Technological Change and the Growing Inequality in Managerial Compensation

Hanno Lustig☆

UCLA Anderson School of Management, UCLA, Box 951477, Los Angeles, CA 90095-1477, tel: (310) 825-8018.

Chad Syverson

Booth School of Business, University of Chicago 1126 E. 59th St. Chicago, IL 60637. tel:(773)702-7815.

Stijn Van Nieuwerburgh

Dept. of Finance, NYU, 44 West Fourth Street, Suite 9-190, New York, NY 10012. tel:(212) 998-0673.

Abstract

Three of the most fundamental changes in US corporations since the early 1970s have been (1) the increased importance of *organizational capital* in production, (2) the increase in managerial income inequality and pay-performance sensitivity, and (3) the secular decrease in labor market reallocation. Our paper develops a simple explanation for these changes: a shift in the composition of productivity growth away from vintage-specific to general growth. This shift has stimulated the accumulation of organizational capital in existing firms and reduced the need for reallocating workers to new firms. We characterize the optimal managerial compensation contract when firms accumulate organizational capital but risk-averse managers cannot commit to staying with the firm. A calibrated version of the model reproduces the increase in managerial compensation inequality and the increased sensitivity of pay to performance in the data over the last three decades. This increased sensitivity of compensation to performance provides large, successful firms with the glue to retain their managers and the organizational capital embedded in them.

☆Corresponding Author

Email addresses: hlustig@anderson.ucla.edu (Hanno Lustig☆), syverson@booth.uchicago.edu (Stijn Van Nieuwerburgh), svnieuwe@stern.nyu.edu (Stijn Van Nieuwerburgh)

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1. Introduction

Three of the most fundamental changes in US corporations since the early 1970s have been (1) the apparent increase in the importance of *organizational capital* in production, (2) the increase in managerial income inequality and pay-performance sensitivity, and (3) the secular decrease in labor market reallocation. Our paper provides an explanation for these changes.

This evidence is consistent with a shift in the composition of productivity growth away from vintage-specific growth, which only affects new firms, to more general productivity growth, which makes all firms more productive. In our model, the vintage-specific growth rate is the depreciation rate of organizational capital in existing firms. The shift allows successful firms to grow larger because their organizational capital effectively depreciates at a slower rate. This results in fewer firm exits and less labor reallocation from old to new firms. The growth composition shift allows our model to match the secular decline in the job reallocation rate in the US economy since the early 1970s, as shown by Davis, Haltiwanger, Jarmin, and Miranda (2006) and Faberman (2006).[1] We attribute the change in the composition of productivity growth, the key driving force in the model, to the diffusion of information technology. However, our model applies to any other explanation for this shift, such as a change in the composition of the work force.

The change in productivity growth composition and the widespread accumulation of organizational capital that resulted creates a new problem for successful firms: how to distribute the rents from organizational capital? The firms' managers have de facto ownership rights on organizational capital, which makes it different from physical capital. These ownership rights arise from their ability to leave the firm, and to take some of its organizational capital to a new firm. Our paper studies the distribution of organizational rents between the owners and the managers in such an environment.

In the data, the dispersion of managerial compensation across firms is much wider now than 35 years ago. In large, successful firms, which accumulate a lot of organizational capital, managerial compensation has increased substantially, while it has not in small firms. We propose an equilibrium theory that ties the accumulation of organizational capital, induced by the shift in the composition of productivity growth, to managerial compensation. A calibrated version of the model can quantitatively account for a large share of these changes in the US economy.

The key element of the model is the optimal managerial compensation contract. This contract insures the risk-averse manager against shocks to the firm's productivity. Insurance is provided because the manager can only work for one firm while the owner invests in a diversified portfolio of firms. But there is only partial insurance because the manager can quit and transfer some of the organizational capital to a new firm. The degree of portability of organizational capital governs the value of the manager's outside option and determines how much risk sharing can be sustained between the manager and the owner. Dunne, Foster, Haltiwanger, and Troske (2004) find a sizeable increase in within-industry between-establishment wage dispersion, while Saks'(2006) data show that the increase in dispersion is even higher for executives. A calibrated version of our model can match most of the increase in compensation inequality if we assume that half of the organizational capital is portable. The same calibration matches about half of the observed increase in Tobin's q. Lowering the portability increases Tobin's q by more, but reduces the impact

[1] The declining volatility of firm growth rates, shown by Davis et al. (2006) for the entire universe of privately held and publicly traded firms, is consistent with this decline. Our model also implies that the fraction of output produced in older establishments increased, also consistent with the findings of Davis et al. (2006). The model of Jovanovic and Rousseau (2007) also relies on the decline in labor reallocation.

on compensation inequality. In the extreme case where organizational capital is not portable, the change in the composition of productivity growth has no impact on compensation inequality.

Why does the growth composition shift increase the dispersion of managerial compensation? As long as firms are small, the manager's outside option constraint does not bind, and the optimal contract prescribes constant managerial compensation (relative to aggregate output). However, when a firm's size exceeds a threshold, optimal management compensation is increasing in the firm's organizational capital. The increased accumulation of organizational capital, resulting from the growth composition change, improves the manager's outside option in successful firms. To retain the manager, the owner of the firm increases compensation in response to high productivity. At the aggregate level, the change in the firm size distribution that results from the growth composition shift triggers an endogenous shift from low-powered to high-powered incentive compensation contracts. Such a shift seems consistent with the increased pay-performance sensitivity of employment contracts since the 1970s. If the manager is more impatient then the owner, this shift is further amplified.

If all the organizational capital is portable and there are no sunk costs, our contract operates like a 'spot market contract.' The manager is paid his outside option in each period and in all states of the world. The shareholders do not capture any of the surplus. This version of the model cannot replicate the increase in pay-performance sensitivity nor the increase in Tobin's q.

In some states in which the match is terminated, our compensation contract leaves room for renegotiation. Both shareholders and managers could agree ex post to avoid a break-up by lowering managerial compensation, provided that the organizational rents that accrue to shareholders are positive when the manager is promised his outside option instead. The compensation predictions of a renegotiation-proof version of the optimal contract would be similar, but separations would be rarer in equilibrium. For tractability, we abstract from renegotiation and explore the implications of the contract in which the match is discontinued in those states. In addition, its implications line up better with a large body of empirical evidence on downward wage rigidity (see, e.g., Beaudry and DiNardo, 1991). First, firms seem to strongly prefer layoffs to salary cuts (see, e.g., Bewley, 1999). Second, the prevalence of repricing of executive stock options and the granting of large amounts of new options in response to share price declines (see Chen, 2004) is consistent with our model.

In our model, the firm shuts down when its managerial team leaves. Hence, the rate of firm entry and exit equals the rate of managerial turnover. Since the model matches the declining firm exit rate in the data, the model also predicts a declining managerial turnover rate. However, in the data, at least in the last ten years, there seems to be an increase in turnover of CEO's. Data on managerial turnover broadly defined are hard to come by. The link between CEO turnover and performance has decreased over time, according to Murphy (1999), who argues that turnover in large firms is driven mostly by executive age and not by performance. A number of explanations for the apparent increase in CEO turnover have been put forward: increased diligence of the board of directors Hermalin (2005) or an increase in business education which promoted managerial mobility across firms (Frydman and Saks, 2006; Murphy and Zabojnik, 2004). Our model abstracts from these issues and focuses only on that part of managerial turnover that is solely driven by firm exit and entry.[2]

Our model has several additional, "out-of-sample" implications which are borne out in the data. First, it matches the sensitivity of log compensation to log firm size in the US Edmans,

[2] An extension of the model could allow for a partial separation of firm exits and managerial turnover by introducing additional manager-specific productivity shocks. We do not pursue such an extension here.

Gabaix, and Landier (2009). Second, it matches the cross-sectional correlation between valuation and wage dispersion in the data. We identify high vintage-specific growth industries as those with low managerial wage dispersion. As predicted by the model, we find that these industries accumulate less organizational capital, using Tobin's q as our measure. The effects are large. We find that a one-standard-deviation increase in wage dispersion increases Tobin's q by six basis points using a broad measure of wage dispersion and by 14 basis points for executive compensation dispersion. These effects of executive wage compensation are stronger in industries with more intangibles. Wheeler (2005) shows that within-industry wage inequality is much higher in industries with higher frequency of computer usage, which are industries with lower vintage-specific growth in our model.

