t/N_t) = \left[(\gamma - (g_t - \delta) + \sigma_N^2)w_t - \sigma_N^2\lambda\right] dt - du_t + \sigma_N(\lambda - w_t)dB_t, \tag{8}$$

where current payments to managers per unit of intangible capital are $du = dU/N$. We also scale the outside option in (7) and define

$$\underline{w}(a_t) \equiv \frac{\underline{W}(a_t, N_t)}{N_t} = \frac{a_t W_0(a_t, a_t N_t)}{a_t N_t} = a_t w_0(a_t).$$

Subject to the incentive constraint in (6), investors optimally choose investment to equate expected returns to their required rate of return, the risk-free rate:

$$rp(a, w)dt = \max_g \,(Z - c(g))dt + \mathbb{E}_t\left[d(Np(a, w))/N\right].$$

This equation's solution is jointly determined with the boundaries, described below, that determine contract termination and current payments to managers.

C. Constant Appropriability

When a is constant, the only state variable is specialists' stake, $w = W/N$, and investors' value function takes the form of an ordinary differential equation subject to the boundaries below. In Appendix A we show how the model's termination boundary could be determined in a search market. Our model of appropriation thus has a natural connection to the search literature.

As mentioned, specialists will be terminated immediately once their continuation utility reaches the value of their outside option, because otherwise they would immediately consume private benefits; therefore,

$$p(\underline{w}) = p(aw_0) = l. \tag{9}$$

This equation is telling. It succinctly captures the model's primary tradeoff of competing interests and determines the threshold at which the contract terminates. As management's outside option becomes more valuable, through skill a or through bargaining w_0, so does the level of wealth they require to remain in the current firm. Once their current wealth w_t falls and hits aw_0 from above, the value of the firm to investors equals their outside option: liquidation of intangible capital at price l. Naturally, if a goes to zero, the agent has no meaningful outside option and the firm liquidates when $w_t = 0$.

Next, investors can always compensate specialists with cash ($du > 0$), so it will cost at most one dollar to increase w by one dollar, implying $p_w(w) \geq -1$. But because termination is costly to investors it will be optimal to grow w at low values as quickly as possible by setting du in (8) to zero. Impatient specialists will eventually require current payments, however. This creates a tradeoff that is determined by the point at which investors are indifferent between paying them a dollar directly and promising them another dollar: $p(w) = p(\overline{w}) - (w - \overline{w})$, where $w - \overline{w}$ is the current payment to keep promised compensation at $\overline{w}$. Continuity implies this equation holds as $w \to \overline{w}$; therefore

$$p'(\overline{w}) = -1, \tag{10}$$

and because this is chosen by investors it satisfies the optimality condition

$$p''(\overline{w}) = 0. \tag{11}$$

To summarize, $du = 0$ within the payment and termination boundaries and $\beta_t = \lambda$ for all t. With the dynamics of specialists' payoff given, the solution to investors' problem in (4) on $w \in [\underline{w}, \overline{w}]$ takes the form

$$rp(w) = \max_g Z - c(g) + p(w)(g - \delta_N) + p'(w)(\gamma - (g - \delta_N))w + \frac{1}{2}p''(w)\sigma_N^2(w - \lambda)^2 \tag{12}$$

subject to the boundaries (9), (10), and (11). This problem is similar to the one studied in He (2009). He shows that relative impatience and optimal contracting requiring the equality of marginal benefits and costs implies the existence of a unique upper bound on w, $\overline{w} < \lambda$.

The first-order condition for the investment rate of intangible capital is

$$c'(g) = p(w) - p'(w)w. \tag{13}$$

When choosing investment, investors internalize its effect on specialists' incentives. For a given W, a growth in capital N reduces specialists' effective claim on the firm $w = W/N$, aggravating the agency friction.

D. Dynamic Appropriability

We now consider the environment where investment creates knowledge that becomes inalienable to managers and the appropriation process follows (3). The payment boundaries on specialists' stake, w, are similar to the case of constant appropriability but now also depend on their skill; namely, for all a

$$p(a, \underline{w}(a)) = p(a, aw_0(a)) = l \qquad p_w(a, \overline{w}(a)) = -1 \qquad p_{ww}(a, \overline{w}(a)) = 0, \tag{14}$$

and, as the problem has two state variables, another optimality condition follows from differentiating the middle equation in (14) with respect to a,

$$p_{wa}(a, \overline{w}(a)) = 0 \text{ for every } a. \tag{15}$$

We now determine the threshold at which highly skilled agents will be convinced to not leave the firm by means of a retention payment. As before in the case with specialists' stake, this threshold will be determined by comparing agents' relative impatience with the likelihood of costly termination.

Suppose that a specialist's skill, a, rises for a given deferred compensation level, w. Because relative impatience is fixed yet the likelihood of costly termination rises with skill, there again will be a threshold where it will be optimal to pay him or her current compensation rather than to let them leave the firm. Formally, there exists a skill level, $\overline{a}(w)$, above which the specialist will be paid immediately and where investors' decision will satisfy the indifference condition

$$p(a, w) = p(\overline{a}(w), w) - (a - \overline{a}(w)), \text{ for } a \geq \overline{a}(w) \text{ for each } w. \tag{16}$$

The point of this current compensation is retention. We give two interpretations to this upper bound. One is that the opportunity to leave is fleeting. The specialist uses the offer to negotiate a bonus with the current firm, discarding the job opportunity. Alternatively, it could be interpreted as a specialist purposefully restricting their marketability in exchange for compensation today, perhaps by setting out to codify some of their knowledge for their current firm to keep or else by publishing work under the company name.

Because specialists can leave the firm and raise a_t dollars per unit of capital, investors optimally pay them $a_t - \overline{a}(w_t)$ immediately to retain them and avoid the cost of liquidation. In words, specialists appropriate everything along the retention boundary when their skill increases. Retention payments, moreover, are proportional to the difference $a_t - \overline{a}(w_t)$. Higher skilled specialists get paid more.

Next, we can use the continuous properties of our model to simplify the conditions above. For each w, as we take a to $\overline{a}(w)$ we get

$$p_a(\overline{a}(w), w) = -1 \qquad\qquad p_{aa}(\overline{a}(w), w) = 0. \tag{17}$$

As before, optimality produces the right equation and our two-state problem further requires that the derivative of the left equation by w satisfy

$$p_{aw}(\overline{a}(w), w) = 0 \text{ for every } w. \tag{18}$$

And finally, from (15) and (18) and Young's theorem it is evident that

$$p_{aw}(\overline{a}(w), \overline{w}(a)) = 0 \text{ for every } a \text{ and } w. \tag{19}$$

We obtain insight on the optimality condition by specializing (16) to the case where $w = \underline{w}(a)$ and taking the limit $a \to \overline{a}(w)$:

$$\begin{aligned} p(a, \underline{w}(a)) &= p(\overline{a}(w), \underline{w}(a)) - (a - \overline{a}(w)) \\ &= l - (a - \overline{a}(w)) \\ \Rightarrow \lim_{a \to \overline{a}(w)} p(a, \underline{w}(a)) &= p(\overline{a}(w), \underline{w}(a)) = l. \end{aligned} \tag{20}$$

Thus, the boundary where specialists' skill approaches $\overline{a}(w)$ when $w = \underline{w}(a)$ are those where investors understand the imminent threat of agents leaving the firm, causing firm value to near the liquidation value. Moreover, a similar approach that first sets a to $\overline{a}(w)$ and then takes the limit $w \to \underline{w}(a)$ also produces a value of l in (20). Therefore, there is an equivalence as the lower boundary for specialists' stake, $\underline{w}(a)$, equals the upper boundary for specialists' skill, $\overline{a}(w)$.

We emphasize that our model provides two sources of current payments or bonuses to specialists. One is the traditional one of maintaining incentive compatibility in the presence of impatient agents, similarly to DeMarzo et al. (2012); this is $\overline{w}(a)$. Our novel channel comes from retention; that is when $\overline{a}(w)$ is crossed from below when an agents' skill becomes more valuable. In contrast to the payments "for impatience" which occur at high w, retention payments could occur at low w.

D.1. Hamilton-Jacobi-Bellman Equation and Investment

To summarize, $du = 0$ within the payment and termination boundaries and $\beta_t = \lambda$ for all t. Assuming the contract always prescribes full effort, the solution to investors' problem in (4) takes the following form subject to the boundaries in (14), (15), (17), (18), and (19):

$$\begin{aligned} rp(a,w) = \max_g Z - c(g) + p(a,w)(g-\delta_N) \\ + p_w(a,w)(\gamma - (g-\delta_N))w + \frac{1}{2} p_{ww}(a,w)\sigma_N^2 (w-\lambda)^2 \\ + p_a(a,w)\kappa(g-\delta_N)a + \frac{1}{2} p_{aa}(a,w)\sigma_a^2 a^2. \end{aligned} \tag{21}$$

We describe our computational procedure to solve this equation in Appendix A. In the appendix we also show that, in our calibration of Section IV, it satisfies both contract optimality and the implementation of full effort by specialists.

The first-order condition for investment becomes

$$c'(g) = p(a,w) - p_w(a,w)w + p_a(a,w)\kappa a, \tag{22}$$

and, relative to (13), is now influenced by its effect on specialists' skill. Intuitively, because investment in intangible capital is not wholly captured by investors, the term $p_a(a,w)\kappa a$ captures how much of investors' firm value is lost by specialists' gaining skill and raising the value of their outside option. This term reflects the thinking of Arrow (1962).

We provide perspective on the conditions of (17) by applying them to the HJB equation and rearranging it:

$$\begin{aligned} rp(\overline{a}(w),w) = \max_g Z - c(g) - \kappa(g-\delta_N)\overline{a}(w) + p(\overline{a}(w),w)(g-\delta_N) \\ + p_w(\overline{a}(w),w)(\gamma-(g-\delta_N))w + \frac{1}{2}p_{ww}(\overline{a}(w),w)\sigma_N^2(w-\lambda)^2. \end{aligned} \tag{23}$$

In effect, there is an extra cost that investors must pay at the retention boundary equal to $\kappa(g - \delta_N)\overline{a}(w)$. Intuitively, the firm makes a retention payment equal to the immediate appropriation of the firm's intangible capital by specialists. Highly skilled agents are more costly to retain, resulting in lower investment. This prediction agrees with the empirical results of Fedyk and Hodson (2022).

D.2. Total Compensation

We define *total compensation* as the sum of deferred compensation plus the current compensation received when $w_t > \overline{w}(a_t)$ and $a_t > \overline{a}(w_t)$ and, respectively, split the sources of current payments u_t into the variables u_{wt} and u_{at}. Per unit of intangible capital it thus follows the process

$$w_t^{\text{total}} = w_t + u_{wt} + u_{at}.$$

This process has the properties that (i) u_{wt} and u_{at} are increasing and continuous with $u_{w0} = u_{a0} = 0$, (ii) $w_t = w_t^{\text{total}} - u_{wt} \in [\underline{w}(a_t), \overline{w}(a_t)]$ for all $t \geq 0$ and $w_t = w_t^{\text{total}} - u_{at} \in [0, \overline{a}(w_t)]$ for all $t \geq 0$, and (iii) u_{wt} only increases when $w_t = \overline{w}(a_t)$ and u_{at} only increases when $a_t = \overline{a}(w_t)$. These properties imply that w_t is a regulated Brownian motion with time-varying controls at $\overline{w}(a_t)$ and $\overline{a}(w_t)$.

Following Harrison (1985), we substitute out u_{wt} and u_{at} from the above equation replace them with primitive model elements. Doing this, we obtain

$$w_t^{\text{total}} = w_t + \max\left(\sup_{0\leq s\leq t}(w_s^{\text{total}} - \overline{w}(a_s)), 0\right) + \max\left(\sup_{0\leq s\leq t}(w_s^{\text{total}} - \overline{a}(w_s)), 0\right)$$

and draw two observations.

First, total compensation, which can be measured, albeit imperfectly, in the data, reflects a combination of deferred and current compensation. We therefore define compensation accordingly in the data.

Total compensation, moreover, depends on the history of agents' skill through the terms $\sup_{0\leq s\leq t}\overline{w}(a_s)$ and $\sup_{0\leq s\leq t}\overline{a}(w_s) = \sup_{0\leq s\leq t}\underline{w}(a_s)$, where equality follows from the equivalence shown in (20). Because in our model specialists' outside option is monotone in a, $\underline{w}'(a) > 0$, we can proxy for appropriability in the data with a measure of specialists' outside options. We construct this measure in Section III and further use it to examine the dynamic contracting implications of our theory in Section IV.

D.3. Stationary Distribution

As we have seen, the threat of contract termination is a salient force that shapes agents' incentives and intangible capital accumulation. A given contract will be eventually terminated with probability one. To have a stationary distribution of contracts, firms, and workers, we allow for entry. We use this distribution to compute model statistics that we compare with the data.

The stationary distribution $h(a, w)$ satisfies the equation

$$0 = \mathcal{A}^* h(a, w) + \psi(a, w) m,$$

where $\mathcal{A}^* h(a, w)$ is the adjoint of the infinitesimal generator of the bivariate diffusion process (da, dw), which intuitively captures the transition rates generated by the dynamics of the model's state variables under the optimal policies.[5] By construction this generator contains the rates of exit that occur along the termination boundary, $\underline{w}(a)$, and so to ensure a stationary mass of firms, we add a product of an entry rate, m, and an entry mass, $\psi(a, w)$, which integrates to one.

We normalize the total mass of firms to one, $\iint h(a, w) dw da = 1$, where the implying that the stationary entry rate equals

$$m = -\iint \mathcal{A}^* h(a, w) dw da.$$

When a specialists' contract is terminated we assume that a fraction $\zeta \in (0, 1)$ of them start new firms with intangible capital $a_t N_t$. The remaining $1 - \zeta$ replaces the exiting specialist with a draw from a skill distribution with positive support, which allows for the model to incorporate uncertainty in the quality of the match of the new specialist-firm pair. The entrant, moreover, also starts with a new continuation payoff, w_0, determined by agents' and investors' bargaining powers.

III. Empirical Setup Used to Discipline Model Calibration

In this section, we present new evidence on how specialists' incentives and firms' policies respond to the value of specialists' outside options and their mobility. We use this evidence to discipline the calibration of our model, specifically the key unobserved parameters governing the appropriation equation (3).

A. Empirical Environment

We first construct a value for the outside options of the firm's specialists. We then devise an empirical environment to provide shocks to those options' values and identify its effect on a range of outcomes, most importantly the rate of specialists' turnover and firms' intangible investment rates.

We define two types of specialists: the chief executive officer (CEO) and employees of "high-skilled" industries.[6] We examine chief executives partly due to the availability of more complete

[5]Specifically, we calculate this with the transpose of the discretized transition matrix $\mathbf{Q}$ in Appendix A.

[6]Specifically, we define in the spirit of Brown, Fazzari and Petersen (2009) to be those in NAICS = 51 (Informa-

data but also because they are known to play an outsized role in the creation of a firm's capital. We supplement with a separate examination of the prospects of high-skilled employees. The results from both types are useful for our calibration because, according to our model, the impact of appropriation on investment will be similar across both types as long as the share of deferred compensation relative to total compensation is comparable across types.

A.1. Value of Outside Options

We measure specialists' outside options following the methodology of Schubert, Stansbury and Taska (2019) by constructing a weighted sum of average compensation at the industry-state-year level:

$$\text{Outside Option}_{j,s,t} = \sum_{j' \in J} \pi_{j \to j'} \overline{w}_{j',s,t}. \tag{24}$$

The variable Outside $\text{Option}_{j,s,t}$ measures the value of outside options that specialists' possess whose firms are located in industry j and state s in year t.

The unconditional transition probability $\pi_{j \to j'}$ reflects the likelihood that a specialist leaves industry j to join industry $j' \in J$, where J is the set of all industries. We estimate this probability by tracking the fraction of all specialists who have left industry j to join j' and averaging across all years. We then multiply this probability by the average specialist compensation in that state-industry-year, $\overline{w}_{j',s,t}$. Altogether, a specialist's outside option will be more valuable the greater the compensation that specialists earn in other states and industries, $\overline{w}_{j',s,t}$ and the more frequent that specialists leave and take jobs in other industries, $\pi_{j \to j'}$.

The logic behind (24) is that an agent's outside option is a function of i) compensation in a given industry in a local labor market (defined as a state in our setting), and ii) the mobility across occupations. Mobility is captured by the transition matrix and reflects the rate of job flows but doubles as an implicit metric of costs associated with changing occupations. These costs represent a broad notion and could reflect many things, including the loss of moving away from family or neighborhood, the uncertainty attributed to a new job, or also proxy for (inverse) market tightness, a salient equilibrium object featured in the class of search-theoretic models of the labor market (Rogerson, Shimer and Wright 2005).

A.2. Shocks to Outside Options

With this measure of outside options in hand, we entertain shocks to these options. We derive our shocks by exploiting variation in the degree of enforcement of non-compete agreements.

tion), 52 (Finance and Insurance), 53 (Real Estate and Rental and Leasing), 54 (Professional, Scientific, and Technical Services), 55 (Professional, Scientific, and Technical Services), 61 (Educational Services), and 62 (Health Care and Social Assistance).