Related literature. Our model combines the technology side of the vintage capital model of Atkeson and Kehoe (2005, 2007) with an optimal compensation contract for managers. The literature on optimal compensation contracts builds on the seminal paper on optimal long-term wage contracts with learning about the manager's productivity by Harris and Holmstrom (1982). As in Harris and Holmstrom (1982), our optimal compensation dynamics display downward rigidity, relative to the benchmark compensation, determined by the productivity of the average establishment in the industry. This rigidity is generated by the inability of managers to commit to staying in the firm, as in Krueger and Uhlig (2006). There is a scope for insurance when at least some of the organizational capital is specific to the match between the owner and the manager. Neal (1995) provides empirical evidence on the importance of match-specific capital.[3] Most of the work on optimal compensation contracts examines the optimal capital structure of the firm in the presence of moral hazard in partial equilibrium. Instead, our paper examines the optimal management compensation contract in the presence of portable capital in a general equilibrium model. We focus on how the compensation contract can provide the right retention incentives, while the literature focuses mostly on incentives to exert effort or make the right investment decisions. However, Oyer (2004) and Himmelberg and Hubbard (2000) do focus on retention. Oyer (2004) points out that firms may implement stock option plans or other pay instruments that reward 'luck' because of binding participation constraints in a model where employees' outside opportunities are correlated with their firms' performance. Our paper provides a fully specified dynamic equilibrium model in which the endogenous outside option depends on the industry's performance. Himmelberg and Hubbard (2000) provide some of the earliest empirical evidence that is consistent with this view.

We use these contracts to connect changes in the distribution of firm size to changes in the distribution of managerial compensation. In closely related work, Gabaix and Landier (2008) explain the increased dispersion of CEO compensation in a matching model with an exogenously changing size distribution. Our paper endogenizes both the evolution of the size and the managerial compensation distribution and explicitly models the compensation contract. The optimal compensation contract that we derive entails benchmarking. As long as the CEO's outside option constraint does not bind, his compensation is kept fixed relative to that of the average firm's CEO compensation. This is a feature of the data (Bizjak, Lemmon, and Naveen, 2008). In addition, we derive a theoretical link between the size and book-to-market ratio of a firm and its labor

[3] Related applications of optimal compensation contracts in finance are Berk, Stanton, and Zechner (2010), Clementi, Cooley, and Wang (2006), DeMarzo and Fishman (2007), Clementi and Hopenhayn (2002), and Albuquerque and Hopenhayn (2004), Falato and Kadyrzhanova (2008), DeMarzo and Sannikov (2006), Biais, Mariotti, and Rochet (2007), Opp (2007), He (2007), DeMarzo, Fishman, He, and Wang (2007), and Atkeson and Cole (2008)

compensation contracts.[4] In recent work, Eisfeldt and Papanikolaou (2008) study the risk characteristics of organizational capital, while Panageas and Yu (2006) and Garleanu, Panageas, and Kogan (2008) study the asset pricing implications of technological change.

A large literature shows the increase of wage inequality in the US in the last three decades and its relation to technological change (see Violante, 2002; Guvenen and Kuruscu, 2009; Autor, Katz, and Kearny, 2008; Acemoglu, 2002). Our paper contributes to this literature by generating an endogenous switch to high-powered incentives contracts and by connecting the changing distribution of payouts to workers to the payouts to the owners of the capital stock, and ultimately to firm value. With the exception of Merz and Yahsiv (2007); Papanikolaou (2007); Bazdrech, Belo, and Lin (2008); Parlour and Walden (2008), the link between labor compensation and firm value is usually ignored in the literature. Parlour and Walden (2008) characterize optimal compensation contracts in the presence of moral hazard and derive predictions relating workers compensation, firm productivity, firm size, and firm value.

One prominent example of the technological change we have in mind is the information technology (IT) revolution after 1973. As its efficiency improved and its price dropped, the use of IT spread, and its adoption affected all sectors of the economy. By now, there is overwhelming evidence that computers have fundamentally altered firms' business processes, relationships with customers and suppliers, and internal organization (see Brynjolfsson and Hitt, 1997, 2000; Bresnahan, Brynjolfsson, and Hitt, 2002; Corrado, Haltiwanger, and Sichel, 2005). This literature convincingly argues that the gradual adoption of IT, a general purpose technology (GPT) (Bresnahan and Trachtenberg, 1996), has increased the productivity of successful establishments of all vintages, not only the new ones. There is indirect evidence that organizational capital is more important in production than three decades ago from the stock market's valuation of US corporations (see Hall, 2001). Moreover, organizational capital and IT are complementary inputs, and investment in IT has increased substantially since the 1970s (Bresnahan et al., 2002). Finally, there is direct evidence on the link between IT and organizational capital and the increased importance of organizational capital. Using micro data, Bloom, Sadun, and Van Reenen (2008) explain the productivity miracle in the US and its absence in Europe by means of a US advantage in IT that is "primarily due to its *people management* practices on promotions, rewards, hiring and firing".

Our paper is organized as follows. Section 2 defines the technology side of the model and the compensation contract between manager and owner, and defines an equilibrium with a continuum of managers and firms along a steady-state growth path. Section 3 highlights the properties of the optimal compensation contract along a steady-state growth path. Its dynamics are fully captured by the current and the highest-ever productivity level of the firm. Managerial compensation increases whenever a new maximum productivity level is reached. These two state variables have a natural interpretation as the *size* and *market-to-book ratio* of the firm. Our model ties these two characteristics to the value of the firm and the compensation of its management. Section 4 describes the calibration of the model. We introduce a gradual increase in general productivity growth and an offsetting reduction in vintage-specific productivity growth so that the total growth rate is constant. The magnitude of this compositional shift is calibrated to match the observed decline in labor reallocation. A second key parameter is the portability of organizational capital. It is calibrated to match the increase in income inequality. Interestingly, the model's cross-

[4] A related literature studies the relationship of firm characteristics such as leverage and riskiness of cash-flows to firm valuation in dynamic settings; see Livdan, Sapriza, and Zhang (2009), Gomes and Livdan (2004), Gomes and Schmid (2007), Hennessy and Whited (2007), Strebulaev (2007), Gourio (2007), and Chen (2010).

sectional distribution of managerial pay shares many features with the observed distribution: it is skewed, fat-tailed, and has the correct relation with firm size. The model also delivers an increase in pay-performance sensitivity similar to the one in the data. Finally, Section 5 provides additional cross-sectional evidence for the effect of managerial compensation inequality on firm valuation.

2. Model

We set up a model with a fixed population (mass 1) of *managers*. Each manager is matched to an owner to form an *establishment*.[5] The formation of a new establishment incurs a one-time fixed cost S_t. Establishments accumulate knowledge as long as the match lasts. We refer to this stock of knowledge as *organizational capital* A_t. This organizational capital affects the technology of production; it is a third factor of production besides physical capital and unskilled labor, earning *organizational rents*.

We assume that a part of the establishment's organizational capital is embodied in the manager. It is neither fully match-specific, as in Atkeson and Kehoe (2005), nor fully manager-specific. The main innovation of our work is to find the optimal division of organizational rents between the owner and the manager, as governed by an optimal long-term risk-sharing contract in the spirit of Harris and Holmstrom (1982). We solve for the optimal contract recursively (see, e.g., Thomas and Worall, 1988; Kocherlakota, 1996), but we use a different state variable from the one commonly used in the literature. The optimal contract maximizes the present discounted value of the organizational rents flowing to the owner subject to the manager's promise-keeping constraint and a sequence of participation constraints that reflect the manager's inability to commit to the current match. We deviate from Krueger and Uhlig (2006) by assuming that the owner has limited liability. Separation occurs whenever there is no joint surplus left in the match. Upon separation, a fraction $0 < \phi < 1$ of the organizational capital can be transferred to the manager's next match, while the remainder of the organizational capital in the old establishment is destroyed. This can be interpreted as the management team being dissolved. Hence, in our model, firm entry and exit is identical to managerial turnover. We will calibrate the model to match entry/exit rates in the data.

If the manager could commit to staying in the match or if none of the organizational capital was destroyed when the manager left the firm, then the changing composition of productivity growth would have no effect on the distribution of compensation.

We start by setting up the model and defining a steady-state growth path. In Section 4, we trace out the *transition* between two steady-state growth paths.

2.1. Technology

On the technology side, our model follows Atkeson and Kehoe (2005). Each establishment belongs to a vintage s. An establishment of vintage s at time t was born at $t-s$. An establishment operates a vintage-specific technology that uses unskilled labor (l_t), physical capital (k_t), and organizational capital (A_t) as its inputs. Output generated with this technology is y_t:

$$y_t = z_t\,(A_t)^{1-\nu}\,F(k_t, l_t)^{\nu}.$$

[5] We use the words establishment and firm interchangeably. The manager can be interpreted as the entire management team.