Non-compete agreements (NCAs) are contracts signed between employees and firms that prohibit employees from joining or forming a competing firm. Their purpose is to protect a given firm's intellectual property from direct competition, thus facilitating the retention of economic rents that, hopefully, encourages more innovative activity. These contracts, however, also restrict the outside options of employees by diminishing their ability to take jobs at other firms. They are widely known to be applicable to our definition of skilled employees. Jeffers (2020), for example, documents that these agreements affect a large set of workers, and are especially prevalent for workers in knowledge-intensive industries. Shi (2022) reports that 64 percent of chief executives are subject to these agreements.

We measure the degree of enforcement of NCAs by using the non-compete enforceability index (NCEI) of Garmaise (2011), which is constructed at the state-level from a sample of twelve questions with thresholds devised by Malsberger (2004) from 1992 to 2004.[7] We use Kini, Williams and Yin's (2021) data to extend the NCEI sample to 2014. The index counts each answer that surpasses a threshold and ranges from zero, the most lax, to twelve.

Figure 1 depicts substantial heterogeneity within the unconditional state-year distribution of the NCEI for our sample. The index, moreover, may change for a given state as a result of litigation or new laws being passed that impact non-compete agreements. We use both sources of variation to derive the shocks used in our empirical analysis.

The first source, *NCEI*, is the value of the index in a given year for the state in which a firm is headquartered. The second source follows Garmaise (2011) and is a categorical variable based on the change in the index, Δ*NCEI*, that takes a value of 1 if the state a firm is located in has an *NCEI* value that is greater than its initial 1992 value in a given year, a value of -1 if the value is lower than its initial 1992 value in a given year, and a value of zero if it is the same as its initial value.

A.3. Empirical Specification

Our empirical strategy takes the form of an instrumented difference-in-difference regression. In particular, we first instrument for specialists' outside option using our shocks, the state-level variation in the enforceability index. We then estimate the impact of the instrument on the firm's intangible investment and their likelihood of leaving the firm. Our identifying assumption is that changes in the enforcement of NCAs affect firm intangible investment and turnover only through their impact on specialists' outside options.

[7] For example, the first question asks whether there is a state statute that governs the enforceability of covenants not to compete. Almost all states other than California and North Dakota permit some form of non-compete agreements. The remaining questions sift through contractual details of enforcement. As two examples, the second question asks whether the employer can prevent the employee from future independent dealings with all the firm's customers, not just those with whom they had had previous contact; the ninth question asks what type of time or geographic restrictions has the court found to be reasonable.

Formally, our first-stage regresses specialists' outside option value on their states' NCEIs, firm-level controls, and a set of fixed effects:

$$\log \text{Outside Option}_{j,s,t} = b_1 \text{NCEI}_{s,t} + B_1 \text{Controls}_{i,t-1} + f_i + f_t + \epsilon_{i,j,s,t}. \tag{25}$$

We measure the outside option, $\log \text{Outside Option}_{j,s,t}$, as the logarithm of one plus the outside option value for firms in state s and industry j in year t, as defined in (24). The variable NCEI is either $NCEI_{s,t}$ or $\Delta NCEI_{s,t}$. Firm fixed effects, f_i, are included to control for time-invariant heterogeneity between firms and year fixed effects, f_t, for time trends. With the inclusion of fixed effects, equation (25) captures changes to the outside options of specialists induced by shocks to the enforcement of NCAs in the states in which their firms are located.

We then use the regression's predicted value, $\log \widehat{\text{Outside Option}}_{i,j,s,t}$, which varies with firm-level characteristics, as an instrument in our second-stage regression to study the response of our outcomes of interest, $y_{i,t}$,

$$y_{i,t} = b_2 \log \widehat{\text{Outside Option}}_{i,j,s,t} + B_2 \text{Controls}_{i,t-1} + f_i + f_t + \epsilon_{i,j,s,t}. \tag{26}$$

We separately estimate (25) and (26) for our two types of specialists. For our specifications involving chief executives, we construct our outside option measure using average CEO wages and transition probabilities between industries for chief executives. For high-skilled employees, we build our measure using average wages of workers in high-skilled industries in a given state, and transition probabilities for workers between industries. Due to the structure of our datasets, our transition probabilities are calculated at the two-digit SIC level for CEOs and at the two-digit NAICS level for high-skilled workers.

We examine intangible investment rates for both types and turnover only when using our specification that involves chief executives. Our data do not permit us to track turnover for high-skilled employees at the firm-level.

B. Data and Summary Statistics

Our sources draw from databases on public firms' financial reports, particularly their accounting and compensation data, US Census data on employment and job-to-job flows, and the aforementioned state-level regulatory changes in the degree of employment contract enforcement. We discuss these in turn before describing interpreting our empirical results.

B.1. Compensation, Turnover, and Outside Options

Our chief executive compensation and turnover data come from Compustat's Execucomp database. We use the variable $tdc1$ that includes salary, bonuses, and deferred compensation in the form of equity and options at the time of granting. We apply Gillan, Hartzell, Koch and Starks's (2018) filter to remove back-filling bias.

Our turnover variable is an indicator that becomes active the first year a firm's CEO leaves office, if ever. We then apply Gentry, Harrison, Quigley and Boivie's (2021) detailed classification of departures to exclude impertinent cases such as company name changes, mergers or acquisitions, bankruptcies, interim executives, Execucomp misreporting, and departures without media or regulatory filings.

The data for calculating the values of outside options for high-skilled workers comes from the Bureau of Labor Statistics' Quarterly Census of Employment and Wages (QCEW) database and the US Census's Job-to-Job Flows database, part of the Longitudinal Household-Employer Database. These datasets collectively contain variables on wages and worker transition rates at the industry-state-year level. We calculate the average wages of employees for each NAICS industry in each industry-state-year and multiply them by industry-to-industry transition rates to for our outside option value for high-skilled employees.

B.2. Intangible Investment and Firm-Level Data

We then use Compustat's accounting data to build our measures of intangible investment and other firm-level control variables. We measure intangible investment in two ways. The first follows recent practice in the literature that capitalizes intangible investment with a perpetual inventory method (Lev and Radhakrishnan (2005), Eisfeldt and Papanikolaou (2013)). Specifically, we construct the level of intangible capital for firm i in year t, $N_{i,t}$, as a function of selling, general, and administrative expenses ($SG\&A$):[8]

$$N_{i,t} = (1 - 0.15) \times N_{i,t-1} + 0.3 \times \frac{SG\&A_{i,t}}{CPI_t}, \tag{27}$$

where CPI_t is the consumer price index. Following Peters and Taylor (2017) who study this construction in detail, we attribute 30 percent of (real) SG&A expenditure to intangible development, use a 15 percent depreciation rate, and initialize the process at $SG\&A_{i,0}/0.25$. Accordingly, we define intangible capital's investment rate as (27)'s right-most term divided by $N_{i,t-1}$.

Our second measure of intangible investment follows Sun and Xiaolan (2019) and uses research

[8]Compustat's record of SG&A ($xsga$) includes expenditure on research and development, and a large part of this consists of expenses related to training (human capital and business processes), skilled labor (programmers), information technology, as well as marketing (brand capital).

and development expense as an alternative measure of intangible investment. We normalize the R&D flow with the lag of intangible capital.

In our regressions, we include a standard set of firm-level regression controls: the lagged investment rate, turnover, cash, profitability, leverage, Tobin's Q, and the lagged logarithm of intangible capital. For our regressions for CEOs, we also include an indicator that takes a value of 1 if firm's chief executive is over 62 years old. We normalize ratios by the level of intangible capital to have common denominators on both sides of our investment regressions. Appendix B defines these variables and provides further details on sample selection.

B.3. Summaries of Samples

Our sample on CEOs begins in 1992, as this is when Execucomp data become available, and ends in 2014, as this is the latest year for which we have NCEI data. The resulting sample is a panel of 20,291 firm-year observations for 2,063 firms. Our sample of high-skilled employees consists of 1,600 firms across 13,296 firm-year observations and runs from 2000, when the QCEW data begin, to 2014.

For both samples, we exclude 2008 and 2009 from our sample to remove crisis-induced outliers that are unrelated to our analysis.[9] We make all level variables real in 1982 dollars. Appendix Table A-I provides summary statistics for the key variables in our sample. In addition, we find that conditional on a change in *NCEI* since 1992, the median change is two index values.

C. EMPIRICAL RESULTS

We present our first- and second-stage results in turn. We then discuss robustness.

C.1. Impact of Enforceability on Outside Option Value

Table I summarizes the principal outcomes of our first-stage estimation for executives. Column (1) shows the impact on outside options of the level of index, *NCEI*, while column (2) lists the point estimate from the change, Δ*NCEI*. The coefficients of interest are significant and the F-statistics of both regressions are much larger than ten, indicating that the instrument satisfies the relevance condition.

Common to both enforcement variables, a strengthening of the NCEI leads to a reduction in the value of a given executive's outside option. Column (2), for example, implies that a two-unit change in the non-compete enforceability index reduces the value of a CEO's outside option by 10.6 percent. Such a shift from the sample average is equivalent to over a fifth of a standard deviation across executives. Columns (3) and (4) report the estimates of the impact on the value of the

[9] Results are largely unaffected by this restriction that is more in line with our theoretical framework.

outside option normalized by the firm's intangible capital, metrics that will be useful when we calibrate our model. Column (4) shows that a two-unit change in the non-compete enforceability index reduces the CEO's outside option by 1 percent of firm's intangible capital, which is equivalent to a half of the sample average of 2 percent.

Because our first-stage compares firms that have been treated with a change in enforceability to those that have not and because this treatment occurs across states at different points in time, it is a staggered difference-in-difference regression. Consequently for our identifying assumption to hold, the outside option values of specialists for the treated and control firms must move in parallel prior to any change in NCEIs and should diverge subsequent to a change.

Staggering can introduce a discrepancy between the estimated coefficients and the actual average treatment effects when examining parallel trends (see Goodman-Bacon (2020) for details). To address this, we use the methodology in Sun and Abraham (2021) and depict the coefficient estimates in Figure 2 using $\Delta NCEI$ for two control groups: the set of firms that are never treated and never experience a change in the enforcement index, and the set of firms that were last treated. We see for both sets of control groups that the parallel trends assumption clearly holds—the treated and control groups move in parallel prior to a strengthening of the NCEI and then the outside option's value for the treated firms drops relative to the control firms after the index changes. The difference becomes significant in the first year after the shock, and the largest reductions concentrate around three to four years afterward.

C.2. Executives' Outside Options, Turnover, and Firms' Intangible Investment

With the first-stage established, we now turn to the results of our second-stage regression shown in Table II. Panel A reports the estimates for the instrumented logarithm of the outside option index and Panel B the instrumented outside option over intangible capital. We find that greater values of specialists' outside options reduce intangible investment in their current firm. The estimated effects are statistically significant and have similar economic magnitudes using either column (1)'s *NCEI* or column (4)'s $\Delta NCEI$ as the instrument. In particular, the estimates point to a 10.6 percentage point increase in the outside option index lowering intangible investment by approximately $10.6 \times 0.066 = 70$ basis points per year. Seventy basis points of growth per year is a material impact.

In columns (2) and (5), we use R&D investment as an alternative proxy of intangible investment and find consistent results. Here we find a negative and significant impact on research and development by $10.6 \times 0.169 = 1.8$ percent as a fraction of intangible capital, a fifth of the average R&D investment rate.

We then examine how CEO turnover responds to variation in outside options. Focusing on column (6), the point estimate shows that a 10.6 percentage point increase in option value raises the likelihood of departure by over $10.6 \times 0.219 = 2.32$ percent. The effects are statistically significant at conventional levels. When considering the economic magnitude, the change accounts for nearly a half of the average turnover rate of 4.7 percent annually. Panel B's results that use the scaled outside option as the focal regressor are consistent with Panel A's. The only exception is that column (3)'s coefficient has a p-value of 0.102.

C.3. High-Skilled Employees' Outside Options and Firms' Intangible Investment

In Table III, we report a similar set of regression results when focusing on high-skilled employees. Columns (1) and (4) show the first-stage results when instrumenting for outside options using *NCEI* and Δ*NCEI*, respectively. The point estimates show that a two-unit increase in non-compete enforcement index leads to around a 4.4 percent reduction in the value of these employees' outside options.

In the third row, we produce the second-stage results for investment rates. Consistent with what we found when studying executives, greater values of outside options in high-skilled industries leads to a decrease in the intangible investment rate, although the effect is not statistically significant; when measuring intangible investment via R&D, however, the effect is. The economic significance of the effect across chief executives and skilled employees is moreover similar for R&D investment: a 4.4 percent drop in outside option value, for example, leads to a $4.4 \times 0.419 = 1.84$ percent drop in annual research and development expenditure.

This result is consistent with skilled employees being more crucial for research and development rather than overall intangible capital investment. This is plausible as chief executives likely have greater control over the firm's total capital rather than just a specific division. Hence, variation in CEO mobility thus affects the whole firm's intangible investment, including its R&D division's. Overall, the results when measuring outside options for workers in high-skilled industries echo what we find when studying chief executives.

C.4. Robustness Checks

We do many robustness checks to confirm the validity and generality of our results:

1. A concern is that changes in the NCEI are correlated with aggregate factors that could influence turnover or intangible investment. We note that we include time fixed effects in all of our regressions, which control for aggregate factors. In Panel B of Appendix Table A-I, we further show that changes in the NCEI exhibit very low correlation with a variety of common aggregate variables.

2. The point estimates from our instrumented differences-in-differences regression best corresponds with the sensitivities of our model, as this regression estimates the *local* average

treatment effect for a firm whose specialists' outside options are changed by non-compete enforcement. An alternative strategy would be to run a reduced-form regression that examines the effect of NCEI changes on outcomes directly. This would provide an estimate of the average treatment effect on the outcome variables attributable to changes in NCEIs. See Hudson, Hull and Liebersohn (2017) for a discussion of this distinction. In Appendix Table A-II, we show that this reduced-form regression produces consistent results.

3. We run a placebo falsification test for the year of the change in the NCEI to ensure that our results are not driven by contemporaneous trends that coincide with the state-level changes in the NCEI. More specifically, we define a variable, $\Delta NCEI_{false}$, that sets the change defined by $\Delta NCEI$ to occur five years before the actual change in the NCEI. Appendix Table A-III shows that we find insignificant results with this test, indicating that our results are driven by the actual changes in the state NCEIs.

4. In Appendix Table A-IV, we investigate the long-run impact on intangible investment rates. The effects become even stronger, consistent with intangible investment being a long-term and potentially strategic decision. The effects of outside options on intangible investments are quite persistent, remaining significant up to four years after. Specifically, at the four-year horizon, a 10.6 percent growth in the value of an outside option translates to a $10.6 \times 0.627 = 6.6$ percentage point fall in average intangible investment rate of a firm operating in a state that has recently relaxed enforcement by two degrees.

5. Our turnover variable measures the probability that a chief executive leaves the company. In Appendix Table A-V, we follow Graham, Kim and Kim (2020) and calculate the probability that a CEO will find another executive job after leaving the current position. Their measure of executive mobility also responds intuitively to a growth in the value of their outside options and shares the same sign as our turnover variable.

6. Appendix Table A-VI reports the effects of our outside option index on the rates of firm entry and exit for both public firms as well as public and private firms. The data on public firm entry and exits come from Compustat, while the data on public and private firm entry/exits are from the Business Dynamics Statistics (BDS) of the US Census. Here we do not find much evidence of a robust impact on these rates. This result separates our mechanism from Shi's (2022) as she focuses on the extensive margin whereas we focus on the intensive margin.

7. In line with this, in unreported tests, we also do not find a significant effect on the Herfindahl index defined at the industry-state-year level in response to changes in the NCEI. This indicates that the competitive structure of the industry is not being changed by the shock; for example, by firms relocating in response to changes in non-compete enforcement.

IV. CALIBRATION AND MODEL ANALYSIS

With our conclusions from our empirical environment drawn, we now calibrate and analyze the model. We first illustrate some of its novel forces when appropriation a is a constant. We then study the full model with dynamic appropriability.

A. ILLUSTRATION OF MODEL MECHANISMS

We fix a to review the model's properties and highlight its novelties. We show how the co-dependence of specialists' and investors' value functions on w_0, the contract's initial relative wealth allocation to agents, affects the form of the optimal contract.

Figure 3 illustrates how specialists' skill a and bargaining power influence the solution to investors' problem. The four figures highlight the tension of competing interests and the impact of mobility on investment that we aim to capture in our model. We first focus on the left two figures under the low agency cost parameterization. In the top-left panel, we plot investors' value function $p(w)$ as a function of specialists' stake w for three cases. All three value functions at the contract termination boundary equal their liquidation payoff, l.

Two forces, common to DeMarzo et al.'s (2012) model, determine the shape of $p(w)$. Initially as w grows from the lower boundary, the severity of the agency conflict falls, thus raising firm value to investors. To further alleviate the agency friction, however, investors must promise a larger and larger share of the firm to specialists, and therefore $p(w)$ begins to decline, reflecting this wealth transfer. Eventually, its slope becomes linear and equal to negative one at the payment boundary. Despite risk neutrality, investors' value function is concave as investors internalize the risk that the optimal contract places on specialists' actions. The case when $a = 0$ essentially mirrors the benchmark result of DeMarzo et al. (2012).

We then increase a to 0.4 and look at two extremes of bargaining power. When investors have all power, the termination boundary increases to aw_0, where $w_0 = \text{argmax}_w \, p(w)$. This boundary follows from the condition in (9) and highlights our novel co-dependency across value functions: specialists' skill a impacts the lower boundary aw_0 that, in turn, affects the location of the maximum of investors' value function, w_0.

Next, granting managers all power further shifts the boundary rightwards to $a\overline{w}$, where $\overline{w} = w_0 = \max\{w : p(w) \geq 0\}$ here. Yet again we see the co-dependency manifesting itself. Here, specialists' skill a impacts that lower boundary $a\overline{w}$ that now affects the placement of specialists' maximum attainable value, $\overline{w}$. Hence, both investors' *and* specialists' maximum values, and more generally the shape of the contract, are affected by bargaining.

Another perspective on bargaining's effect can be seen by fixing w and enhancing specialists' option value. Investors' value function $p(w)$ falls, reflecting a loss in their wealth. This is not a wealth transfer, however, because total firm value $p(w) + w$ actually falls. In effect, greater bargaining power has made it more difficult to incentivize agents for a given w—the agency conflict has been exacerbated, lowering firm value.

We plot the investment rate of intangible capital, g, in the bottom-left panel. Better outside opportunities for specialists lowers the marginal return to investors on intangible capital. This pares investment. The smaller return reflects both a lower average value per unit of capital $p(w)$ and an aggravation of principals' and agents' separate interests, $p'(w)$. To maximize growth, then, is to maximize investors' share of rewards. This is the traditional prescription of Arrow (1962).

Turning to the right panels, we see the polar perspective when we increase λ. Intuitively, the cost of providing deferred compensation to specialists' has grown. Their outside option acts as a lower bound to their compensation, which is valuable to them, so when reducing their skill or when shifting bargaining power to investors, their incentive to work falls. Thus in this case, reducing managers' outside option aggravates the agency friction, which in turn flattens capital's average value and consequently its return on investment. The prescription for growth here is to ensure managers are adequately compensated and retain the value of their outside option, precisely the opposite prescription to the traditional view.

B. Calibration

We now calibrate our model that has dynamic appropriability. We divide the parameters into two groups, externally- and internally-calibrated. We tabulate them in Table IV along with the moments targeted by the internal calibration.

For regressions and sorts in the model, we simulate the model 5,000 times at a monthly frequency and aggregate the data to form annual observations. Each simulation contains 1,000 firms and has a length of 20 years after a burn-in to avoid dependence on initial values, giving us an firm-year observation count of 20,000 that is close to the size of our data sample. We average over simulations for point estimates and conditional moments.

B.1. External Calibration

We begin with the external parameters and set the annual real interest rate, r, to 4 percent. We use a value of $\delta_N = 15$ percent to be consistent with our definition in (27) and the Bureau of Economic Analysis's rate used for research and development. As we are interested in analyzing the long-run steady state of our model, we specify our smooth adjustment cost technology to study the model's long-run properties. Following Hall (2001), we interpret the parameter θ as a doubling time for a capital stock and set it to 20 years.

The threat of termination in the optimal contract is used to ensure agents' proper incentives.

The true costs of replacing managers has been little studied. Taylor (2010) provides a structural estimate in a dynamic compensation model of total chief executive firing costs to be 5.9 percent of firm assets. In line with this evidence, we impose $l = 0.94$.

The variability of the growth rate of intangible capital which influences the severity of the agency friction and the likelihood of contract termination. Equation (1) shows that the variability of cash flows is directly related to the variability of intangible capital. We equate σ_N to 0.2 to target unconditional cash flow volatility used in previous studies (for example, Gomes (2001) and Miao (2005)).

Upon contract termination at time t, a fraction $\zeta \in (0, 1)$ of matches are good quality and the specialist starts a new firm with capital $a_t N_t$. We set $\zeta = 0.3$, which is the value obtained by Gertler, Huckfeldt and Trigari (2020) in their internal calibration targeted to the share of job transitions involving positive wage changes. The remainder $1 - \zeta$ obtain a skill draw from a distribution of positive support. We fit a log normal curve to the distribution of skill for all US workers, weighted by individual employment in 1999 from the Bureau of Labor Statistics.[10] The estimates are a mean of -4 and standard deviation of 1.5 and we use those parameters. We then truncate the density so that its support remains compact as in our model.

We assume that the entry mass is conditional on the distribution of these skill levels a_0, $\psi(a_0, w_0) = \psi_w(w_0|a_0)\psi_a(a_0)$. Given the skill draw, the distribution of w_0 is degenerate and depends on investors' and specialists' bargaining power. Following Taylor (2010) who structurally estimates relative bargaining power to be equally split between shareholders and the chief executive, we assume that investors and specialists have equal power: $\psi = 0.5$.

B.2. Internal Calibration

As we focus on long-run growth, our internal calibration chooses parameters that are important in determining the shape of stationary distribution as well as entry and exit (turnover) rates. We first calibrate the marginal product of intangible capital to match average profitability and investment rates. In our data sample, the average profitability across all firm-years is 0.042 and this requires $Z = 0.224$. The exogenous growth rate z is calibrated to 0.028 to match our sample's average intangible investment rate of 0.212.

Average rates of contract termination are targeted with the parameter λ that measures the severity of the agency friction. All else equal, a higher value will increase the probability of termination. We calibrate parameter λ to 0.29 to match the sample's average CEO turnover rate of 4.7 percent.

Manager's time rate of preference is $\gamma > r$. Its value influences the length of the interval $[\underline{w}(a), \overline{w}(a)]$ for every a. More impatient agents (higher γ) require relatively sooner current pay-

[10]https://www.bls.gov/opub/mlr/2017/article/wage-and-job-skill-distributions-in-the-national-compensation-survey.htm

ments, lowering $\overline{w}(a)$ all else equal. We convert the agent's stock of compensation w to a flow by multiplying it by γ.[11] Altogether, we parameterize time preference to $\gamma = 0.11$ by calibrating to average compensation in the data, which is 0.018.

We use the results of our empirical environment to discipline key parameters; namely, the appropriability parameter κ and the volatility of the skill shock σ_a. First, given an investment rate $g - \delta_N$, equation (3) shows that the parameter κ determines the conditional mean growth rate of appropriation and thus the average value of outside options. Hence, investment is informative about appropriability. Second, Variation in a and thus in the value of outside options, $\underline{w}(a)$, influences the likelihood of turnover.

We target these two parameters with indirect inference. Specifically, we run panel regressions in each simulation to replicate the coefficients obtained in our empirical regressions:

$$g_{it+1} = f_i + \beta_g \times \underline{w}(a_{it}) + u_{it+1} \tag{28}$$

$$\mathbf{1}\{w_{it+1} < \underline{w}(a_{it+1})\} = f_i + \beta_w \times \underline{w}(a_{it}) + v_{it+1}, \tag{29}$$

where f_i are firm fixed effects, u and v errors, and β_g and β_w the target coefficients. As in the data, we regress the investment rate and an indicator for turnover on the outside option value and include firm fixed effects. The stationary economy obviates the need for year fixed effects. We set the values $\kappa = 0.4$ and $\sigma_a = 0.035$ to match Table I's coefficients.

C. Numerical Solution and Model Analysis

Figure 4 shows the top-down view of investors' value function as a function specialists' skill a and stake w. The form of the sail-shaped figure is determined by (21)'s maximum in conjunction with the attainment of the optimal boundaries described in Section II.

The calibrated model places the greatest value to investors in the bottom-right of the state space. Consequently, the stationary distribution will place a large mass in this region where low skills but high stakes are observed. There is thus a compromise: investors keep the risk of appropriation small and, in concession, give specialists a large stake in their firm.

The bottom boundary, along which $a \geq 0$, is reflecting. The right boundary is the impatience boundary $\overline{w}(a)$. Starting from $a = 0$, it initially rises and shifts out and to the right with a as it is optimal to reduce the likelihood of termination. At some point, however, the probability that a high-skilled specialist will leave is too great and motivating them with deferred compensation is too costly, thus bringing the boundary back in and to the left. The boundary where specialists leave the firm, $\underline{w}(a)$, coincides with the boundary where they are paid retention payments, $\overline{a}(w)$. In

[11] This conversion is consistent with a dynamic contracting model with an agent whose consumption-savings decisions are invariant to wealth effects, for example with CARA utility. See He (2011) and Ward (2022).

accordance with the equivalence shown in (20), investor value equals l all along these overlapping boundaries. Specialists with skill along the very top of the sail and who experience positive skill shocks receive retention payments at all levels of w.

Two black lines overlay the figure. The first is dotted and tracks the maximum of the value function for each a. We see that at low values of skill the maximum lies in the interval $[\underline{w}(a), \overline{w}(a)]$ but when $a > 1$ it lies on the lower boundary $\underline{w}(a)$. This depicts the continuous transition from a "low agency cost" to a "high agency cost" environment that we saw in Figure 3.

The second line is dashed and equals $a\overline{w}(a)$. In the special case where specialists were to have all bargaining power, the value function would lie completely below this line as this is how the lower boundary $\underline{w}(a)$ would be determined. We see that part of the value function lies above it for a given w, reflecting the expansion of the contracting space by giving some bargaining power to investors.

As in DeMarzo et al. (2012), investors' scaled value function $p(a, w)$ is concave in specialists' stake w. For a given a, investors' value to the right of the dotted line decline, a result of wealth transfers from investors to specialists to provide sufficient incentive for them to continue working. What is new is that the value function declines in a for a given stake. Greater skill raises the probability of costly termination as it becomes more likely a valuable agent will leave. Investors' value consequently is reduced as it becomes more costly to motivate agents.

C.1. Distribution of Outside Options

To further verify our model's ability to match the data, we compare distributions of outside options, something not targeted in our calibration. The variable being compared is an executive's value of outside options divided by their firm's intangible capital, $\underline{W}(a)/N$.

We make two adjustments before doing so. First, we convert the model's numbers to a flow by multiplying $\underline{w}(a)$ by γ, consistent with our treatment of compensation and the measurement in the data. Second, in the model when a specialist leaves they find a new firm with probability one. In the data, not all find a new job immediately. Consequently, we adjust the empirical option value by multiplying by the probability of finding a job conditional on leaving one, which is 7.75 percent in the data for chief executives.

After these adjustments, we compare the stationary distribution of scaled outside options in the model to our empirical measure in Figure 5. We see that the model's marginal distribution of outside options is clustered near zero and has a long right tail, as in the data—being truly highly skilled is a rarity. On the whole, the model fit is very close.

C.2. Portfolio Sorts and Model Predictions

We turn to examining the model's predictions for compensation, turnover, and investment and how they vary with the distribution of outside options. Each year in both model and data, we rank executives by their scaled outside options $\gamma\underline{w}(a)$ sort them into quintiles. We then form five equal-weighted portfolios on various statistics based on these ranks and rebalance every year. Because specialists' skill is monotone in their outside option, $\underline{w}'(a) > 0$, our non-parametric sorts on options are equivalently sorts on skill.

We tabulate each quintile's time-series average across in Table V. Panel A reports the data and Panel B reports the model. In both panels, the value of specialists' outside options per unit of intangible capital increases along these quintiles, rising from near zero all the way to 91 basis points in the data.

We first analyze compensation. Compensation grows with outside option values in both model and data. In the model, as specialists' option values grow, the optimal contract prescribes an increase in their compensation as a form of retention. Intuitively, because contract termination is costly to investors, raising specialists' compensation level is consistent with lowering the likelihood of termination. This positive correlation across outside options and compensation arises endogenously from the optimal contract despite the independence of shocks across (3) and (5).

In the third rows we tabulate the annual probability of turnover. We count the instances of contract termination in the empirical and simulated data and convert them to a frequency. As the values of outside options rise, this probability falls, reflecting investors' effort at retaining specialists by paying them more.

C.3. Investment Decomposition

In the fourth row of each panel in Table V, we compare the effects of outside options on intangible investment. To isolate the effect of outside options on investment we control for compensation. In the model, this is like holding stake w fixed while we vary skill a. Investment net of compensation is the residual from a regression of intangible investment rates on compensation. Investment rates decline with specialists' value of outside options in both model and data. Once controlling for compensation, they are positive at low quintiles but become negative at high quintiles.

We use the model to gain insight on these investment patterns by decomposing it in the bottom three rows of Panel B via the marginal benefit of investment in (22). First, the average gain to investors per unit of intangible capital, $p(a, w)$, falls. Specialists with large outside options effectively possess a great share of inside equity and thus the return for investors has been reduced. In effect, a greater fraction of the rewards to intangible capital are earned by specialists, not owners.

Second, agency's impact on investment, similar to DeMarzo et al.'s (2012), is reported in the second-to-last row. Investment reduces the effective share that specialists have in the firm as $w = W/N$ declines in N. This exacerbates the agency friction and results in lower investment. We see that the magnitude of this effect becomes pronounced when specialists have a valuable outside option. The risk of appropriation thus magnifies the agency conflict's adverse effect on investment.

Third and last, appropriation lowers the marginal benefit to investment. Intuitively, investment raises agents' skill and their likelihood of leaving, which impacts the probability of costly termination. This effect is captured in the right-most term of (22), $\kappa p_a(w,a)a$, which is negative. In addition, the set of firms near the termination boundary are also likely to face retention costs, as captured in (23). Both retention costs and appropriation serve to lower the expected return on capital. This appropriation cost has about one-third to one-half of the impact that agency costs alone have on lowering investment.

C.4. Dynamic Contracting Implications

Recall that Section II.D.2 shows our model has history dependence. In particular, specialists' total compensation depends on the history of agents' skill a. Following Ai et al. (2021) we proxy for this history by the running maximum of the value of specialists' outside options; specifically, we compute $\max \gamma \underline{w}(a_t) = \sup_{0 \leq s \leq t} \gamma \underline{w}(a_s)$ and let changes in time t update this maximum.

We begin by testing if total compensation depends on the running maximum. We present results in Table VI. Panel A shows that in both model and data a larger maximum positively correlates with compensation at the firm-level after controlling for fixed effects. Histories where outside option values have grown are those that correlate with greater compensation going forward, reflecting the firm's effort in retaining the executive.

We also look at three-year differences in this maximum that, once controlling for compensation, are informative about changes the severity of the agency conflict. Intuitively, all else equal, a recent growth in the value of outside options would exacerbate the severity of the agency conflict, lowering the expected return on investment. Thus we expect the coefficient on the three-year change to be negative. In Panel B we test this prediction by regressing investment on compensation and the three-year change. Consistent with this intuition, we find a negative effect on the three-year change in both model and data.

Altogether, these dynamic contracting implications of the model are supported empirically. This confirms the model's ability in replicating the key features of the data.

V. Counterfactual Analysis on Worker Mobility

Having verified the model's ability to match the data, in this section we use the model to run counterfactuals. We use steady state analysis (Hopenhayn (1992)) to see how a change in model parameter impacts the stationary density of firms and their policy functions. Here, we are interested in how the distribution of investment rates vary in response to the appropriation parameter, κ. We use this to analyze whether growth rates could possibly be increased by tightening or easing constraints on the ability of specialists to appropriate knowledge. Though the stationary distributions remain constant conditional on a choice of κ, they do so only by the offsetting effects of firm expansion and contraction, of specialist departure and re-employment. Steady state analysis is thus suited to understanding the long-run effects of these changes.

We summarize our steady state analysis with Figure 6. The model produces a hump-shaped pattern that reflects the tension between competing interests. On the one hand, strict enforcement of appropriability (low values of κ) are too burdensome on employees. As a result, it is harder to motivate specialists and providing them incentive to work becomes costly. This is a world of severe agency conflicts. On the other hand, lax enforcement (high κ) reduces the ability of the firm's owners to capture the rents associated with intangible investment (Arrow 1962). Investment is thus pared.

The graph finds the maximum value to be attained at $\kappa = 0.3$, a value 0.1 units smaller than the current estimate. The economy's growth rate could be raised by approximately 10 basis points a year from a modest tightening of restrictions on labor mobility. This prediction is consistent with our empirical results of Section III and, in the language of Arrow (1962), owners' concerns modestly taking precedence over employees'.

How do we map κ to the data? In the data, we exploit variation in an ordinal variable, *NCEI*, which does not measure directly the appropriation parameter. Instead, we link both model and data through the variation in the scaled value of outside options observed when changing either *NCEI* by one unit or κ by an appropriate amount. Thus, outside options are the key to bridging model and data.

Empirically, column (4) of our first-stage regression in Table I shows that a unit increase in *NCEI* leads to a 0.005 reduction in the value of an executive's outside option per unit of intangible capital. By way of simulation, we estimate that the required decline in κ in the model to generate the same reduction in the scaled outside option value is 0.1. Hence, the model predicts that to increase investment the non-compete enforcement index should grow by approximately one unit on average across all states.

We should be cautious, however, in advocating only for owners' interest. The figure shows that one should not restrict mobility too much, as the average growth rate begins to drop after more than a 0.1 reduction in κ. Thus, extrapolating local average treatment effects in conducting policy might lead to unintended consequences.