Following Lucas (1987), ν is the 'span of control' parameter of the manager. It governs the decreasing returns to scale at the establishment level.

There is no aggregate uncertainty in our model. There are two sources of productivity growth, which we label general and vintage-specific growth. The *general productivity* level z_t grows at a deterministic and constant rate g_z:

$$z_t = (1 + g_z)z_{t-1}.$$

General productivity growth affects establishments of all vintages alike. General productivity growth is often referred to as *disembodied* technical change. In addition, it is *skill-neutral* because it affects all three production inputs symmetrically.

Following Hopenhayn and Rogerson (1993), the match-specific level of organizational capital, A_t, follows an exogenous process. It is hit by random match-specific shocks ε, which are log-normally distributed $N(0, \sigma^2)$:

$$\log A_{t+1} = \log A_t + \log \varepsilon_{t+1}. \tag{2.1}$$

We do not explicitly model the learning process that underlies the accumulation process of organizational capital. However, the ε shocks can be interpreted as productivity gains derived from active or passive learning, from matching, or from adoption of new technologies in existing firms, as Atkeson and Kehoe (2005) point out.[6]

A new establishment can always start with a *blueprint* or *frontier* technology level θ_t: $A_t \geq \theta_t$. The productivity level of the blueprint grows at a deterministic and constant rate g_θ:

$$\theta_t = (1 + g_\theta)\theta_{t-1}.$$

This *vintage-specific growth* is often referred to as *embodied* technical change.

2.2. Contract between owner and manager

Owner. There is a stand-in owner who is perfectly diversified.[7] He maximizes the expected present discounted value of aggregate payouts from all establishments D_t using a discount rate r_t:

$$E_0 \sum_{t=0}^{\infty} e^{-\sum_{s=0}^{t} r_s} D_t = V_t + K_t. \tag{2.2}$$

This object is the value of the aggregate capital stock V_t+K_t, which consists of the physical capital K_t and the owner's residual claim to the aggregate rents from organizational capital, denoted V_t. The owner's value of organizational capital is the expected present discounted value of the aggregate stream of cash flows $\{\Pi_t\}$ that is not already claimed by the other factors:

$$\Pi_t = Y_t - W_t L_t - R_t K_t - C_t - S_t^a, \tag{2.3}$$

where $W_t L_t$ is the aggregate compensation of unskilled labor, $R_t K_t$ that of physical capital, C_t the aggregate compensation of all the managers of the establishments, and $S_t^a \equiv N_t S_t$ the total sunk

[6]Additionally, they can be interpreted as reduced-form for heterogeneity across managers, or for the outcomes from good or bad decisions made by the manager. Bertrand and Schoar (2003), Bennedsen, Perez-Gonzalez, and Wolfenzon (2007), and Bloom and Van Reenen (2007) show that heterogeneity across managers leads to heterogeneity in firm outcomes. Jovanovic and Nyarko (1982) explicitly model learning-by-doing and McGrattan and Prescott (2007) and Carlin, Chowdhry, and Garmaise (2008) explicitly model the accumulation of intangible capital.

[7]Equivalently, there is a continuum of atomless and identical owners.

costs incurred for starting N_t new establishments. Since we assume that the owner also owns the physical capital stock K_t, aggregate payouts to the owner D_t are the sum of organizational rents and the factor payments to physical capital less physical investment:

$$D_t = \Pi_t + R_t K_t - I_t, \ \forall t.$$

Since the sunk cost is lost, value-added is defined as $Y_t - S_t^a$.

An individual establishment's organizational rents (before sunk costs and physical capital income) accruing to its owners are defined with lower-case letters:

$$\pi_t = y_t - W_t l_t - R_t k_t - c_t.$$

Manager. The owner offers the manager a complete contingent contract $\{c_t(h^t), \beta_t(h^t)\}$ at the start of the match, where $c_t(h^t)$ is the compensation of the manager as a function of the history of shocks $h^t = (\varepsilon_t, \varepsilon_{t-1}, ...)$ and $\beta_t(h^t)$ governs whether the match is dissolved or not in history h^t. This contract cannot be renegotiated. The manager can always accept a job at another establishment, while the owner has limited liability.

The optimal contract maximizes the total expected payoff of the owner subject to delivering initial utility v_0 to the manager:

$$v_0(h^0) = E_{h^0}\left[\sum_{\tau=0}^{\infty} e^{-\rho_m t} \frac{c_\tau(h^\tau)^{1-\gamma}}{1-\gamma}\right].$$

The manager is risk averse with constant relative risk aversion (CRRA) parameter γ and his time discount rate is denoted ρ_m. In general, the history-dependence of the manager's compensation makes this a complicated problem. However, as is common in the literature on dynamic contracts, we use the manager's promised utility as a state variable to make the problem recursive. The contract delivers v_t in total expected utility to the manager today by delivering current compensation c_t and state-contingent compensation promises $v_{t+1}(\cdot)$ tomorrow. These promised utilities lie on a domain $[\underline{v}, \overline{v}]$.

We use $V_t(A_t, v_t)$ to denote the value of the owner's equity in an establishment with current organizational capital A_t, and an outstanding promise to deliver v_t to the manager. It is the value of the owner's claim to the rents from organizational capital. This does not include the value of income from physical capital. Importantly, the owner has limited liability: the option to terminate the contract when there is no joint surplus in the match. Limited liability implies the constraint: $V_t(A_t, v_t) \geq 0$.

Finally, we use $\omega_t(A_t)$ to denote the outside option of a manager currently employed in an establishment with organizational capital A_t. When a manager switches to a new match, a fraction ϕ of the organizational capital is transferred to the next match and a fraction $1-\phi$ is destroyed. Free disposal applies: If the manager brings organizational capital worth less than the current blueprint θ_t, then the new match starts off with the blueprint technology for the new vintage. Taken together, the organizational capital of a match of vintage t is $\max\{\phi A_t, \theta_t\}$. The value of the outside option ω is determined in equilibrium by a zero-profit condition for new firm entry.

Recursive formulation. For given outside option $\{\omega_t\}$ and discount rate $\{r_t\}$ processes, the optimal contract in an establishment that has promised v_t to its manager maximizes the owner's value V

$$V_t(A_t, v_t) = \max\left[\widehat{V}_t(A_t, v_t), 0\right], \tag{2.4}$$

and

$$\widehat{V}_t(A_t, v_t) = \max_{c_t, v_{t+1}(\cdot)} \left[\pi_t + \int e^{-r_t} V(A_{t+1}, v_{t+1}) \Gamma(\varepsilon_{t+1}) d\varepsilon_{t+1} \right], \tag{2.5}$$

by choosing the state-contingent promised utility schedule $v_{t+1}(\cdot)$ and the current compensation c_t, subject to the law of motion for organizational capital (2.1), a promise keeping constraint

$$\begin{aligned} v_t &= u(c_t) + e^{-\rho_m} \int \beta_{t+1}(v_t, \varepsilon_{t+1}) v_{t+1}(A_{t+1}) \Gamma(\varepsilon_{t+1}) d\varepsilon_{t+1} \\ &\quad + e^{-\rho_m} \int \omega_{t+1}(A_{t+1})(1 - \beta_{t+1}(v_t, \varepsilon_{t+1})) \Gamma(\varepsilon_{t+1}) d\varepsilon_{t+1}, \end{aligned} \tag{2.6}$$

and a series of participation constraints

$$v_{t+1}(A_{t+1}) \geq \omega_{t+1}(A_{t+1}). \tag{2.7}$$

The indicator variable β is one if continuation is optimal and zero elsewhere:

$$\begin{aligned} \beta_{t+1} &= 1 \text{ if } v_{t+1}(A_{t+1}) \leq v^*(A_{t+1}) \\ \beta_{t+1} &= 0 \text{ elsewhere.} \end{aligned}$$

The minimum at zero in Eq. (2.4) for the owner's value reflects limited liability of the owner: The match is terminated if the joint surplus of the match is negative. If the match is dissolved, the manager receives $\omega_{t+1}(A_{t+1})$ in promised utility. To obtain this recursive formulation, we have used the fact that $V_t(A_t, \cdot)$ is non-increasing in its second argument. For each A_t, there exists a cut-off value $v^*(A_t)$ that satisfies $\widehat{V}_t(A_t, v^*(A_t)) = 0$. The match is dissolved when the compensation promised to the manager exceeds the cutoff level: $\beta_{t+1} = 0$ if and only if $v_{t+1}(A_{t+1}) > v^*(A_{t+1})$. Put differently, only establishments with high enough productivity $A_t > \underline{A}_t(v_t)$ survive.