Our analysis provides a forceful critique to the sweeping proposal put forward by the FTC. Our results point towards owners' and specialists' interests being nearly adequately balanced in the US economy. Economically, there is no need to tinker. On the whole, the growth rate achieved in the model calibrated to current US data is nearly maximized.

A. What Forces Change with Appropriation in the Equilibrium Distribution?

We inspect the mechanism that a modest strengthening of restrictions has worker mobility and growth.

In Figure 7 we show both the marginal distribution of specialists' stake, w, and the conditional investment rates given w in the top and bottom panels, respectively. Here we see that lowering κ to 0.3 shifts the distribution. In particular, there is a greater probability mass at lower values of w, especially below $w = 0.15$. Hence, specialists' in the lower tail of the compensation distribution are expected to change from this policy.

This greater mass coincides with a higher investment rate as seen in the bottom panel, explaining our finding in the previous section. Mathematically, the upper bound on stake at smaller values of skill, $\underline{w}(a \approx 0)$ has been lowered. This explains the shift in the local peak of the marginal density of w moving from 0.15 to 0.14. Investors have effectively become less averse to contract termination, flattening their value function and lowering the upper bound. As a result, the marginal return on investment has grown as the adverse effects of appropriation on investment, $\kappa p_a(\cdot)a$, have fallen. Thus, lower appropriability enhances the expected return on investment.

Conclusion

William Shockley left Bell Labs in New Jersey to eventually establish Shockley Semiconductor in California. Shockley, both brilliant and abrasive, proved to be intolerable for some of his employees. A group of eight engineers, including Gordon Moore, quit Shockley to start several ventures, including Kleiner Perkins and Fairchild Semiconductor, which led to Intel. What would our world be like today if Shockley, Moore, and others were prohibited from leaving their firms? While this sequence of events was among the most fateful, history is littered with countless examples.

We lay the foundation and take a solid step towards answering this question. We formulate a novel structural growth model that places at its fore the competing interests of investors and specialists. We then calibrate the model to a crafted empirical environment that exploits variation in a state-level enforcement index of non-compete agreements. We use our theoretical environment to study counterfactuals on how worker mobility affects growth.

We conclude that the *current* structure of employment restrictions is near growth-optimal and adequately balances stakeholders' interests. Our work emphasizes the importance of a perspective that may be being downplayed or outright ignored by the FTC when deciding how to regulate workers' mobility—the investment incentives of owners to be able to fully retain the rewards from their continued investment in intangible capital.

REFERENCES

Acemoglu, Daron, *Introduction to Modern Economic Growth*, Princeton University Press, 2009.

Achdou, Yves, Jiequn Han, Jean-Michel Lasry, Pierre-Louis Lions, and Benjamin Moll, "Income and Wealth Distribution in Macroeconomics: A Continuous-Time Approach," *Review of Economic Studies*, 2022, *89* (1), 45–86.

Aghion, Phillipe and Peter Howitt, "A Model of Growth Through Creative Destruction," *Econometrica*, March 1992, *60* (2), 323–351.

Ai, Hengjie and Anmol Bhandari, "Asset pricing with endogenously uninsurable tail risk," *Econometrica*, 2021, *89* (3), 1471–1505.

____ **and Rui Li**, "Investment and CEO Compensation under Limited Commitment," *Journal of Financial Economics*, 2015, *116* (3), 452–472.

____**, Dana Kiku, Rui Li, and Jincheng Tong**, "A Unified Model of Firm Dynamics with Limited Commitment and Assortative Matching," *Journal of Finance*, 2021, *76* (1), 317–356.

____**, Mariano Massimiliano Croce, and Kai Li**, "Toward a Quantitative General Equilibrium Asset Pricing Model with Intangible Capital," *Review of Financial Studies*, 2013, *26* (2), 491–530.

Akcigit, Ufuk, Murat Alp Çelik, and Jeremy Greenwood, "Buy, Keep or Sell: Economic Growth and the Market for Ideas," *Econometrica*, 2015. Forthcoming.

Albuquerque, Rui and Neng Wang, "Agency Conflicts, Investment, and Asset Pricing," *Journal of Finance*, 2008, *63* (1), 1—40.

Arrow, Kenneth J., *Economic Welfare and the Allocation of Resources for Invention*, Princeton University Press, Princeton, NJ, 1962.

Atkeson, Andrew and Patrick J. Kehoe, "Modeling the Transition to a New Economy: Lessons from Two Technological Revolutions," *American Economic Review*, March 2007, *97* (1), 64–88.

Babina, Tania and Sabrina Howell, "Entrepreneurial Spillovers from Corporate R&D," 2022. Working Paper.

Barles, Guy and Panagiotis E. Souganidis, "Convergence of Approximation Schemes for Fully Nonlinear Equations," *Asymptotic Analysis*, 1991, *4* (3), 271–283.

Bell, Alex, Raj Chetty, Xavier Jaravel, Neviana Petkova, and John Van Reenen, "Who Becomes an Inventor in America? The Importance of Exposure to Innovation," *Quarterly Journal of Economics*, 2019, *134* (2), 647–713.

Belo, Frederico, Jun Li, Xiaoji Lin, and Xiaofei Zhao, "Labor-Force Heterogeneity and Asset Prices: The Importance of Skilled Labor," *Review of Financial Studies*, 2017, *30* (10), 3669–3709.

Biais, Bruno, Thomas Mariotti, Guillaume Plantin, and Jean-Charles Rochet, "Dynamic Security Design: Convergence to Continuous Time and Asset Pricing Implications," *Review of Economic Studies*, 2007, *74*, 345–390.

Bolton, Patrick, Neng Wang, and Jinqiang Yang, "Optimal Contracting, Corporate Finance, and Valuation with Inalienable Human Capital," *Journal of Finance*, 2019, *74* (3), 1363–1429.

Brown, James R., Steven M. Fazzari, and Bruce C. Petersen, "Financing Innovation and Growth: Cash Flow, External Equity, and the 1990s R&D Boom," *Journal of Finance*, 2009, *44* (1), 141–185.

Burdett, Kenneth and Randall Wright, "Two-Sided Search with Nontransferable Utility," *Review of Economic Dynamics*, January 1998, *1* (1), 220–245.

Çelik, Murat Alp and Xu Tian, "Agency Frictions, Managerial Compensation, and Disruptive Innovations," *Review of Economic Dynamics*, Forthcoming.

Comin, Diego and Mark Gertler, "Medium-Term Business Cycles," *American Economic Review*, June 2006, *96* (3), 523–551.

Crouzet, Nicholas and Janice Eberly, "Rents and Intangible Capital: a Q+ Frameworkl," *Journal of Finance*, Forthcoming.

____ , ____ , Andrea Eisfeldt, and Dimitris Papanikolaou, "A Model of Intangible Capital," 2022. Working Paper.

____ , ____ , ____ , and ____ , "The Economics of Intangible Capital," *Journal of Economic Perspectives*, Forthcoming.

DeMarzo, Peter M. and Yuliy Sannikov, "Optimal Security Design and Dynamic Capital Structure in a Continuous-Time Agency Model," *Journal of Finance*, 2006, *61* (6), 2681–2724.

____ , Michael J. Fishman, Zhiguo He, and Neng Wang, "Dynamic Agency and the q Theory of Investment," *Journal of Finance*, 2012, *67* (6), 2295–2340.

Donangelo, Andrés, "Labor Mobility: Implications for Asset Pricing," *Journal of Finance*, 2014, *69* (3), 1321–1346.

____ , Francois Gourio, Matthias Kehrig, and Miguel Palacios, "The Cross-Section of Labor Leverage and Equity Returns," *Journal of Financial Economics*, 2019, *132* (2), 497–518.

Dow, James, Gary Gorton, and Arvind Krishnamurthy, "Equilibrium Investment and Asset Prices under Imperfect Corporate Control," *American Economic Review*, 2005, *95* (3).

Eisfeldt, Andrea L. and Dimitris Papanikolaou, "Organization Capital and the Cross-Section of Expected Returns," *Journal of Finance*, 2013, *68* (4), 1365–1406.

____ , Antonio Falato, and Mindy Zhang Xiaolan, "Human Capitalists," 2019. Working Paper.

Fedyk, Anastassia and James Hodson, "Trading on Talent: Human Capital and Firm Performance," 2022. Working Paper.

Garmaise, Mark J., "Ties that truly bind: Noncompetition agreements, executive compensation, and firm investment," *Journal of Law, Economics, and Organization*, 2011, *27* (2), 376–425.

Gentry, Richard J., Joseph S. Harrison, Timothy J. Quigley, and Steven Boivie, "A database of CEO turnover and dismissal in S&P 1500 firms, 2000–2018," *Strategic Management Journal*, 2021, *42* (5), 968–991.

Gertler, Mark, Christopher Huckfeldt, and Antonella Trigari, "Unemployment Fluctuations, Match Quality, and the Wage Cyclicality of New Hires," *Review of Economic Studies*, 2020, *87*, 1876–1914.

Gillan, Stuart L., Jay C. Hartzell, Andrew Koch, and Laura T. Starks, "Getting the Incentives Right: Backfilling and Biases in Executive Compensation Data," *Review of Financial Studies*, 2018, *31* (4), 1460–1498.

Gomes, Joao F., "Financing Investment," *American Economic Review*, 2001, *91* (5), 1263–1285.

Goodman-Bacon, Andrew, "Difference-in-Differences with Variation in Treatment Timing," Technical Report, Mimeo Federal Reserve Bank of Minneapolis 2020.

Graham, John R., Dawoon Kim, and Hyunseob Kim, "Executive Mobility in the United States, 1920 to 2011," 2020. Working Paper.

Grossman, Gene M. and Elhanan Helpman, *Innovation and Growth in the Global Economy*, MIT Press, 1991.

Harrison, J. Michael, *Brownian Motion and Stochastic Flow Systemz*, John Wiley & Sons, 1985.

He, Zhiguo, "Optimal Executive Compensation When Firm Size Follows Geometric Brownian Motion," *Review of Financial Studies*, 2009, *22* (2), 859–892.

——, "A Model of Dynamic Compensation and Capital Structure," *Journal of Financial Economics*, 2011, *100* (2), 351–366.

Hopenhayn, Hugo A., "Entry, Exit, and Firm Dynamics in Long-Run Equilibrium," *Econometrica*, 1992, *60* (5), 1127–1150.

Hudson, Sally, Peter Hull, and Jack Liebersohn, "Interpreting instrumented difference-in-differences," *Metrics Note, Sept*, 2017.

Jeffers, Jessica S., "The Impact of Restricting Labor Mobility on Corporate Investment and Entrepreneurship," 2020. Working Paper.

Jones, Larry E. and Rodolfo E. Manuelli, *Neoclassical Models of Endogenous Growth: The Effects of Fiscal Policy, Innovation and Fluctuations*, North-Holland, Amsterdam, 2005.

Jorgenson, Dale W., "Accounting for Growth in the Information Age," in Philippe Aghion and Steven N. Durlauf, eds., *Handbook of Economic Growth*, Vol. 1, Elsevier B.V., 2005, chapter 10, pp. 743–815.

Kini, Omesh, Ryan Williams, and Sirui Yin, "CEO noncompete agreements, job risk, and compensation," *Review of Financial Studies*, 2021, *34* (10), 4701–4744.

Kogan, Leonid, Dimitris Papanikolaou, and Noah Stoffman, "Left Behind: Creative Destruction, Inequality, and the Stock Market," *Journal of Political Economy*, 2020, *128* (3).

Lev, Baruch and Suresh Radhakrishnan, "The Valuation of Organization Capital," in Carol Corrado, John Haltiwanger, and Dan Sichel, eds., *Measuring Capital in the New Economy*, National Bureau of Economic Research: Cambridge, MA, 2005.

Lucas, Robert E., "On the Mechanics of Economic Development," *Journal of Monetary Economics*, 1988, *22*, 3–42.

Lustig, Hanno, Chad Syverson, and Stijn Van Nieuwerburgh, "Technological Change and the Growing Inequality in Managerial Compensation," *Journal of Financial Economics*, 2011, *99* (3), 601–627.

Malsberger, Brian M., *Covenants Not to Compete: A State-by-State Survey*, Washington, DC: BNA Books, 2004.

Miao, Jianjun, "Optimal Capital Structure and Industry Dynamics," *Journal of Finance*, 2005, *60* (6), 2621–2660.

Peters, Ryan H. and Lucian A. Taylor, "Intangible Capital and the Investment-q Relation," *Journal of Financial Economics*, 2017, *123* (2), 251–272.

Prescott, Edward C. and Michael Visscher, "Organization Capital," *Journal of Political Economy*, 1980, *88* (3), 446–461.

Rogerson, Richard, Robert Shimer, and Randall Wright, "Search-Theoretic Models of the Labor Market: A Survey," *Journal of Economic Literature*, 2005, *43*, 959–988.

Romer, Paul M., "Increasing Returns and Long-run Growth," *Journal of Political Economy*, 1986, *94* (5), 1002–1037.

——, "Are Nonconvexities Important for Understanding Growth?," *American Economic Review*, 1990, *80* (2).

——, "Endogenous Technological Change," *Journal of Political Economy*, 1990, *98* (5), S71–S102.

Sannikov, Yuliy, "A Continuous-Time Version of the Principal-Agent Problem," *Review of Economic Studies*, 2008, *75* (3), 957–984.

Schubert, Gregor, Anna Stansbury, and Bledi Taska, "Getting labor markets right: Outside options and occupational mobility," *Working Paper*, 2019.

Schumpeter, Joseph, *Capitalism, Socialism, and Democracy*, Harper, New York, NY, 1942.

Shi, Liyan, "The Macro Impact of Noncompete Contracts," *Econometrica*, 2022. Forthcoming.

Solow, Robert, "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, 1956, *41* (1), 65–94.

Spear, Stephen E. and Sanjay Srivastava, "On Repeated Model Hazard with Discounting," *Review of Economic Studies*, 1987, *54* (4), 599–617.

Sun, Liyang and Sarah Abraham, "Estimating dynamic treatment effects in event studies with heterogeneous treatment effects," *Journal of Econometrics*, 2021, *225* (2), 175–199.

Sun, Qi and Mindy Z. Xiaolan, "Financing Intangible Capital," *Journal of Financial Economics*, 2019, *132*, 472–496.

Taylor, Lucian A., "Why Are CEOs Rarely Fired? Evidence from Structural Estimation," *Journal of Finance*, 2010, *65* (6), 2051–2087.

Uzawa, Hirofumi, "Optimum Technical Change in an Aggregative Model of Economic Growth," *International Economic Review*, 1965, *6*, 18–31.

Ward, Colin, "Is the IT Revolution Over? An Asset Pricing View," *Journal of Monetary Economics*, 2020, *114*, 283–316.

____ , "Agency in Intangibles," 2022. Working Paper.

Xiaolan, Mindy Zhang, "Who Bears Firm-Level Risk? Implications for Cash Flow Volatility," 2014. Working Paper.

TABLE I: FIRST STAGE: ENFORCEABILITY ON CEOS' OUTSIDE OPTION VALUES

This table reports the first-stage regression results for the effect of the enforceability of non-compete agreements on the value of CEO outside options. The variable $\log$ Outside Option is the logarithm of one plus the outside option index for CEOs. The level of non-compete enforceability index is *NCEI* and changes in the index, Δ*NCEI*, are one if the firm's state's *NCEI* is higher than the 1992 initial value in a given year, negative one if it is lower than that, and zero if unchanged. Control variables are all lagged and include the investment rate, turnover, Tobin's Q, cash, profitability, leverage, the logged level of intangible capital, and a CEO indicator for whether her/his age is above 62. We include firm- and year-fixed effects. Observations are at the firm-year level. Standard errors are clustered at the firm level and are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
Dep. Variable:	$\log$ Outside Option	$\log$ Outside Option	$\frac{\text{Outside Option}}{\text{Intangible Capital}}$	$\frac{\text{Outside Option}}{\text{Intangible Capital}}$
NCEI	-0.041***		-0.004***	
	(0.01)		(0.00)	
Δ*NCEI*		-0.053***		-0.005***
		(0.01)		(0.00)
Controls	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y
Year FEs	Y	Y	Y	Y
N	20,316	20,316	20,316	20,316
F-stat	49.66	60.79	23.51	23.46

TABLE II: SECOND STAGE: CEOS' OUTSIDE OPTION VALUES ON INVESTMENT AND TURNOVER

This table provides the second-stage regression results for the effect of shocks to outside options on intangible investment and CEO turnover. The variables $\log \widehat{\text{Outside Option}}$ and $\widehat{\text{Outside Option}/\text{Intangible Capital}}$ are the instrumented outside option index for CEOs obtained in Table I. Intangible Investment Rate is the investment rate of intangible capital in a given year. R&D Investment is R&D expenditure scaled by intangible capital. CEO Turnover is one if the company has a CEO turnover and zero otherwise. Control variables are all lagged and include the investment rate, turnover, Tobin's Q, cash, profitability, leverage, the logged level of intangible capital, and a CEO indicator for whether her/his age is above 62. We include firm- and year-fixed effects. Observations are at the firm-year level. Standard errors are clustered at the firm level and are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Logged Outside Option						
	Instrument: *NCEI*			Instrument: Δ*NCEI*		
	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Variable:	Intangible Investment Rate	R&D Investment	CEO Turnover	Intangible Investment Rate	R&D Investment	CEO Turnover
$\log \widehat{\text{Outside Option}}$	−0.072*	−0.169***	0.166*	−0.066*	−0.169***	0.219**
	(0.04)	(0.06)	(0.10)	(0.03)	(0.06)	(0.11)
Controls	Y	Y	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y	Y	Y
Year FEs	Y	Y	Y	Y	Y	Y
N	20,316	20,316	20,316	20,316	20,316	20,316
Panel B: Outside Option over Intangible Capital						
	Instrument: *NCEI*			Instrument: Δ*NCEI*		
	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Variable:	Intangible Investment Rate	R&D Investment	CEO Turnover	Intangible Investment Rate	R&D Investment	CEO Turnover
$\frac{\widehat{\text{Outside Option}}}{\text{Intangible Capital}}$	-0.711*	-1.685***	1.652	-0.705*	-1.799**	2.333*
	(0.39)	(0.65)	(1.03)	(0.38)	(0.70)	(1.24)
Controls	Y	Y	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y	Y	Y
Year FEs	Y	Y	Y	Y	Y	Y
N	20,316	20,316	20,316	20,316	20,316	20,316

TABLE III: HIGH-SKILLED EMPLOYEES' OUTSIDE OPTION VALUES ON FIRM INVESTMENT

This table shows both first- and second-stage regression results for the effect of shocks to high-skilled employees' outside options on firms' intangible investment. The variable $\log \widehat{\text{Outside Option}}_{HS}$ is the instrumented outside option index for workers in high-skilled industries. Intangible Investment Rate is the investment rate of intangible capital in a given year. R&D Investment is R&D expenditures scaled by intangible capital. Control variables are all lagged and include the investment rate, turnover, Tobin's Q, cash, profitability, leverage, and the logged level of intangible capital. We include firm- and year-fixed effects. Observations are at the firm-year level. Standard errors are clustered at the firm level and are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	Instrument: *NCEI*			Instrument: Δ*NCEI*		
	First stage	Second stage		First stage	Second stage	
	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Variable:	$\log$ Outside Option$_{HS}$	Intangible Investment Rate	R&D Investment	$\log$ Outside Option$_{HS}$	Intangible Investment Rate	R&D Investment
NCEI	−0.023***					
	(0.00)					
Δ*NCEI*				−0.022***		
				(0.00)		
$\log \widehat{\text{Outside Option}}_{HS}$		−0.061	−0.352***		−0.081	−0.419***
		(0.07)	(0.12)		(0.09)	(0.15)
Controls	Y	Y	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y	Y	Y
Year FEs	Y	Y	Y	Y	Y	Y
N	13,306	13,306	13,306	13,306	13,306	13,306
F-stat	93.14			51.31		

TABLE IV: SUMMARY OF CALIBRATION (ANNUAL)

This table summarizes the chosen values of the benchmark calibration discussed in Section IV

Panel A: External Parameters	
Description	Value
Real interest rate, r	0.04
Intangible depreciation rate, δ_N	0.15
Capital doubling time, θ	20
Loss given turnover, l	0.94
Volatility of intangible capital growth, σ_N	0.20
Fraction of good matches, ζ	0.30
Specialists' relative bargaining power, ψ	0.50

Panel B: Internal Parameters	
Description	Value
Average investment growth, z	0.028
Specialists' discount rate, γ	0.100
Agency friction, λ	0.290
Productivity, Z	0.224
Variation in skill, σ_a	0.035
Appropriability, κ	0.400

Panel C: Targeted Moments		
Moment/regression coefficient	Model	Data
Average compensation	0.013	0.018
Average turnover rate	0.051	0.047
Average profitability	0.022	0.042
Average investment rate	0.197	0.212
Turnover on scaled outside option	3.416	2.333
Investment rate on scaled outside option	-2.150	-0.705

TABLE V: CHARACTERISTICS OF PORTFOLIO SORTS AND INVESTMENT DECOMPOSITION

This table lists time-series averages of characteristics of portfolios sorted into quintiles annually on firms' outside option-to-intangible capital ratio in both data and model. In the model, we use our simulated data from model's steady state. Outside option is $\underline{w} = \underline{W}/N$, agent's compensation is $\gamma w = \gamma W/N$, the probability of turnover is annualized average exit rate: $P\{w_{t+1} < \underline{w}(a_t)\}$, and the investment rate is g.

Panel A: Data					
	Outside Option Quintile				
	1	2	3	4	5
Outside option	0.00003	0.0002	0.0006	0.0017	0.0091
Compensation	0.0090	0.0072	0.0124	0.0193	0.0371
P(turnover)	0.040	0.045	0.042	0.041	0.029
Investment net of compensation	0.0004	0.0021	0.0005	-0.0019	-0.0018
Panel B: Model					
	Outside Option Quintile				
	1	2	3	4	5
Outside option	0.0004	0.0008	0.0013	0.0021	0.0054
Compensation	0.0124	0.0127	0.0130	0.0135	0.0155
P(turnover)	0.0525	0.0547	0.0530	0.0492	0.0461
Investment net of compensation	0.0023	0.0008	0.0001	-0.0011	-0.0039
Investment decomposition: $c'(g) = p(a,w) - p_w(a,w)w + \kappa p_a(a,w)a$					
Investor value, $p(a,w)$	1.583	1.411	1.218	1.054	0.950
Agency cost, $p_w(a,w)w$	0.038	-0.022	-0.091	-0.130	-0.133
Appropriation cost, $\kappa p_a(a,w)a$	-0.030	-0.062	-0.084	-0.076	-0.056

TABLE VI: IMPLICATIONS OF DYNAMIC CONTRACTING

This table presents estimates of panel regression coefficients in both data and model. All data regressions exclude 2008 and 2009 and control for firm- and year-fixed effects

$$y_{it} = f_i + f_t + \alpha_i C_{it-1} + \beta_i X_{it-1} + \epsilon_{it},$$

where C_{it-1} is our set of lagged controls listed in Appendix B.
Compensation is the variable $tdc1$ that includes salary, bonuses, and deferred compensation in the form of equity and options at the time of granting, scaled by lagged intangible capital. Investment is the investment rate of intangible capital. In the data, we calculate $\gamma \underline{w}(a_{it-1})$ using the ratio of outside option values (24) to firm's intangible capital (27).
All model regressions are done in the stationary distribution and control for firm-fixed effects:

$$y_{it} = f_i + \beta_i X_{it-1} + \epsilon_{it},$$

where $X_{it-1} = \max \gamma \underline{w}(a_{it-1}) = \sup_{0 \leq s \leq t-1} \gamma \underline{w}(a_{is})$.
Panel A reports the point estimates of a regression of compensation on the running maximum of scaled outside options.
Panel B lists the coefficient estimates of the intangible investment rate, g, regressed on compensation, γw, and a three-year difference of the running maximum, $\Delta_3 \max \gamma \underline{w}(a_{it-1}) = \max \gamma \underline{w}(a_{it-1}) - \max \gamma \underline{w}(a_{it-4})$.

Panel A: Compensation			
Model		Data	
$\max \underline{w}(a_{it-1})$	0.353	$\max \underline{w}(a_{it-1})$	2.662
Panel B: Investment			
Model		Data	
Compensation	1.894	Compensation	0.003
$\Delta_3 \max \underline{w}(a_{it-1})$	-1.430	$\Delta_3 \max \underline{w}(a_{it-1})$	-0.080

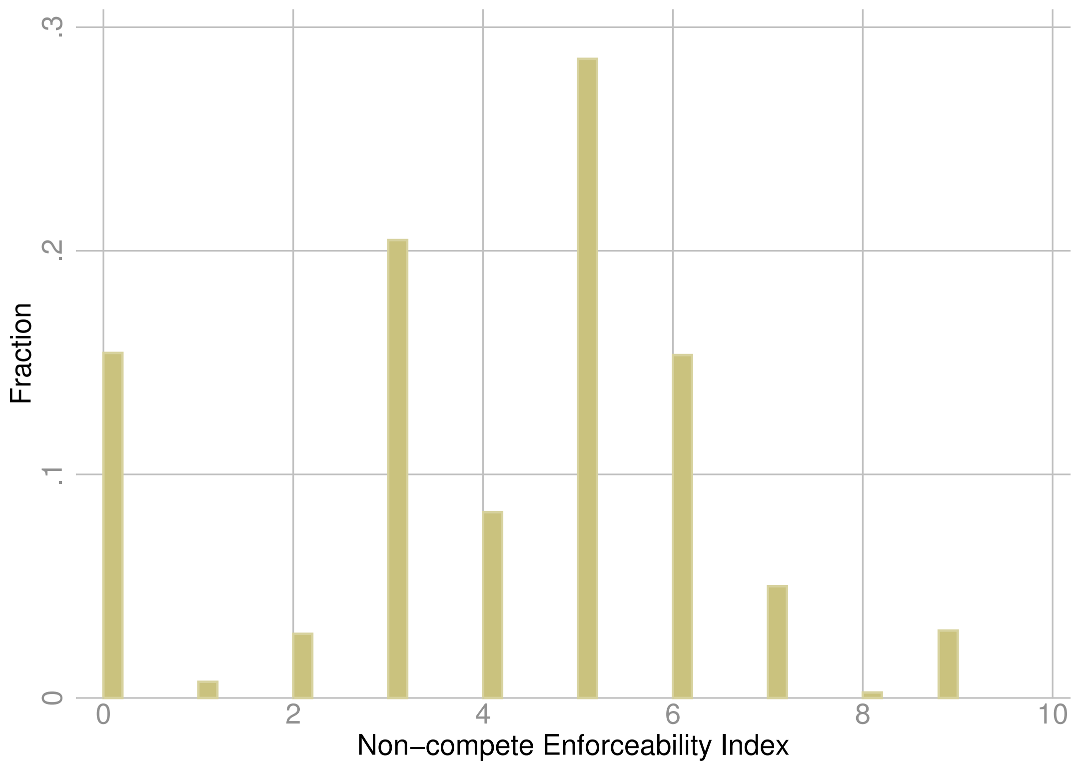
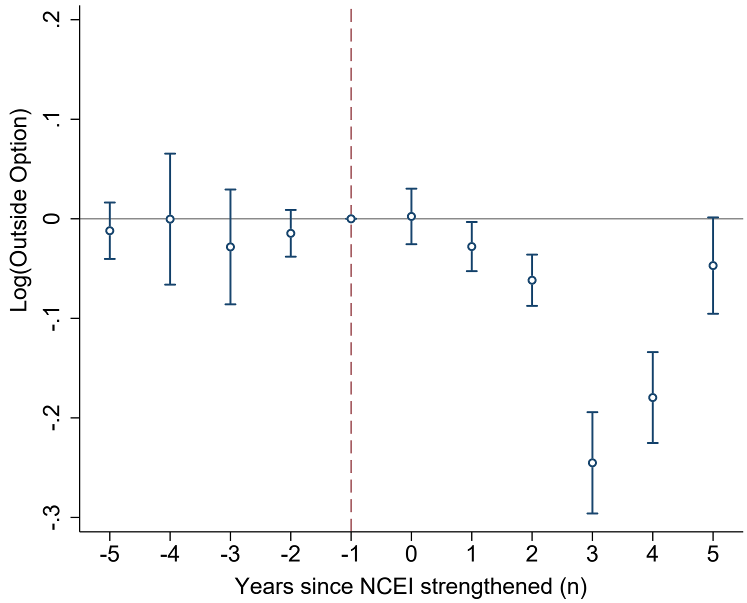


FIGURE 1: DISTRIBUTION OF NCEI

This figure shows the distribution of the values of the non-compete enforceability index (NCEI) across our state-year sample. Higher values indicate stricter enforcement of non-compete agreements.

(a) Control Group: Never Treated



(b) Control Group: Last Treated

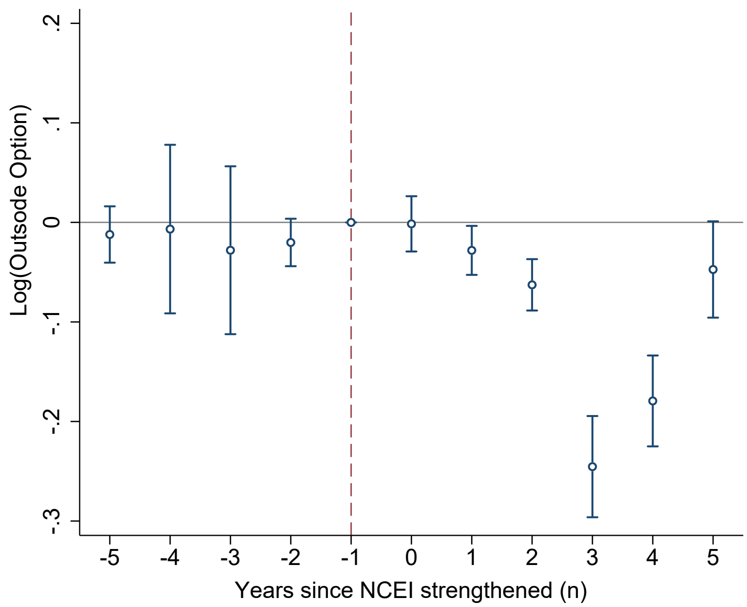


FIGURE 2: PARALLEL TRENDS: NCEI CHANGES ON OUTSIDE OPTIONS

This figure provides parallel trends for the first-stage regressions, the effect of strengthening of the NCEI ($\Delta NCEI > 0$) on the outside option ($\log$(Outside Option)). Each data point represents the point estimate of the interaction of time dummies with $\Delta NCEI$. The control groups are constructed following the methodology of Sun and Abraham (2021): the top figure uses firms that are never treated as the control group, while the bottom figure uses firms that were last treated as the control group. Bars represent 95% confidence intervals based on errors clustered at the firm-level.

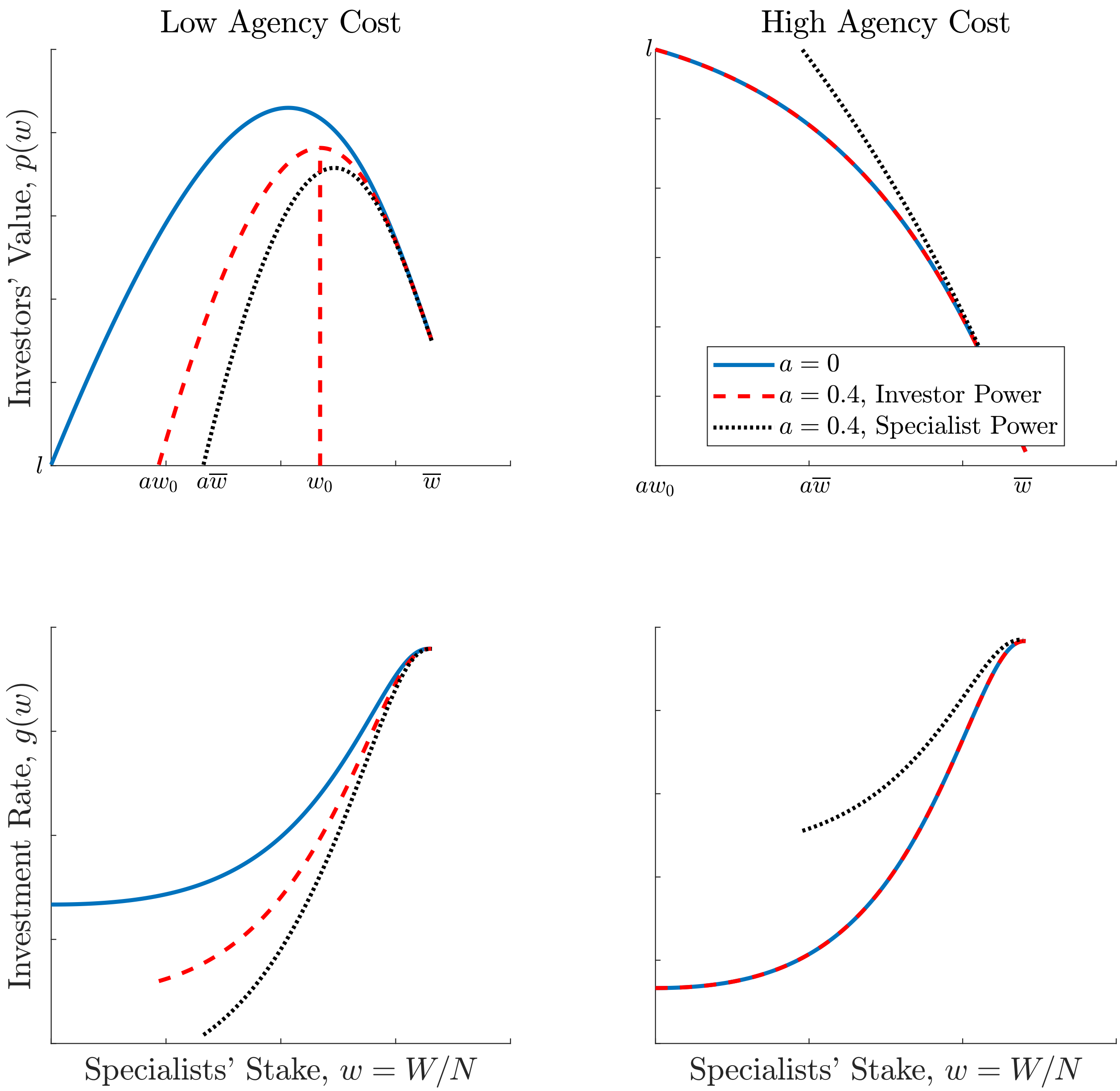


FIGURE 3: ILLUSTRATION OF AGENCY, APPROPRIATION, AND BARGAINING POWER

This figure illustrates how specialists' skill of appropriation and bargaining power affect the solution to investors' problem. Figures in the left panel plot the investor's value function $p(w)$ and investment rate $g(w)$ when the agency cost is low, $\lambda = 0.7$, and figures in the right panel plot the investor's value function and investment rate when the agency cost is high, $\lambda = 1.3$. In each figure there are three cases: (1) no skill of appropriation: $a = 0$, (2) positive skill of appropriation and investor power, (3) positive skill of appropriation and specialist power. The other parameters are $r = 0.04$, $\gamma = 0.045$, $\theta = 30$, $\delta_N = 0.1$, $Z = 0.16$, $\sigma_N = 0.35$, and $l = 0.8$.