2.3. *Equilibrium*

A competitive equilibrium is a price vector $\{W_t, R_t, r_t\}$, an allocation vector $\{k_t, l_t, c_t, \beta_t\}$, an outside option process $\{\omega_t\}$, and a sequence of distributions $\{\Psi_{t,s}, \lambda_{t,s}, N_t\}$ that satisfy optimality and market clearing conditions spelled out below.

Physical capital and unskilled labor. Unskilled labor l and physical capital k can be reallocated freely across different establishments. Hence, the problem of how much l and k to rent at factor prices W and R, is entirely static. We use K_t and L_t to denote the aggregate quantities, and we use $\overline{A}_t$ to denote the average stock of organizational capital across all establishments and vintages:

$$\overline{A}_t = \sum_{s=0}^{\infty} \int_A A \Phi_{t,s} dA,$$

where $\Phi_{t,s}$ denotes the measure over organizational capital at the start of period t for vintage s. Physical capital and unskilled labor are allocated in proportion to the establishment's organizational capital level A_t:

$$\begin{aligned} k_t(A_t) &= \frac{A_t}{\overline{A}_t} K_t \\ l_t(A_t) &= \frac{A_t}{\overline{A}_t} L_t. \end{aligned}$$

This allocation satisfies the first-order conditions and the market clearing conditions for capital and labor. The fact that establishments with larger organizational capital A have more physical capital and hire more unskilled labor suggests an interpretation of A as the *size* of the establishment. In the model, employment in a firm varies with A_t; labor reallocates every period. Firm exits, however, only occur when A_t falls below a critical threshold which is determined by the sunk cost of starting a new firm.

The equilibrium wage rate W_t for unskilled labor and rental rate for physical capital R_t are determined by the standard first-order conditions:

$$W_t = \nu z_t \overline{A}_t^{1-\nu} F_L(K_t, L_t)^{\nu-1}, \quad R_t = \nu z_t \overline{A}_t^{1-\nu} F_K(K_t, L_t)^{\nu-1}.$$

The factor payments to unskilled labor and physical capital absorb a fraction $(1-\nu)$ of aggregate output Y_t, where Y_t is given by:

$$Y_t = z_t \overline{A}_t^{1-\nu} F(K_t, L_t)^{\nu}.$$

In the remainder, we assume a Cobb-Douglas production function $F(k, l) = k^{\alpha} l^{1-\alpha}$.

Organizational rents. A fraction ν of aggregate output Y_t goes to organizational capital. These organizational rents are split between the owners Π_t, managers C_t, and sunk costs $S_t^a = N_t S_t$:

$$\sum_{s=0}^{\infty} \int_{\nu} \int_{A} \pi_t(A, \nu) \Psi_{t,s}(A, \nu) d(A, \nu) - N_t S_t = Y_t - W_t L_t - R_t K_t - C_t - S_t^a = \Pi_t,$$

where the measure $\Psi_{t,s}(A, \nu)$ is defined below. The second equality follows from (2.3) and ensures that the goods market clears.

Discount rate. The payoffs are priced off the inter-temporal marginal rate of substitution (IMRS) of the representative owner. Just like the manager, the owner has constant relative risk aversion preferences with parameter γ. His subjective time discount factor is ρ_o. Let g_t denote the rate of change in $\log D_t$. Then, the equilibrium log discount rate or "cost of capital" r_t is given by the owner's log IMRS:

$$r_t = \rho_o + \gamma g_t. \tag{2.8}$$

Because there is no aggregate uncertainty and the owner holds a diversified portfolio of establishments, the cost of capital evolves deterministically. Thus, our setting is equivalent to one with a risk neutral owner who discounts future cash-flows, as in equation (2.2).

Managerial compensation. Having solved for the value function $\{V_t(\cdot,\cdot)\}$ that satisfies the Bellman equation above for given $\{\omega_t(\cdot), r_t\}$, we can construct the optimal contract for a new match starting at t $\{c_{t+j}(h^{t+j}), \beta_{t+j}(h^{t+j})\}$ in sequential form.

Outside option. We assume the sunk cost S_t grows at the same rate as output. Free entry stipulates that the equilibrium value of a new establishment to the owner is equal to the sunk cost S_t:

$$V_t\left(max(\phi A_t, \theta_t), \omega_t(A_t)\right) = S_t. \tag{2.9}$$

The first argument indicates that a new establishment starts with organizational capital equal to the maximum of the frontier level of technology θ_t and the organizational capital ϕA_t that the manager brought from the previous match. The total utility $\omega_t(A_t)$ promised to the manager at the start of a new match is such that the value of the new match is zero in expectation. Therefore, Eq. (2.9) pins down the equilibrium outside option $\omega_t(A_t)$.

Law of motion for distributions. We use χ to denote the implied probability density function for A_{t+1} given A_t. κ is an indicator function defined by the policy function for promised utilities: $\kappa(A'; A, v) = 1$ if $v'(A'; A, v) = v'$, and equals zero elsewhere. Using this indicator function, we can define the transition function Q for (A, v):

$$Q\left((A', v'), (A, v)\right) = \chi(A'|A)\kappa(A'; A, v).$$

We use $\Psi_{t,s}$ to denote the joint measure over organizational capital A and promised utilities v for matches of vintage s. Its law of motion is implied by the transition function:

$$\Psi_{t+1,s+1}(A', v') = \int_0^\infty \int_{\underline{v}}^{\overline{v}} Q((A', v'), (A, v))\lambda_{t,s}(A, v)d(A, v), \tag{2.10}$$

where $\lambda_{t,s}(A, v)$ is the measure of surviving establishments in period t of vintage s:

$$\lambda_{t,s}(A, v) = \int_0^A \int_{\underline{v}}^{v} \beta(a, u)d\Psi_{t,s}(a, u) \geq 0. \tag{2.11}$$

In equilibrium, the mass of new establishments created in each period N_t (entry) equals the mass of matches destroyed in that same period (exit):

$$N_t = \sum_{s=0}^{\infty} \int_0^\infty \int_{\underline{v}}^{\overline{v}} (1 - \beta_{t,s}(A, v))\Psi_{t,s}(A, v)d(A, v) \geq 0.$$

2.4. Back-loading

The free entry condition implies that the expected net present discounted value of a start-up is exactly zero:

$$\int_0^\infty \int_{\underline{v}}^{\overline{v}} \sum_{j=0}^{\infty} e^{-\sum_0^j r_s ds}\pi_{t+j}(A, v)\Psi_{t+j,s}(A, v)d(A, v) - S_t = 0$$

Importantly, this does not imply that the organizational rents that flow to the owners are zero. As long as discount rates r are strictly positive, the zero-profit condition in (2.9) implies that expected net payouts are strictly positive:

$$\int_0^\infty \int_{\underline{v}}^{\overline{v}} \sum_{j=0}^{\infty} \pi_{t+j}(A, v)\Psi_{t+j,s}(A, v)d(A, v) - S_t > 0,$$

for two reasons. The first reason is a *back-loading* effect (see Atkeson and Kehoe, 2005). The owners are compensated for waiting in the form of positive payouts. The more back-loaded the payments are, the higher the expected payments. The expected payout profile of an establishment is steeply increasing: the first payout is a large negative number ($-S_t$), the establishment then grows and starts to generate higher and higher profits (in expectation). Most of the organizational rents are paid in the future. Second, there is a *selection* effect operative. Only the establishments that have fast enough organizational capital growth (high enough ε shocks) survive. When we compute aggregate (or expected) payouts, we are only sampling from the survivors who satisfy $A_t > \underline{A}_t(v_t)$.

As pointed out by Hopenhayn (2002), selection among establishments can explain why Tobin's (average) q is larger than one, on average. The aggregate value of establishments is given by the present discounted value of a claim to $\{D_t\}$. It equals the sum of all equity values across all establishments minus sunk costs plus the value of the physical capital stock K_t:

$$V_t^a = \sum_{s=0}^{\infty} \int_0^{\infty} \int_{\underline{v}}^{\overline{v}} V_t(A,v)\Psi_{t,s}(A,v)d(A,v) - S_t^a + K_t \geq K_t.$$

Tobin's q, $q_t = \frac{V_t^a}{K_t}$, is larger than one, on average, in spite of the fact that new matches are valued at zero (net of their physical capital). The reason is again selection: when we compute q, we only sample survivors. For future reference, we also define aggregate managerial wealth in the economy as:

$$M_t = \sum_{s=0}^{\infty} \int_A \int_v v_t(A,v)\Psi_{t,s}(A,v)d(A,v).$$

It is the value of a claim to all the rents from organizational capital that flow to the managers.