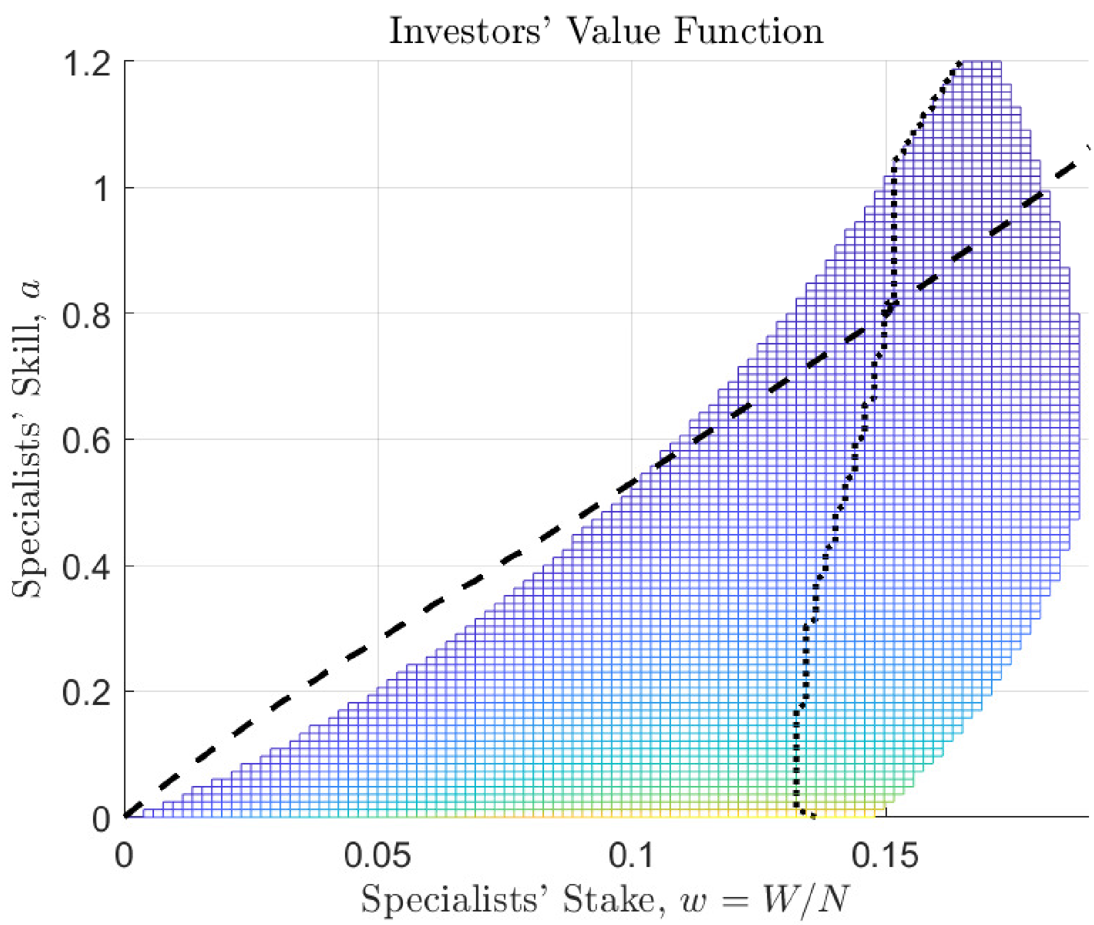


FIGURE 4: VALUE FUNCTION

This figure plots top-down investors' scaled value $p(a, w) = P(a, N, W)/N$ as a function of specialists' skill a and stake $w = W/N$ (their scaled continuation payoff). A brighter color denotes a higher value. The dotted line depicts $\text{argmax}_w\, p(a, w)$ for each a. The dashed line represents $a\overline{w}(a)$.

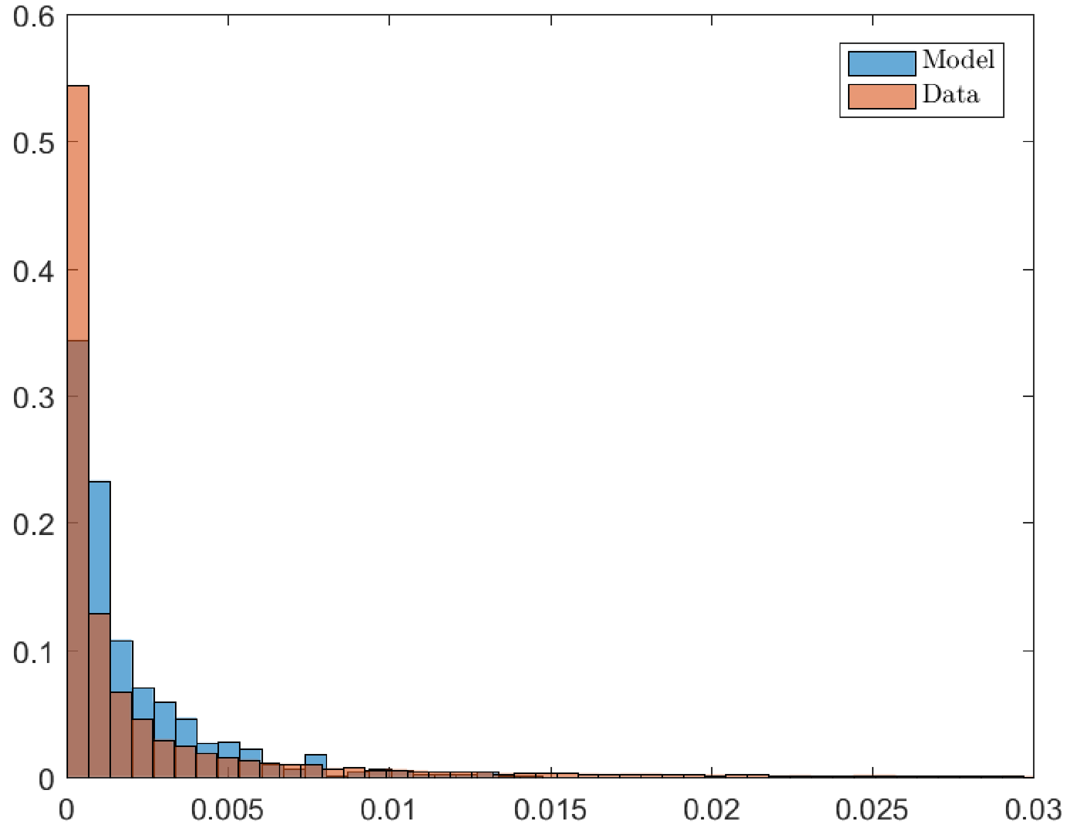


FIGURE 5: COMPARISON OF DISTRIBUTION OF OUTSIDE OPTIONS

This figure plots the density distribution of specialists' outside options in model and data (for CEOs). The data's outside option value is scaled by intangible capital and has a correction for a CEO's probability of finding a job conditional on leaving one. The outside option in the model is $\gamma\underline{w}$.

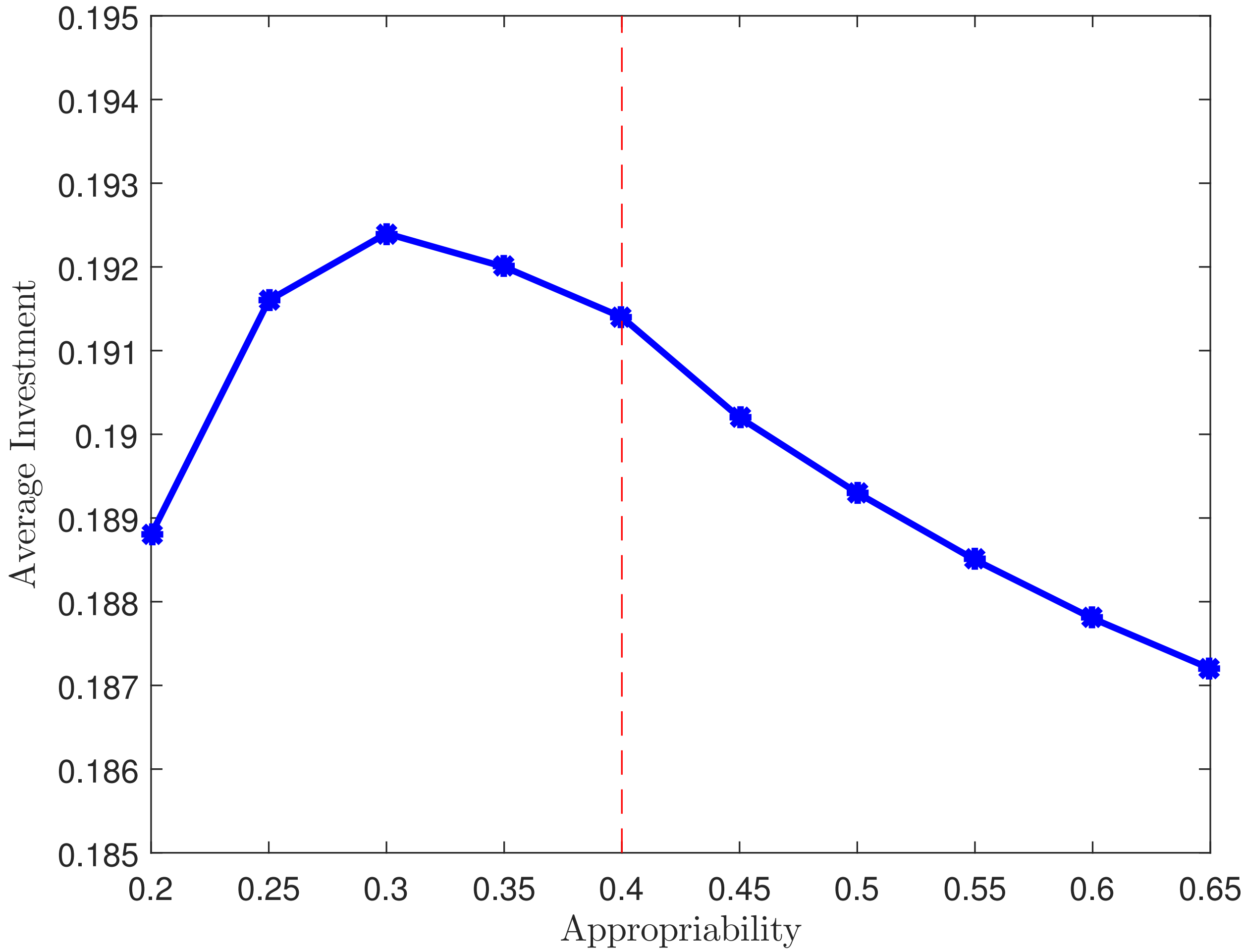


FIGURE 6: AVERAGE INVESTMENT AND APPROPRIABILITY

This figure depicts average intangible investment rate as a function of appropriability using simulated data from the model. We compute the average intangible investment rate as the time series average of mean investment rate g across firms as a function of the appropriability parameter is κ. Our current estimate is denoted by the vertical dashed red line.

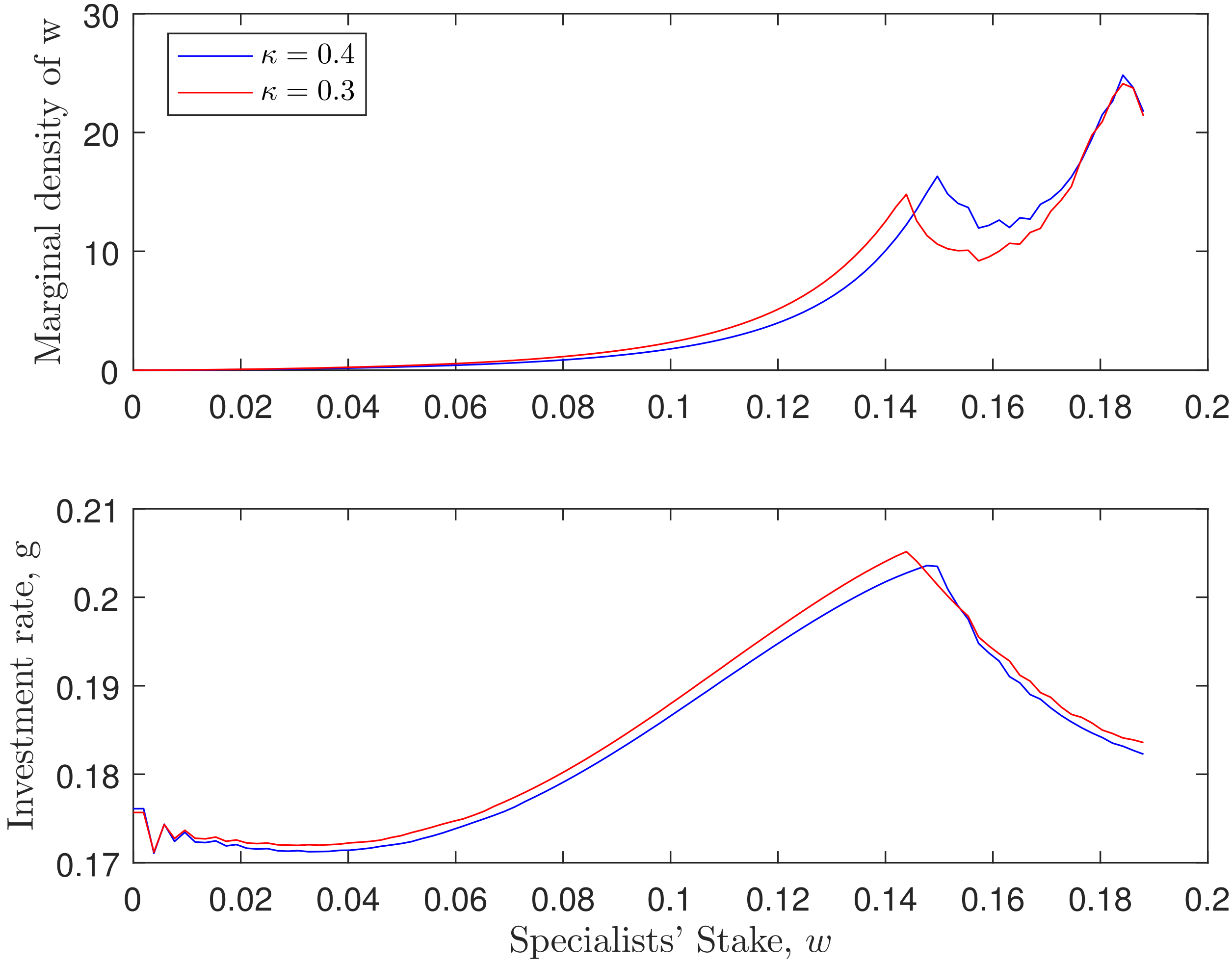


FIGURE 7: DECOMPOSITION OF AVERAGE INVESTMENT

The top panel depicts the marginal density of specialists' stake, w, for two values of appropriability κ. The bottom panel shows the conditional investment rate as a function of w for each value of appropriability.

A. Technical Appendix

A. Model Relation: Random Search Market

In this section, we consider a variation on the simple model of Section II.C to allow the termination payoffs to be determined endogenously in a random search market governed by free entry across firms. In the market, unmatched specialists search costlessly and earn an unemployment benefit $B > 0$ and unmatched firms pay a flow cost $\Omega > 0$ to post a vacancy.

We begin with assumptions on how investors and specialists meet and how initial compensation is determined. Suppose that at some point in time there are v job vacancies and u unemployed specialists looking for jobs. The flow of contracts between firms and specialists is given by a matching technology $m(u, v)$, which we specialize to be homogeneous of degree one in u and v: $m(u, v) = u^{\phi}v^{1-\phi}$.

Because specialists (with constant a) and firms are identical, the arrival rates for unemployed specialists and firms with vacancies are then given by

$$\alpha_S = m(u, v)/u = (v/u)^{1-\phi} \text{ and } \alpha_F = m(u, v)/v = (v/u)^{-\phi},$$

where the ratio v/u is commonly referred to as market tightness.