2.5. Steady-state growth path

In a first step, we solve for a steady-state growth path in which all aggregate variables grow at a constant rate. Aggregate establishment productivity $\{\overline{A}_t\}$ and the productivity of the newest vintage $\{\theta_t\}$ grow at a constant rate g_θ, the variables $\{r_t, R_t, N_t\}$ are constant, the general productivity-level grows at a constant rate g_z, and all other aggregate variables grow at a constant rate

$$g = \left((1+g_z)(1+g_\theta)^{1-\nu}\right)^{\frac{1}{1-\alpha\nu}}. \tag{2.12}$$

We normalize the population of unskilled labor L to one.

Definition 1. *A steady-state growth path is defined as a path for which aggregate establishment productivity $\{\overline{A}_t\}$ and the productivity of the newest vintage $\{\theta_t\}$ grow at a constant rate g_θ, the variables $\{r_t, R_t, N_t\}$ are constant, the economy-wide productivity-level grows at a constant rate g_z, and all aggregate variables $\{Y_t, K_t, W_t, S_t, C_t, D_t, V_t^a\}$ grow at a constant rate*

$$g = \left((1+g_z)(1+g_\theta)^{1-\nu}\right)^{\frac{1}{1-\alpha\nu}}.$$

Along the steady-state growth path, the measure over establishment productivity and promised utilities satisfies:

$$\Psi_{t+1,s+1}(A,v) = \Psi_{t,s}\left(\frac{A}{1+g_\theta}, v\right),$$

the measure of active establishments satisfies:

$$\lambda_{t+1,s}(A,v) = \lambda_{t,s}\left(\frac{A}{1+g_\theta}, v\right),$$

and the value of an establishment of vintage s *evolves according to:*

$$V_{t+1}(A,v;s+1) = (1+g)V_t\left(\frac{A}{1+g_\theta}, v(1+g)^{1-\gamma}, s\right).$$

To construct the steady-state growth path, we normalize organizational capital by the frontier level of technology, and we denote the resulting variable with a hat: $\widehat{A}_t = A_t/\theta_t$. By construction, $\widehat{A} \geq 1$ for a new establishment. A key insight is that the organizational capital of existing establishments, expressed in units of the frontier technology, *shrinks* at a rate $(1+g_\theta)$:

$$\log\left(\widehat{A}'\right) = \log\left(\widehat{A}\right) - \log(1+g_\theta) + \log(\varepsilon'). \tag{2.13}$$

The prime denotes next period's value. The lower the g_θ, the higher the growth rate of $\widehat{A}$. Below, we introduce a secular decline in g_θ. We normalize variables in efficiency units. This allows us to restate the production technology as follows :

$$\widetilde{y}_t = \widetilde{k}_t^{\alpha\nu},$$

where a variable with a tilde, $\widetilde{x}_t$, denotes the variable, x, expressed in per capita terms and in adjusted efficiency units of the latest vintage (blueprint):

$$\widetilde{x}_t = \frac{x_t}{z_t^{\frac{1}{1-\alpha\nu}}\theta_t^{\frac{1-\nu}{1-\alpha\nu}}}.$$

This notation allows us to reformulate the optimal contract along the steady-state growth path. The owner maximizes his value $\widehat{V}(\widehat{A},\widetilde{v})$ by optimally choosing current compensation $\widetilde{c}$ and future promised utilities $\widetilde{v}'(\cdot)$:

$$\widetilde{V}(\widehat{A},\widetilde{v}) = \max\left[\widehat{V}(\widehat{A},\widetilde{v}), 0\right]$$

and

$$\widehat{V}(\widehat{A},\widetilde{v}) = \max_{\widetilde{c},\widetilde{v}'(\cdot)}\left[\begin{array}{c} \widetilde{y} - \widetilde{W} - R\widetilde{k} - \widetilde{c} \\ +e^{-(\rho_o-(1-\gamma)\widetilde{g})}\int \widetilde{V}(\widehat{A}',\widetilde{v}')\Gamma(\varepsilon')d\varepsilon' \end{array}\right], \tag{2.14}$$

subject to the law of motion for organizational capital in (2.13), the promise-keeping

$$\widetilde{v} \quad = \quad u(\widetilde{c}) + e^{-(\rho_m-(1-\gamma)\widetilde{g})}\left[\int \beta_{s'}(\widetilde{v},\varepsilon')\widetilde{v}'(\widehat{A}')\Gamma(\varepsilon')d\varepsilon' + \widetilde{\omega}(\widehat{A}')\int(1-\beta(\widetilde{v},\varepsilon'))\Gamma(\varepsilon')d\varepsilon'\right] \tag{2.15}$$

and subject to participation constraints for all $\widehat{A}'$:

$$\widetilde{v}'(\widehat{A}') \geq \widetilde{\omega}(\widehat{A}').$$

The indicator variable β is one if continuation is optimal and zero elsewhere:

$$\begin{aligned}\beta &= 1 \text{ if } \widetilde{v}'\left(\widehat{A}'\right) \leq \widetilde{v}^*(\widehat{A}') \\ \beta &= 0 \text{ elsewhere.}\end{aligned}$$

The outside option process is determined in equilibrium by the zero-profit condition for new entrants:

$$\widehat{V}\left(max(\widehat{A}\phi, 1), \omega(\widehat{A})\right) = S. \tag{2.16}$$

Eq. (2.16) implies that the outside option $\omega(\widehat{A}_t)$ is constant in the range $A \in [0, \phi^{-1}]$. We refer to this range as the insensitivity region, because the outside option does not depend on the organizational capital accumulated in the current establishment. When the fraction of capital ϕ that is portable is zero, the outside option is constant for all $A > 0$.

3. Properties of compensation contract

Although the managerial compensation contract allows for complicated history-dependence, the optimal contract along a steady-state growth path turns out to have intuitive dynamics. Two state variables summarize all necessary information: the current level of productivity A_t, which we have given an interpretation as the size of the establishment, and the highest level of productivity recorded thus far $A_{max,t}$, which we will give an interpretation as the book-to-market ratio of the establishment.

3.1. No discount rate wedge

First, we consider the case in which the manager and the owner are equally impatient ($\rho_m = \rho_o$). The promised utility state variable v_t can be replaced by the running maximum of the productivity process: $\widehat{A}_{max,t} = max\{\widehat{A}_\tau, \tau \leq t\}$. We let T denote the random stopping time when the establishment is shut down:

$$T = inf\{\tau \geq 0 : \widehat{V}(\widehat{A}_\tau, \widetilde{v}_\tau) = 0\}.$$

Proposition 2. *Optimal management compensation along a steady-state growth path is determined by the running maximum of productivity:* $\tilde{c}_t(\widehat{A}_{max,t}) = \max\left\{c_0, C\left(\omega(\widehat{A}_{max,t}), \widehat{A}_{max,t}\right)\right\}$ *for all* $0 < t < T$ *where the function* $C\left(\widetilde{v}, \widehat{A}\right)$ *is defined such that the implied compensation stream* $\{\widetilde{c}_\tau\}_{\tau=t}^{\infty}$ *delivers total expected utility* $\widetilde{v}_t$ *to the manager.*

Proof: See Appendix B. Management compensation is constant in efficiency units as long as the running maximum is unchanged. The constancy is optimal because of the concavity of the manager's utility function, and arises as long as the participation constraint does not bind. This amounts to *benchmarking*, because the manager's compensation simply keeps up with the industry's productivity growth as long as the manager's participation constraint does not bind. When the productivity process reaches a new high, the participation constraint binds, and the compensation is adjusted upwards. Armed with this result, we can define the owner's value recursively as a function of $\widehat{A}_t$ and the running maximum $\widehat{A}_{max,t}$:

$$\widetilde{V}(\widehat{A}, \widehat{A}_{max}) = \max\left[\widehat{V}(\widehat{A}, \widehat{A}_{max}), 0\right]$$

and

$$\widehat{V}(\widehat{A},\widehat{A}_{max}) = \widetilde{y} - \widetilde{W}l - R\widetilde{k} - \widetilde{c}(\widehat{A}_{max}) + e^{-(\rho_o-(1-\gamma)g)} \int \widetilde{V}(\widehat{A}',\widehat{A}'_{max})\Gamma(\varepsilon')d\varepsilon',$$

subject to the law of motion for organizational capital in (2.13) and the implied law of motion for the running maximum.