Now when specialists and a firm meet, they bargain over specialists' initial compensation under a Nash bargaining protocol with threat points R_S and R_F:

$$W_0 \in \underset{W}{\operatorname{argmax}}(W - R_S)^{\theta}(P(N, W) - R_F)^{1-\theta},$$

where $\theta \in [0, 1]$ is specialists' bargaining power.

The value of unemployment R_S and posting a vacancy R_F satisfy

$$\gamma R_S = B + \alpha_S(W_0 - R_S) \text{ and } rR_F = -\Omega + \alpha_F(P(N, W_0) - R_F). \tag{A1}$$

A.1. Equilibrium and Solution

We simplify the model with homogeneity. In particular, we make the additional assumption that specialists' unemployment benefits scale with the intangible capital of their previous firm, $b = B/N$, and also depreciates at rate δ_N. The flow cost of posting a vacancy is also assumed to grow with the scale of the firm, $\omega = \Omega/N$, which also depreciates at rate δ_N. Larger firms presumably have more generous compensation packages for ex-employees and also the recruitment costs to find someone suitable for an important job also plausibly grow with firm scale.

We now discuss the computation of the equilibrium. First, free entry drives R_F to zero, so we rewrite the right equation of (A1) under homogeneity as

$$\alpha_F p(w_0) = \omega.$$

The solution of the model involves the following steps

1. Guess $\underline{w} = r_s \equiv R_S/N$
2. Solve for $p(w)$ from (12) on the space $w \in [\underline{w}, \overline{w}]$ subject to the appropriate boundary and first-order conditions
3. Given r_s and $p(w)$ and using the three equations, $\alpha_F = \omega/p(w_0) = (v/u)^{-\phi}$, $\alpha_S = (v/u)^{1-\phi}$, and $r_s = (b + \alpha_S w_0)/(\alpha_S + \gamma)$, we solve for α_S, α_F, and w_0

4. Check w_0 satisfies $w_0 = \text{argmax}_w (w - r_s)^\theta (p(w))^{1-\theta}$; if not, update the guess

As the solution shows, the lower bound $\underline{w}$ is endogenized by the frictions in the search market, the matching function, as well as the cost of vacancies and benefit of unemployment. We take the intricacy of this market as given, avoiding the difficulty of multiple equilibria arising in two-sided search models (see Burdett and Wright (1998) for discussion), and instead relying on our lower bound aw_0 and in particular a as a reduced-form device to capture these collective effect of these equilibrium forces.

B. Details of Computational Solution

We solve the partial differential equation in (21) with a finite difference method that approximates the function $p(a, w)$ on a two-dimensional non-rectangular grid: $a \in \{a_i(w_j)\}_{i=1}^{I^j}$ and $w \in \{w_j(a_i)\}_{j=1}^{J^i}$, where we define $\overline{w}(a_i) = w_{J^i}(a_i)$ and $\overline{a}(w_j) = a_{I^j}(w_j)$. Each set of grid points along j, $w_j(a_i)$, depend on the value of a_i, because of the boundary curve $\{\overline{w}(a_i)\}_{i=1}^{I}$. The set along i, $a_i(w_j)$ shares the same logic.

We approximate first derivatives of p using both backward and forward differences and second derivatives with central differences. All differences of a and w are calculated respectively over the fixed increments Δ_a and Δ_w. For the approximation of the derivatives at the boundaries, there are three different cases:

i. The boundary conditions of w imply that $p(a, 0) = l \Rightarrow p(a_i, a_i w_0) \approx l$ and $p_w(a, \overline{w}(a)) = -1 \Rightarrow p(a_i, w_{J^i+1}) \approx p(a_i, w_{J^i}) - \Delta_w$ under a forward difference, where both conditions hold for all i.

ii. The boundary conditions of a imply that $p_a(\overline{a}(w), w) = -1 \Rightarrow p(a_{I^j+1}, w_j) \approx p(a_{I^j}, w_j) - \Delta_a$ under a forward difference, where both conditions hold for all j.

iii. The boundary conditions along the joint upper boundary where $p_{aw}(\overline{a}(w), \overline{w}(a)) = 0$ for all $\overline{a}(w)$ and $\overline{w}(a)$ implies

$$p(a_{I^j+1}, w_{J^i+1}) \approx p(a_{I^j+1}, w_{J^i}) - \Delta_w \approx p(a_{I^j}, w_{J^i}) - \Delta_w - \Delta_a.$$

We describe our computational algorithm below:

1. Guess the value of $p^b(\cdot)$ on the two-dimensional non-rectangular grid: $a \in \{a_i\}_{i=1}^{I^j}$ and $w \in \{w_j(a_i)\}_{j=1}^{J^i}$ and approximate the derivatives,

2. Calculate the investment policy function in (22),

3. We update the value function through an implicit method that solves the vector $p^{b+1} = (p_{1,1}^{b+1}, \ldots, p_{1,J^1}^{b+1}, p_{2,1}^{b+1}, \ldots, p_{2,J^2}^{b+1}, \ldots, p_{I^J,J^I}^{b+1})'$ with notation $p_{i,j} = p(a_i, w_j)$. It begins with a guess $b = 1$ and proceeds to iterate until convergence ($\max(|p^{b+1} - p^b|) < 10^{-9}$) on the value function

$$p^{b+1}\left[\left(\frac{1}{\Delta} + r - (g - \delta_N)\right) - \mathbf{Q}\right] = p^b/\Delta + D, \tag{A2}$$

4. After convergence, check to see if the boundaries in (14), (15), (17), (18), and (19) are numerically satisfied; if not, then update the shape of the non-rectangular grid. We report statistics on the numerical accuracy of these boundaries in Table A-VII.

During each iteration of (A2), g is calculated from step 2, $\Delta > 0$ is the step size of the iterative method, and $\mathbf{Q}$ is the transition matrix defined by the diffusion processes of the states a and w and the boundaries described above

$$\mathbf{Q}=\begin{bmatrix}
q^{ss}_{1,1} & q^{su}_{1,1} & 0 & \cdots & 0 & q^{us}_{1,1} & 0 & 0 & \cdots & 0 & \cdots & 0\\
q^{sd}_{1,2} & q^{ss}_{1,2} & q^{su}_{1,2} & \ddots & \vdots & 0 & q^{us}_{1,2} & 0 & \ddots & \vdots & \ddots & \vdots\\
\vdots & \ddots & \ddots & \ddots & \vdots & \vdots & \ddots & \ddots & \ddots & \vdots & \ddots & \vdots\\
\vdots & \ddots & \ddots & \ddots & \vdots & \vdots & \ddots & \ddots & \ddots & \vdots & \ddots & \vdots\\
0 & \cdots & \cdots & q^{sd}_{1,J^1} & q^{ss}_{1,J^1} & 0 & \cdots & \cdots & 0 & q^{us}_{1,J^1} & \ddots & \vdots\\
q^{ds}_{2,1} & 0 & 0 & \cdots & 0 & q^{ss}_{2,1} & q^{su}_{2,1} & 0 & \cdots & 0 & \ddots & \vdots\\
0 & q^{ds}_{2,2} & 0 & \ddots & \vdots & q^{sd}_{2,2} & q^{ss}_{2,2} & q^{su}_{2,2} & \ddots & \vdots & \ddots & \vdots\\
\vdots & \ddots & \ddots & \ddots & \vdots & \vdots & \ddots & \ddots & \ddots & \vdots & \ddots & \vdots\\
\vdots & \ddots & \ddots & \ddots & \vdots & \vdots & \ddots & \ddots & \ddots & \vdots & \ddots & \vdots\\
0 & \cdots & \cdots & 0 & q^{ds}_{2,J^2} & 0 & \cdots & \cdots & q^{sd}_{2,J^2} & q^{ss}_{2,J^2} & \ddots & \vdots\\
\vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \vdots\\
0 & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & q^{sd}_{I^J,J^I} & q^{ss}_{I^J,J^I}
\end{bmatrix}.$$

Adjustments to transition rates along the boundaries are made to $\mathbf{Q}$ for the non-rectangular grid as it is an approximation and ensure that the non-termination-boundary rows of the transition matrix $\mathbf{Q}$ sum to zero. The termination-boundary rows do not sum to zero as they measure the (absorbing) exiting mass of firms. The transition matrix $\mathbf{Q}$ is the discretized analogy of the infinitesimal generator of (da_t, dw_t): $\mathcal{A}\vartheta(a,w)$ for some arbitrary function $\vartheta(\cdot)$. The elements of $\mathbf{Q}$ are based on an upwind scheme and defined as

- $q^{ss}_{i,j} = -\max(\mathbb{E}_t[dw],0)/\Delta_w + \min(\mathbb{E}_t[dw],0)/\Delta_w - \max(\mathbb{E}_t[da],0)/\Delta_a + \min(\mathbb{E}_t[da],0)/\Delta_a - \mathbb{E}_t[dw^2]/\Delta_w^2 - \mathbb{E}_t[da^2]/\Delta_a^2$
- $q^{su}_{i,j} = \max(\mathbb{E}_t[dw],0)/\Delta_w + \mathbb{E}_t[dw^2]/(2\Delta_w^2)$
- $q^{sd}_{i,j} = -\min(\mathbb{E}_t[dw],0)/\Delta_w + \mathbb{E}_t[dw^2]/(2\Delta_w^2)$
- $q^{us}_{i,j} = \max(\mathbb{E}_t[da],0)/\Delta_a + \mathbb{E}_t[da^2]/(2\Delta_a^2)$
- $q^{ds}_{i,j} = -\min(\mathbb{E}_t[da],0)/\Delta_a + \mathbb{E}_t[da^2]/(2\Delta_a^2)$

where the conditional moments of state variables are $\mathbb{E}_t[dw] = (\gamma - (g-\delta_N))w$, $\mathbb{E}_t[da] = \kappa a\,(g-\delta_N)$, $\mathbb{E}_t[dw^2] = \sigma_N^2\,(\lambda - w)^2$ and $\mathbb{E}_t[da^2] = \sigma_a^2 a^2$.

Lastly, the vector of constants D required by the boundaries takes the form

$$D = Z - c(g_{i,j}) + \begin{bmatrix} q^{sd}_{1,1} \times l \\ \vdots \\ (q^{su}_{1,J^1}) \times (-\Delta_w) \\ q^{sd}_{2,1} \times l \\ \vdots \\ (q^{su}_{2,J^2}) \times (-\Delta_w) \\ \vdots \\ \vdots \\ (q^{su}_{I^J,J^I}) \times (-\Delta_w) \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \\ \vdots \\ (q^{us}_{I^1,1}) \times (-\Delta_a) \\ \vdots \\ \vdots \\ (q^{us}_{I^J,J^I}) \times (-\Delta_a) \end{bmatrix},$$

and intuitively captures the firm profit, $Z - c(g_{i,j})$, where $i = 1,..,I^j$ and $j = 1,..,J^i$, the rates of cash outflows from payments to specialists, $-\Delta_w$ and $-\Delta_a$, and liquidation, l.

Convergence to the unique solution is assured by Barles and Souganidis (1991) (see Achdou, Han, Lasry, Lions and Moll (2022) for discussion). They show that if the solution method satisfies monotonicity, stability, and consistency, then as Δ_a and Δ_w get small the solution converges locally uniformly to the unique viscosity solution. Here, monotonicity is ensured by the upwind scheme; stability, by the implicit method (on a uniformly bounded value function that is independent of Δ_a and Δ_w); and consistency, by the backwards time-step of the iterative method.

C. Optimality

Define the gain process $\{G\}$ under any incentive-compatible contract $\mathcal{C} = (g, U, \tau)$ for any $t < \tau$ as

$$G_t(\mathcal{C}) = \int_0^t e^{-rs}(\Pi_s ds - dU_s) + e^{-rt} P(a_t, N_t, W_t),$$

where N_t, a_t, and W_t follow (2), (3), (5), respectively. Homogeneity and Ito's lemma imply

$$e^{rt} dG_t = N_t \left\{ \begin{array}{c} \left[\begin{array}{c} -rp + Z - c(g_t) + p(g_t - \delta_N) + p_w(\gamma - (g_t - \delta_N))w_t + \frac{1}{2}p_{ww}\left((\beta_t - w_t)\sigma_N\right)^2 \\ +p_a\kappa(g_t - \delta_N)a + \frac{1}{2}p_{aa}a^2\sigma_a^2 \end{array} \right] dt \\ -(1 + p_w)du_t + (p + p_w(\beta_t - w_t))\sigma_N dB_t \end{array} \right\},$$

where $p(\cdot)$'s dependence on states (a_t, w_t) and $G(\cdot)$'s dependence on a contract $\mathcal{C}$ have been henceforth omitted for conciseness.

Under the optimal investment $g^\star$ and incentive policies $\beta^\star_t = \lambda$, the top two lines in the square brackets are the optimized PDE in (21) and therefore zero. For models in which the only state variable is agents' continuation utility this nonpositivity condition follows from the concavity of $p(w)$. In this more general case, we verify numerically that for any other incentive compatible policy both p_{ww} and $\beta p_{ww}/2 + p_{aw}$ under the policy with the smallest β are nonpositive. We depict both conditions density-weighted and conditional on w in Panel A of Figure A-1.

The term capturing the optimality of the continuation payment policy, $-(1 + p_w)dU_t$, is non-positive since $p_w \geq -1$ but equals zero under the optimal contract. Therefore, for the auxiliary gain process we have

$$dG_t = \mu_G(t)dt + e^{-rt} N_t(p + p_w(\beta_t - w_t))\sigma_N dB_t$$

where $\mu_G(t)dt \leq 0$. Let $\varphi_t \equiv e^{-rt}N_t(p + p_w(\beta_t - w_t))\sigma_N$. We impose the usual regularity conditions to ensure that $\mathbb{E}\left[\int_0^T \varphi_t dB_t\right] = 0$ for all $T \geq 0$. This implies that $\{G\}$ is a supermartingale.

Now we can evaluate the investor's payoff for an arbitrary incentive compatible contract. Recall that $P(a_\tau; N_\tau; W_\tau) = lN_\tau$. Given any $t < \infty$,

$$
\begin{aligned}
&\mathbb{E}\left[\int_0^\tau e^{-rt}(\Pi_t dt - dU_t) + e^{-r\tau} lN_\tau\right] \\
=&\mathbb{E}\left[G_{t\wedge\tau} + 1_{t\leq\tau}\left(\int_t^\tau e^{-rs}(\Pi_s ds - dU_s) + e^{-r\tau} lN_\tau - e^{-rt}P(a_t, N_t, W_t)\right)\right] \\
=&\mathbb{E}\left[G_{t\wedge\tau}\right] + e^{-rt}\mathbb{E}\left[1_{t\leq\tau}\left(\mathbb{E}_t\left[\int_t^\tau e^{-r(s-t)}(\Pi_s ds - dU_s) + e^{-r(\tau-t)} lN_\tau\right]\right) - P(a_t, N_t, W_t)\right] \\
\leq& G_0 + (q^{FB} - l)\mathbb{E}[e^{-rt}N_t]
\end{aligned}
$$

Here we use the notation $t \wedge \tau = \min\{t, \tau\}$. The first term of the inequality follows from the nonpositive drift of dG_t and the martingale property of $\int_0^{t\wedge\tau} \varphi_s dB_s$. The second term follows from

$$
\mathbb{E}_t\left[\int_t^\tau e^{-r(s-t)}(\Pi_s ds - dU_s) + e^{-r(\tau-t)} lN_\tau\right] \leq q^{FB}N_t - w_t N_t
$$

which is the first-best result and

$$
q^{FB}N_t - w_t N_t - P(a_t, N_t, W_t) \leq (q^{FB} - l)N_t
$$

We impose the standard transversality condition $\lim_{T\to\infty}\mathbb{E}[e^{-rT}N_T] = 0$. Let $t \to \infty$

$$
\mathbb{E}\left[\int_0^\tau e^{-rt}(\Pi_t dt - dU_t) + e^{-r\tau} lN_\tau\right] \leq G_0
$$

for all incentive-compatible contracts. On the other hand, under the optimal contract $\mathcal{C}^\star$, investor's payoff $G(\mathcal{C}^\star)$ achieves G_0 because the above weak inequality holds with equality when $t \to \infty$.

C.1. Full-Effort Condition

In the full-effort case, we require the rate of private benefits $\lambda g_t N_t dt$ to be sufficiently small to ensure the optimality of $e_t = 1$ is implemented all the time. If specialists' shirked ($e_t = 0$), intangible capital would evolve as

$$
dN_t = -\delta_N N_t dt + \sigma_N N_t dB_t,
$$

and their continuation payoff would change according to

$$
dW_t = \gamma W_t dt - \lambda \widehat{g}_t N_t dt + \widehat{\beta}_t N_t \sigma_N dB_t,
$$

where $\widehat{g}_t$ and $\widehat{\beta}_t$ are the chosen investment rate and incentive coefficient under the shirking policy.