Fig.1 illustrates the dynamics of the optimal compensation. It plots $\widehat{A}$ on the vertical axis against $\widehat{A}_{max}$ on the horizontal axis. By definition, $\widehat{A} \leq \widehat{A}_{max}$, so that only the area on and below the 45-degree line is relevant. New establishments start with $\widehat{A} = \widehat{A}_{max} \geq 1$. When an establishment grows and this growth establishes a new maximum productivity level, it travels along the 45-degree line. When its productivity level falls or increases but not enough to establish a new record, it travels along a vertical line in the $(\widehat{A}_{max}, \widehat{A})$ space. The region $[0, 1/\phi]$ for $\widehat{A}_{max}$ is an *insensitivity region*. Managerial compensation is constant ($\tilde{c} = c_0$) in this region. Compensation is constant in efficiency units for small establishments because of the sunk cost. The manager will not leave because his productivity level is insufficiently high to justify a new sunk cost. To the right of this region, managerial compensation is pinned down by the binding outside option that was last encountered: $\tilde{c}(\widehat{A}_{max})$. As long as current productivity stays below the running maximum, the manager's compensation is constant in efficiency units. Along this $\Delta\tilde{c} = 0$ locus, the variation in current productivity is fully absorbed by the net payouts to owners, as long as A_t stays above the $\widehat{V} = 0$ locus. The owner bears all downside idiosyncratic productivity risk. When productivity falls below this locus, the match is terminated.

[Fig. 1 about here.]

Growth and value. In the $(\widehat{A}_{max}, \widehat{A})$ space, there is a line with slope ϕ along which the owner's value is constant: $\widehat{V} = \widehat{S}$. This is the locus of pairs for which $\widehat{A} = \phi\widehat{A}_{max}$. On this locus, an existing establishment pays the same compensation as a new establishment and it has the same productivity:

$$\widehat{V}\left(\phi\widehat{A}_{max}, \omega(\widehat{A}_{max})\right) = \widehat{S}. \tag{3.1}$$

This means that the firm's market-to-book ratio, or average q ratio, on this line is given by:

$$q = 1 + \frac{\widehat{V}(\widehat{A},\widehat{A}_{max})}{\widehat{k}(\widehat{A})} = 1 + \frac{\widehat{S}}{\widehat{k}(\widehat{A})}.$$

This suggests a natural interpretation of the ratio of current productivity relative to the running maximum as an indicator of the market-to-book ratio. Compare two establishments with the same size $\widehat{A}$. The establishment with the lower ratio of $\widehat{A}/\widehat{A}_{max}$ has the same physical capital stock $\widehat{k}(\widehat{A})$, but higher (current and future) managerial compensation. This is because the manager is compensated for the best past performance, which is substantially above current productivity. Hence, the value of its organizational capital going to the owners $\widehat{V}(\widehat{A},\widehat{A}_{max})$ is lower. These low $\widehat{A}/\widehat{A}_{max}$ firms have a low market-to-book ratio $1 + \widehat{V}/\widehat{k}$. They are *value* firms. High $\widehat{A}/\widehat{A}_{max}$ firms are growth firms. In Fig.1, firms with the same market-to-book ratio are on the same line through the origin. Value firms are farther from the 45-degree line, growth firms are closer.

Organizational capital as collateral. The limited portability of organizational capital creates the collateral in the matches necessary to sustain risk sharing. Two extreme cases illustrate this point. In the first case, there is no capital specific to the match and there are no other frictions, as in Krueger and Uhlig (2006). The manager can transfer 100% of the organizational capital of the establishment to a future match ($\phi = 1$) and there are no sunk costs ($\widehat{S} = 0$). When $\phi = 1$ in Fig. 1, the $\widehat{V} = \widehat{S}$ line coincides with the 45-degree line. Therefore, $\widehat{V} \leq \widehat{S} = 0$ everywhere. Limited liability then implies that $\widehat{V} = 0$. Because there is no relationship capital, no risk sharing can be sustained, and the managers earn all the rents from organizational capital. The value of the owner's stake in the organizational capital is zero. This implies that Tobin's q equals one for all t. In this case, the contract actually operates like a "spot market contract" because the manager will be paid his outside option ω in each state and date. The participation constraints bind in equilibrium, at least if shareholders and managers share the same rate of time preference and we rule out the manager posting a bond at the start of the employment relationship.[8]

In the second case that we consider, $\phi = 0$: all of the organizational capital is match-specific. This is the case considered by Atkeson and Kehoe (2005). The insensitivity region extends over the entire domain of $\widehat{A}$. The manager's outside option is constant so that perfect risk sharing can be sustained. There is zero dispersion in managerial compensation. The owner receives all organizational rents, which is reflected in high q ratios.

Compensation and payout dynamics. We use a random 300-period simulation from a calibrated version of the model to illustrate the compensation dynamics; the details of the calibration are in Section 4.2. Fig. 2 tracks a single, successful establishment through time. The left panel plots the realized $(\widehat{A}_{max,t}, \widehat{A}_t)$ values, as in Fig. 1. The right panel shows the corresponding time series for productivity (or size) $\widehat{A}$ (solid line, measured against the left axis) and managerial compensation $\widetilde{c}$ (dashed line, measured against the right axis). Because $\phi = 0.5$, the insensitivity region extends until $\widehat{A} = 2$. In that region, the compensation is constant. When the establishment size exceeds 2.0, around period 50, and leaves the insensitivity region, managerial compensation starts to increase in response to increases in $\widehat{A}$, i.e., every time a new running maximum for $\widehat{A}$ is attained. The establishment moves along the 45-degree line in the left panel in the $(\widehat{A}_{max,t}, \widehat{A}_t)$ space. The manager's compensation does not track the downward movements in productivity/size that occur between periods 75 and 100. This is the first vertical locus of points in the left panel. The second big run-up in productivity increases the manager's compensation once more. Eventually, when the productivity level drops below the lower bound $\underline{A}(v)$, the owner's residual value equals zero $\widehat{V} = 0$, the match is dissolved, and the manager switches to a new match. This endogenous break-up is indicated by an arrow. A new match starts off at productivity level $max\left(\phi\widehat{A}, 1\right)$. This second match only lasts for about 20 periods because of poor productivity shock realizations. The third match on the figure lasts longer, but the establishment never leaves the insensitivity region, so that wages are constant.

[Fig. 2 about here.]

Fig.3 compares the manager's payouts $\tilde{c}$ (left panel) and the owner's payouts $\tilde{\pi}$ (right panel) for the same history of shocks as the previous figure. The left panel is identical to the right panel in Fig.2. The key message of the figure is that the owner's payouts are more sensitive to productivity shocks than the manager's compensation. The dashed line in the right panel is more volatile than the dashed line in the left panel. In the insensitivity region, the owner bears all the

[8] The case of spot contracts cannot explain the observed patterns in compensation inequality or Tobin's q. Furthermore, firm size is not well-defined. A large firm just happens to be one that hires a manager with lots of organizational capital this period, but next period, this manager could be in a different match. There is no glue to keep the manager in the match.

risk from fluctuating productivity. In addition, whenever the productivity level falls below the running maximum, the owner's payouts absorb the entire decline in output. This is because the owner provides maximal insurance to the risk-averse manager.

[Fig. 3 about here.]

Renegotiation. In the general case in which $S_t > 0$ or $\phi < 1$, the contract is not renegotiation-proof in some states in which the match is discontinued. For example, in those discontinuation states (states with $\beta_T = 0$) where shareholder value is positive when evaluated at the outside option, $\widehat{V}_T(A_T, \omega_T(A_T)) > 0$, the managers and the shareholders could ex post amend the contract such that the manager's promised utility is the outside option $\omega_T(A_T)$ in that state of the world (instead of v_T), and lower current compensation c_T accordingly. In that case, the compensation itself is identical to the one that is delivered by our original contract, but is delivered by the *old* match, rather than a new one.[9]

To derive the renegotiation-proof version, we would have to impose an additional non-negativity constraint on shareholder surplus V in those states with joint surplus when the manager's pay package is reduced to her outside option ($\widehat{V}_T(A_T, \omega_T(A_T)) > 0$). The characterization of this optimal contract is not straightforward because current productivity and the running maximum of productivity are no longer sufficient state variables. However, the compensation implications from the renegotiation-proof contract would likely be similar, but the lowered compensation after a very bad productivity shock would be paid out by the old match instead of the new match. Separations would be less frequent in equilibrium. The empirical evidence on downward wage rigidity and the preference of firms for layoffs over salary cuts (see the discussion in the introduction) seems more consistent with our contract. Hence, we assume that the match is discontinued when V_t hits zero, as described in Proposition 2.

3.2. Discount rate wedge

In the benchmark case with equal rates of time preference for the managers and the owners, managerial compensation does not respond to *decreases* in firm size and productivity. The management is completely 'entrenched.' In the quantitative section of the paper, we consider a less extreme version, by allowing for a wedge between the discount rates of the management and the owners. In particular, we consider the case in which the manager discounts cash flows at a higher rate than the owner ($\rho_m > \rho_o$). This is the relevant case when the manager faces binding borrowing constraints, has a lower willingness to substitute consumption over time, or simply has a higher rate of time preference. This is a standard assumption in the literature; see DeMarzo et al. (2007) for a recent example.

Proposition 3. *Let t_{max} denote the random stopping time that indicates when the participation constraint was last binding: $t_{max} = sup\{\tau \geq 0 : \omega(\widehat{A}_\tau) = \widetilde{v}_\tau\}$. Optimal management compensation evolves according to: $\widetilde{c}_t = c(\widehat{A}_{t_{max}})e^{-\gamma(\rho_m-\rho_o)(t-t_{max})}$ for all $0 < t$. We define $c(\widehat{A}_{t_{max}})$ such that $\{\widetilde{c}_\tau\}_{\tau=t_{max}}^{\infty}$ delivers total expected utility $\omega(\widehat{A}_{t_{max}})$ to the manager.*

Proof. See Appendix B. Instead of $\widehat{A}_{max}$, the new state variable is a discounted version of the running maximum; it depreciates at a rate that is governed by the rate of time preference gap between the manager and the owner. In the absence of binding participation constraints,

[9] The contract is renegotiation-proof if $S_t = 0$ and $\phi = 1$.

managerial compensation c grows at a rate smaller than the rate of value-added on the steady-state growth path. Put differently, whenever the current productivity of the establishment declines below its running maximum, the manager's scaled compensation $\tilde{c}$ drifts down. The left panel of Figure 4 illustrates this downward drift, for example between periods 150 and 200. Management is less 'entrenched.' This feature will help to match equilibrium entry and exit rates in the data. Without it, the model generates too much entry and exit.

[Fig. 4 about here.]

4. Transition experiment

We feed a gradual increase in general productivity growth into the model: $g_z \uparrow$. To keep the analysis tractable, we assume that the total productivity growth rate of the economy g_t is constant at its initial *steady-state growth path* value:[10]

$$g = \left[(1 + g_{t,z})(1 + g_{t,\theta})^{1-\nu}\right]^{\frac{1}{1-\alpha\nu}}. \tag{4.1}$$

Holding fixed g, the increase in g_z corresponds to a decrease in the rate of depreciation of organizational capital $\widehat{A}$ in the stationary version of the model: $g_\theta \downarrow$. The growth composition change allows existing firms in traditional industries to remain competitive longer, and grow larger. Their organizational capital depreciates less quickly in 2005–2008 than in 1970–74 (see Eq. 2.13).

In Fig.1, a lower g_θ has two distinct effects. First, it reduces the rate at which $\widehat{A}$ drifts down along a vertical line. Second, it shifts more probability mass to higher realizations of $\widehat{A}_{max}$. So, a decrease in g_θ shifts more probability mass closer to the 45-degree line, and more mass in the northeast quadrant. Thus, the the growth composition change creates larger establishments and more of them are *growth* rather than *value* firms. The increased importance of growth firms seems intuitively consistent with the notion of the IT revolution.

Establishments accumulate more organizational capital and are longer-lived in the new steady state. Because more establishments grow larger, the managers' outside option constraint binds more frequently. This increases the sensitivity of pay to performance. In addition, the arrival of more large establishments increases the back-loading of the owner's payouts. This raises the owner's average payouts in the cross-section as a fraction of output. Managerial compensation, in contrast, is more front-loaded.

We study the transition between a low and a high general-purpose innovation growth path. At $t = 0$, agents know the entire future path for $\{g_{t,\theta}\}_{t=0}^{T}$, although the arrival of the General Purpose Technology (GPT) itself at $t = 0$ is not anticipated at $t = \ldots, -2, -1$. Appendix C defines the constant cost-of-capital transition. It also explains the reverse shooting algorithm we use to solve for prices and quantities along the transition path. This is a non-trivial problem because we need to keep track of how the cross-sectional distribution of (A, ν) evolves over time. We then simulate the economy forward for a cross-section of 5,000 establishments, starting in the initial steady state. We assume the change in the relative importance of growth rates is accomplished in 20 years. However, the economy continues to adjust substantially afterwards on its way to the final steady state.

[10] First, there is little evidence that the last 35 years have seen higher average Gross Domestic Product (GDP) growth g than the 35-year period that preceded it. Second, changing GDP growth along the transition path is computationally challenging.

4.1. Target moments in the data

Several of the model's parameters were chosen to match moments of the data we describe below. This is true for the decline in job reallocation, the increase in wage dispersion, and the initial exit rate.

Increased dispersion in compensation. We provide three sources of data, all of which document a large increase in wage inequality. The first and broadest measure studies wages of all workers. The data are from the Quarterly Census of Employment and Wages (QCEW) collected by the Bureau of Labor Statistics (BLS). The unit of observation is an establishment, and the data report the average wage. We calculate the within-industry wage dispersion from a panel of 55 two-digit Standard Industrial Classification (SIC)-code industries, and average across industries. Panel A of Table 1 shows that the cross-sectional standard deviation of log wages increased by 7.3%, the interquartile range (IQR) by 5.4%, and the interdecile range(IDR) by 14.7% between 1975–1979 and 2000–2004.[11]

The second body of evidence comes from managerial wages. While our model has implications for overall wage inequality, managerial data arguably provide a cleaner match. We use wage income data from the March Current Population Survey and select only workers in managerial occupations (see Appendix A.4). Panel B of Table 1 shows that in this sample, the cross-sectional standard deviation of log wages increased by 9.4%, the IQR by 11.3%, and the IDR by 19.6% between 1975-1979 and 2000-2004. Hence the increase in managerial compensation is more pronounced than for the population at large.

The third and most narrow metric focusses on the top of the compensation scale. Measuring total compensation (salaries, bonuses, long-term bonus payments, and the Black-Scholes value of stock option grants) for the three highest-paid officers in the largest 50 firms, Frydman and Saks (2006) show a strong increase in executive compensation. Panel C of Table 1 uses the same data to show an equally spectacular increase in the *dispersion* of top managers' compensation.[12] Since the mid-1970s, the cross-sectional standard deviation of log compensation increased by 43 log points, the IQR and IDR more than doubled to 1.5 and 2.6, respectively. The inequality and the increase in inequality are strongest for this group of executives.

[Table 1 about here.]

Declining excess job reallocation. The excess job reallocation rate is a direct measure of the cross-sectional dispersion of establishment growth rates. It is defined as the sum of the job creation rate plus the job destruction rate less the net employment growth rate. Before 1990, we only have establishment-level reallocation data for the manufacturing sector. Fig. 5 shows that the excess reallocation rate in manufacturing declined from 11.9% in 1965-1969 to 8.4% in 2000–2005, and further to 7.8% between 2006 and 2007. After 1990, the BLS provides establishment-level data for all sectors of the economy. Over the 1990–2007 sample, the excess reallocation rate declined from 10.6% to 7.2% in manufacturing, from 15% to 12.4% in services, and from 15.6% to 12.3% in the entire private sector. Half of this decline is due to a decline in

[11] According to Dunne et al. (2004), increasing within-industry, between-establishment wage dispersion accounts for a large fraction of the increase in overall income inequality in the US. This is true especially for non-production workers, which includes managers. They study US manufacturing establishments. Between 1977 and 1988, the between-plant coefficient of variation for non-production workers' wages increased from 44% to 56%, while the within-plant dispersion actually decreased. They also show a similar increase in the dispersion of productivity between plants.

[12] We thank Carola Frydman for graciously making these data available to us.

entry and exit rates for establishments, from 4% to 2.5%. The other half is due to a decline in expansions and contractions of existing establishments.

[Fig. 5 about here.]

Similar trends have been shown in *firm-level* (rather than establishment-level) data. Davis et al. (2006) find large declines in the dispersion and the volatility of firm growth rates for the US economy, either measured based on employment or sales growth. The employment-weighted dispersion of firm growth rates declined from .70% in 1978 to .55% in 2001, while the employment-weighted volatility of firm growth rates declined from .22% in 1980 to .12% in 2001. The former measures the cross-sectional standard deviation of firm growth rates, while the latter measures the standard deviation of firm growth rates over time.[13] This decline in volatility is present across sectors.

Finally, Haltiwanger and Schuh (1999) construct a proxy for establishment-level reallocation by studying *intra-industry* job flows. This is the only economy-wide series that is continually available for our sample period. The excess reallocation rate for the non-financial sector declines from 19% in 1960 to an average of 11.5% in 2000. This 19–11.5% change is what we calibrate to in our benchmark model.