For full effort ($e_t = 1$) to remain optimal, we need investors' payoff rate from allowing agents to shirk to be lower than under the optimal contract. Equivalently, investors' optimal gain process needs to remain a supermartingale with respect to this shirking policy:

$$rp \geq Z - c(\widehat{g}) - \delta_N p + p_w((\gamma + \delta_N)w_t - \lambda\widehat{g}) + \frac{1}{2}p_{ww}(\widehat{\beta} - w)^2\sigma_N^2$$
$$+ p_a\kappa(\widehat{g} - \delta_N)a + \frac{1}{2}p_{aa}a^2\sigma_a^2, \text{ for all } a \text{ and } w,$$

where we omit $p(\cdot)$'s dependence on states for brevity.

Because $p(\cdot)$ is concave in w, it is optimal to set the incentive coefficient to w: $\widehat{\beta}_t = w_t$ for all t. Since investment is unproductive when agents shirk, it is also optimal to set it to zero: $\widehat{g}_t = 0$.

Under these choices, the following equation must be satisfied for full effort to remain the optimal solution at all times:

$$rp \geq Z - c(0) - \delta_N p + p_w((\gamma + \delta_N)w) - p_a\kappa\delta_N a + \frac{1}{2}p_{aa}a^2\sigma_a^2, \text{ for all } a \text{ and } w.$$

We plot this weakly positive condition as a density-weighted function conditional on w in Panel B of Figure A-1.

B. EMPIRICAL APPENDIX

We use all industrial, standard format, consolidated accounts of firms in Compustat. We exclude all utility (SIC 4900-4999) and financial (SIC 6000-6999) firms and those missing assets (at) or sales ($sale$). We retain only those listed on the AMEX, NASDAQ, or NYSE.

A. VARIABLE DEFINITIONS

- Age Indicator = 1 if CEO is over 62 years old and 0 otherwise
- Cash-to-Capital = Cash (che) / Intangible Capital
- Intangible Capital = see equation (27)
- Leverage = Total Debt ($dltt$ + dlc) / Intangible Capital
- Market Equity = Price per Share $\times$ Shares Outstanding (December values of abs(prc) $\times$ shrout from CRSP)
- Profitability = (EBIT (ebit(t)) - Physical Capital Investment (capx(t))) / Intangible Capital (N(t-1))
- Tobin's Q = (Market Equity ($prcc_f \times csho$) + Long-term Debt ($dltt$) + tdc1/0.11) / Intangible Capital, where 0.11 is the calibrated value of γ in Table IV.
- Turnover = 1 if CEO leaves firm in a given year and 0 otherwise

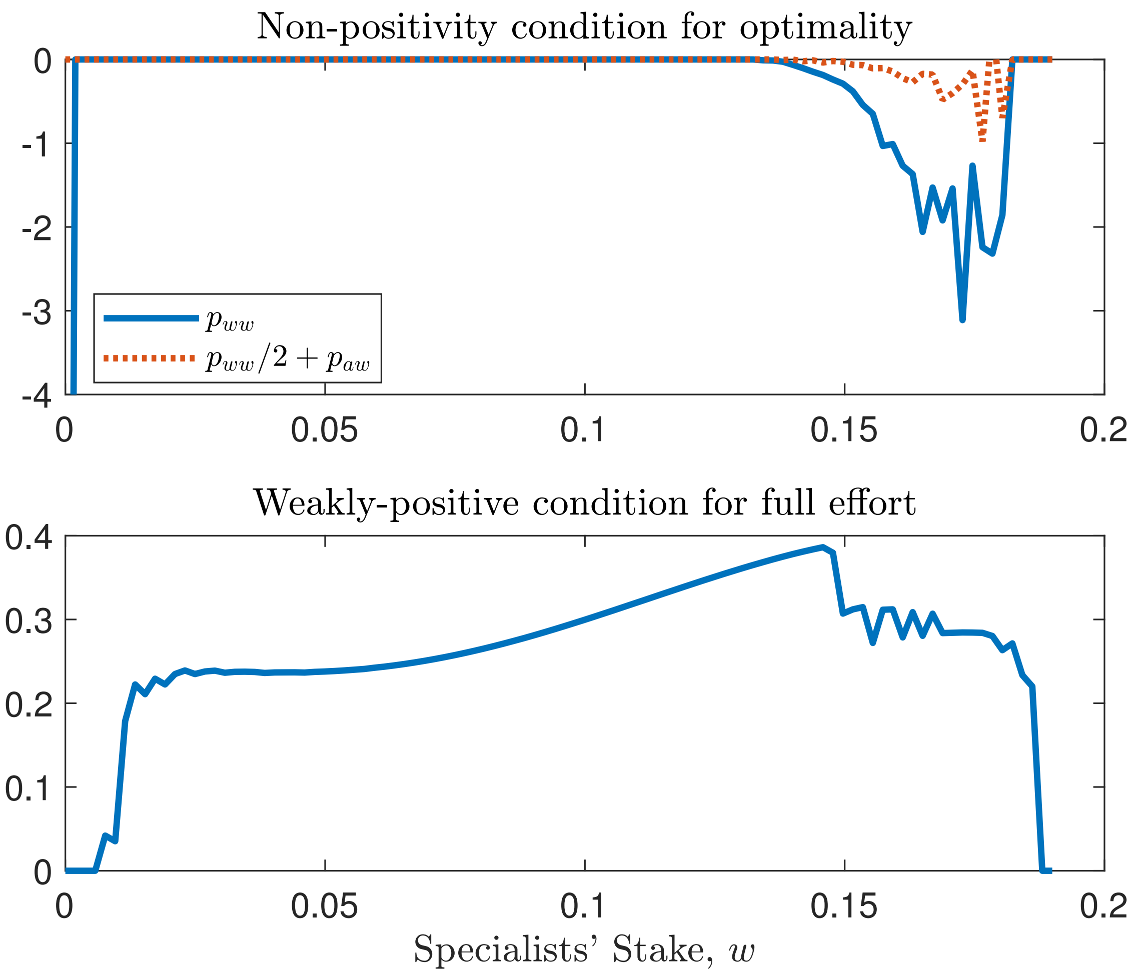


FIGURE A-1: OPTIMALITY AND FULL EFFORT CONDITIONS

The top panel depicts the non-positivity condition required for optimality. The bottom panel shows that the full effort condition ($e_t = 1$ for all t) is optimal. Both figures depict conditional densities.

TABLE A-I: SUMMARY STATISTICS

Panel A of this table provides the summary statistics of the main variables in the empirical analysis. *Age Indicator* takes a value of one if the firm's CEO is over 62 years old, and is lagged. *Cash* is the lagged ratio of cash to intangible capital. *Intangible Capital* is from (27) and is the level of intangible capital for a firm in a given year, in millions of real 1982 dollars. *Investment Rate* is the investment rate of intangible capital for a firm in a given year. *R&D Investment* is R&D expenditure scaled the intangible capital. *Leverage* is the lagged ratio of total debt to intangible capital. *NCEI* is the non-compete enforceability index. Δ*NCEI* takes a value of one if the firm's state's *NCEI* is higher in a given year than the 1992 initial value, negative one if it is lower, and zero if it is the same. *Outside Option* is the outside option value for a given firm's CEO in a given year (in millions of 1982 dollars). *Profitability* is the lagged ratio of after-tax EBITDA net of physical capital investment to intangible capital. *Tobin's Q* is the lagged sum of market equity, long-term debt and the stock of CEO compensation to intangible capital. *Turnover* is an indicator that takes a value of one if the firm has CEO turnover in a given year and zero otherwise. Panel B provides the correlation matrix between changes in the NCEI, Δ*NCEI*, and changes in aggregate factors which include: the percentage change in real GDP, the percentage change in the unemployment rate, the percentage change in real consumption, and the percentage change in the Fed Funds Rate. All data items are from the St. Louis Federal Reserve's FRED database.

Panel A: Summary Statistics

	N	Mean	Std	P25	P50	P75
Age Indicator	20,468	0.171	0.376	0	0	0
Cash	20,468	0.748	1.534	0.085	0.274	0.733
Intangible Capital	20,468	8.197	23.872	0.778	1.986	5.941
Investment Rate	20,468	0.212	0.113	0.149	0.194	0.250
R&D Investment	20,468	0.090	0.146	0.000	0.017	0.127
Leverage	20,468	1.955	5.221	0.096	0.510	1.430
NCEI	20,468	4.094	2.223	3	5	5
ΔNCEI	20,468	0.006	0.399	0	0	0
log Outside Option	20,468	0.946	0.456	0.691	0.987	1.224
$\frac{\text{Outside Option}}{\text{Intangible Capital}}$	20,468	0.020	0.043	0.002	0.007	0.019
Profitability	20,468	0.042	1.465	-0.003	0.135	0.322
Tobin's Q	20,468	11.167	23.606	2.471	4.717	9.582
Turnover	20,468	0.047	0.213	0	0	0

Panel B: Correlation Between NCEI and Aggregate Outcomes

	%ΔReal GDP	%ΔUnemployment Rate	%ΔReal Consumption	%ΔFed Funds Rate
ΔNCEI	0.0215	-0.1563	0.0200	0.0105

TABLE A-II: REDUCED FORM: NCEI ON INVESTMENT AND TURNOVER

This table provides reduced-form estimates for the effect of the NCEI on intangible investment and CEO turnover. *NCEI* is the non-compete enforceability index. Δ*NCEI* takes a value of one if the firm's state's *NCEI* is higher in a given year than the 1992 initial value, negative one if it is lower, and zero if it is the same. Intangible Investment Rate is the investment rate of intangible capital in a given year. R&D Investment is R&D expenditures scaled by intangible capital. CEO Turnover is one if the company has a CEO turnover and zero otherwise. Control variables are all lagged and include: investment rate, turnover, Tobin's Q, cash, profitability, leverage, the logged level of intangible capital, and a CEO indicator for whether her/his age is above 62. Firm fixed effects and year fixed effects are included. Observations are at the firm-year level. Standard errors are clustered at the firm level and are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Dep. Variable:	(1) Intangible Investment Rate	(2) Intangible Investment Rate	(3) R&D Investment	(4) R&D Investment	(5) CEO Turnover	(6) CEO Turnover
NCEI	0.003**		0.007***		−0.007*	
	(0.00)		(0.00)		(0.00)	
Δ*NCEI*		0.004**		0.009***		−0.012**
		(0.00)		(0.00)		(0.01)
Controls	Y	Y	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y	Y	Y
Year FEs	Y	Y	Y	Y	Y	Y
N	20,316	20,316	20,316	20,316	20,316	20,316

TABLE A-III: FALSIFICATION TEST FOR THE TIMING OF NCEI CHANGES

This table provides a falsification test for the year of changes in the NCEI. $\Delta NCEI_{false}$ sets the change defined by $\Delta NCEI$ to falsely occur 5 years before the actual change in the NCEI. Intangible Investment Rate is the investment rate of intangible capital in a given year. R&D Investment is R&D expenditures scaled by intangible capital. CEO Turnover is one if the company has a CEO turnover and zero otherwise. Control variables are all lagged and include: investment rate, turnover, Tobin's Q, cash, profitability, leverage, the logged level of intangible capital, and a CEO indicator for whether her/his age is above 62. Firm fixed effects and year fixed effects are included. Observations are at the firm-year level. Column (1) provides first-stage estimates, while columns (2)-(4) provides second-stage estimates. Standard errors are clustered at the firm level and are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Dep. Variable:	(1) $\log$ Outside Option	(2) Intangible Investment Rate	(3) R&D Investment	(4) CEO Turnover
$\Delta NCEI_{false}$	-0.017			
	(0.01)			
$\log \widehat{\text{Outside Option}}$		-0.224	-0.062	0.487
		(0.30)	(0.22)	(0.67)
Controls	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y
Year FEs	Y	Y	Y	Y
N	11,041	11,041	11,041	11,041

TABLE A-IV: CUMULATIVE INTANGIBLE INVESTMENT RATES

This table provides the empirical results of CEO outside options on cumulative intangible investment rates. Panel A provides the results instrumented by $NCEI$, while Panel B provides the results instrumented by $\Delta NCEI$. $Inv\,Rate_{t,t+k}$ is the cumulative investment rate from year t to $t+k-1$, defined as

$$Inv\,Rate_{t,t+k} = \left(Inv_t^N + Inv_{t+1}^N .. + Inv_{n+k-1}^N\right)/N_{t-1},$$

where Inv_t^N is the intangible capital investment in year t. Control variables are all lagged and include: investment rate, turnover, Tobin's Q, cash, profitability, leverage, the logged level of intangible capital, and a CEO indicator for whether her/his age is above 62. Firm fixed effects and year fixed effects are included. Observations are at the firm-year level. Standard errors are clustered at the firm level and are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Instrumented by $NCEI$				
	(1)	(2)	(3)	(4)
Dep. Variable:		$Inv\,Rate_{t,t+k}$		
Lags (k):	2	3	4	5
$\log \widehat{\text{Outside Option}}$	−0.237**	−0.505**	−0.745*	−0.759
	(0.12)	(0.25)	(0.41)	(0.55)
Controls	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y
Year FEs	Y	Y	Y	Y
N	19,485	18,619	17,823	17,051

Panel B: Instrumented by $\Delta NCEI$				
	(1)	(2)	(3)	(4)
Dep. Variable:		$Inv\,Rate_{t,t+k}$		
Lags (k):	2	3	4	5
$\log \widehat{\text{Outside Option}}$	−0.210**	−0.446**	−0.627*	−0.541
	(0.11)	(0.22)	(0.35)	(0.45)
Controls	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y
Year FEs	Y	Y	Y	Y
N	19,485	18,619	17,823	17,051

TABLE A-V: EFFECT OF OUTSIDE OPTIONS ON CEO MOBILITY

This table provides the empirical results for the effect of outside options on CEO mobility. Following Graham et al. (2020), for each firm i in industry j, mobility is measured as the fraction of CEOs in industry j leaving their offices in year t and finding another executive job within 2 years (Mobility$_{t,t+2}$), 5 years (Mobility$_{t,t+5}$) or ultimately in our sample (Mobility). The other details are the same as Panel A of Table II. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	Instrument: *NCEI*			Instrument: Δ*NCEI*		
	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Variable:	Mobility$_{t,t+2}$	Mobility$_{t,t+5}$	Mobility	Mobility$_{t,t+2}$	Mobility$_{t,t+5}$	Mobility
$\log \widehat{\text{Outside Option}}$	0.167***	0.296***	0.333***	0.043	0.209**	0.250***
	(0.06)	(0.08)	(0.09)	(0.07)	(0.08)	(0.09)
Controls	Y	Y	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y	Y	Y
Year FEs	Y	Y	Y	Y	Y	Y
N	20,316	20,316	20,316	20,316	20,316	20,316

TABLE A-VI: INSTRUMENTED EFFECT OF NON-COMPETE ENFORCEMENT ON ENTRY AND EXITS

This table provides the empirical results for the effect of outside options on firm entries and exits. Panel A measures the entries and exits of public firms, and Panel B measures those for both public and private firms using data from Business Dynamics Statistics of Census Bureau. In Panel A, $\log$ Entry is the logged yearly number of new Compustat firms in state s and industry j. In Panel B, $\log$ Entry is the logged yearly number of new establishments from BDS in state s and industry j. In Panel A, $\log$ Exits is the logged yearly number of Compustat firm exits in state s and industry j. In Panel B, $\log$ Entry is the logged yearly number of closed establishments from BDS in state s and industry j. Observations are at the state-industry-year level. Control variables are all lagged and include: Herfindahl-Hirschman Index, number of firms, and average firm age. $State \times Industry$ fixed effects and $Industry \times Year$ fixed effects are included. Standard errors are clustered at the state level and t-statistics are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Compustat Firms				
	Instrument: *NCEI*		Instrument: Δ*NCEI*	
	(1)	(2)	(3)	(4)
Dep. Variable:	$\log$ Entry	$\log$ Exits	$\log$ Entry	$\log$ Exits
$\log \widehat{\text{Outside}}$ Option	0.626	0.322**	0.445	0.228
	(0.52)	(0.13)	(0.34)	(0.20)
Controls	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y
Year FEs	Y	Y	Y	Y
N	10,251	10,251	10,251	10,251

Panel B: BDS Firms				
	Instrument: *NCEI*		Instrument: Δ*NCEI*	
	(1)	(2)	(3)	(4)
Dep. Variable:	$\log$ Entry	$\log$ Exits	$\log$ Entry	$\log$ Exits
$\log \widehat{\text{Outside}}$ Option	-1.124	-0.188	-1.008*	-0.346
	(0.82)	(0.40)	(0.55)	(0.42)
Controls	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y
Year FEs	Y	Y	Y	Y
N	10,120	10,120	10,120	10,120

TABLE A-VII: STATISTICS OF MODEL BOUNDARY CONDITIONS

This table provides the mean and the median across a of the following boundary conditions: smooth pasting $p_w(a, \overline{w}(a)) = -1$, super contact $p_{ww}(a, \overline{w}(a)) = 0$, and the lower boundary $p(a, \underline{w}(a)) - l = 0$.

	Smooth Pasting $p_w(a, \cdot)$	Super Contact $p_{ww}(a, \cdot)$	Lower Boundary $\lvert p(a, \cdot) - l \rvert$
Mean	-1.051	-7.423	0.075
Median	-1.004	0	0.067