Valuation. The increase in the payouts to securities holders over the last 30 years coincided with a doubling of Tobin's average q and the value-output ratio. Tobin's q is measured as the market value of US non-financial corporations, constructed from the Flow of Funds (FOF) data divided by the replacement cost of physical capital:

$$q_t = 1 + \frac{V_t^a}{K_t}.$$

We construct the replacement cost of physical capital using the perpetual inventory method with FOF investment and inventory data (see Appendix A.1). The first column in Table 2 shows that Tobin's q decreased from 2.0 in the 1965–1969 period to 1.0 in the 1975–1979 period. After that, it gradually increases to 2.6 in the 1995–1999 period and then it levels off to 2.3 and 2.0. The value-output ratio for the US corporate sector, reported in column 2, is computed as the ratio of V_t^a to gross value-added Y_t. It tracks the evolution of Tobin's q almost perfectly.

The value of US corporations per unit of physical capital has more than doubled since the late seventies. The increase in valuations seems to be linked to the accumulation of organizational capital rather than physical capital. Note that the secular increase in Tobin's q cannot be explained solely by a decrease in taxes. Indeed, in a model without organizational capital and no adjustment costs, Tobin's q is always one. In a world with reasonable adjustment costs, a decrease in taxes could increase Tobin's q above one, but only temporarily. Finally, the large deviations of Tobin's q from one occur in the second half of the sample when the average tax rate is slightly *increasing*.

[Table 2 about here.]

[13] Comin and Philippon (2005) show that there is an increase in volatility for the subsample of publicly traded firms. Our analysis is for the entire non-financial sector, publicly traded and privately held. The discrepancy between the findings for public and for all firms may have to do with private firms that go public earlier. The Initial Public Offering (IPO) decision is outside of our model.

4.2. Benchmark Parameter Choices

In order to assess its quantitative implications, we calibrate the model at annual frequency. Table 3 summarizes the parameters.

Production technology and preferences. The parameter ν governs the decreasing returns to scale at the establishment level. It is set to 0.75, at the low end of the range considered by Atkeson and Kehoe (2005). The other technology and preferences parameters are chosen to match the depreciation, the average capital-to-output ratio, and the average cost of capital for the US non-financial sector over the period 1950–2005. The depreciation rate δ is calibrated to 0.06 based on National Income and Products Accounts (NIPA) data. Next, we calibrate the Cobb-Douglas productivity exponent on capital, α. Because there is no aggregate risk, the rate of return on physical capital is deterministic in the model. In equilibrium, that rate equals the discount rate. Both are fixed along the transition path. From the Euler equation for physical capital, we get:

$$r = \left(1 - \delta + \alpha\nu\frac{Y}{K}\right).$$

We compute the cost of capital r in the data as the weighted-average realized return on equity and corporate bonds; it is 5.5%. The weights are given by the observed leverage ratio.[14] The average capital-to-output ratio is 1.77. The above equation then implies $\alpha\nu = 0.23$. As a result, $\alpha = 0.30$.

We choose the rate of time preference of the owner $\rho_o = 0.02$ such that his subjective time discount factor is $\exp(-\rho_o) = 0.98$. In our benchmark results, we assume that the manager is less patient: $\rho_m = 0.03$. Finally, we choose a coefficient of relative risk aversion $\gamma = 1.6$. This is the value that solves Eq. (2.8) given our choices for r, ρ_o, and given the average growth rate of real aggregate output of $g = 0.022$.

[Table 3 about here.]

Organizational capital accumulation and portability. To calibrate the organizational capital accumulation, its portability, and the sunk costs of forming a new match, we match the excess job reallocation rate and the firm exit rate in the initial steady state to those observed in the data in 1970–1974, and we match the increase in managerial wage inequality to that in the data.

Following Atkeson and Kehoe (2005), we assume the ε shocks are log-normal with mean m_s and standard deviation σ_s. We abstract from the dependence on these parameters on the vintage s. For parsimony, the mean m_s is set zero. However, younger matches (lower s) will grow faster in equilibrium because of selection, even without age-dependence in m_s. The standard deviation $\sigma_s = \sigma$ of these shocks is chosen to generate an excess job reallocation rate of 19% in the initial steady state. This choice matches the 1970–1974 reallocation rate in the data. The size of the sunk cost (S) is chosen to match the entry-exit rates in the initial steady state. The sunk cost is equal to 6.5 times the annual cash flow generated by the average firm. This delivers an entry/exit rate of 4.3% in the initial steady state, again matching the 1970–1974 data. The portability or match-specificity parameter ϕ governs the increase in wage dispersion in the model. We set it equal to 0.5, which means that 50% of organizational capital is transferable to a next match. This value of the parameter enables the model to match the increase in intra-industry wage inequality.

[14] Since the model has no taxes, but there are taxes in the data, we take into account the corporate tax rate (28%) in the calculation of the cost of capital. Appendix D provides more details on the cost of capital calibration.

Productivity growth composition In the baseline experiment, we assume the change in the composition of growth to $g_{new,z}$ occurs over 20 years, and we assume it starts in 1971. After 20 years, in 1990, productivity growth settles down at $(g_{new,z}, g_{new,\theta})$. The actual transition to a new steady-state growth path takes much longer. The change in the composition of growth is calibrated to match the decline in reallocation rates in the data from 19% to 11%. General productivity growth increases from $g_{old,z} = 0.3\%$ in the initial steady state to $g_{new,z} = 1.45\%$ in the new steady-state. Correspondingly, vintage-specific productivity growth decreases from $g_{old,\theta} = 5.5\%$ to $g_{new,\theta} = 0.8\%$.

4.3. Main results: Compensation and size Distribution

We start by comparing the size and compensation distribution in the initial and final steady states, as well as its evolution during the transition.

Fig.6 illustrates how a relatively modest change in the size distribution of firms, brought about by a change in the composition of productivity growth, translates into a much larger change in the distribution of compensation. The left panel plots the log compensation of managers ($\log \tilde{c}$) against the log of establishment size ($\log \widehat{A}$) in the initial steady-state growth path of the model. The right panel shows the same plot for the final steady state growth path. Each dot represents one establishment in the cross-section. The key to the amplification is the compensation contract. The optimal contract features a lower bound on size below which the manager's compensation does not respond to changes in size. Above a certain size, the manager's compensation only responds to good news about the establishment's productivity. In the initial steady state, few establishments become large enough to exceed the insensitivity range. Managerial compensation hardly responds to changes in size; there is little cross-sectional variation in compensation. The right panel shows that this is no longer true in the new steady-state. Establishments live longer on average and the successful ones grow larger. The log size distribution is more skewed than in the initial steady state. The figure shows a strong positive cross-sectional relationship between size and managerial compensation. Thus, the model endogenously generates a shift from low-powered to high-powered incentive compensation contracts.

[Fig. 6 about here.]

On the new steady-state growth path, the distribution of managerial compensation has much fatter tails than the size distribution, as shown in Fig. 7. Its left panel shows the histogram of log compensation in the new steady state; the right panel is the histogram of log size. Both were demeaned. The distribution of managerial compensation is more skewed and it has fatter tails than the size distribution. The kurtosis of log compensation is 19.82, compared to 3.38 for log size. The skewness is 3.81 for log compensation, compared to 0.47 for log size.

[Fig. 7 about here.]

There is a large finance literature that studies compensation for top managers (see Frydman and Saks, 2006; Kaplan and Rauh, 2007). Gabaix and Landier (2008) and other studies have shown that managerial compensation is well-described by a power function of size, a finding referred to as *Roberts' law*. In our model too, the compensation distribution has much fatter tails than a log-normal. On average, the relation between compensation and size in the new steady state satisfies $\log \widetilde{c} = \alpha + \kappa \log \widehat{A}$. The slope coefficient κ is 0.24 in the new steady-state, close to the value of 1/3 found in the empirical literature. Our model, therefore, not only provides a rationale for the large and skewed increase in managerial compensation, but is also quantitatively consistent with the observed size-compensation distribution.

The model has implications for the size distribution of firms. Luttmer (2007) and others show that the size distribution for *large* firms follows a Pareto distribution. The same is true for the large firms in our new steady state. Fig.8 shows that the relation between log rank and log size is linear for large establishments. Quantitatively, the model's Pareto coefficient is 1.5 whereas the tails in the data are slightly thicker with a Pareto coefficient of 1.0[15] For small firms, the relationship is less steep, a finding reminiscent of the city-size literature.

[Fig. 8 about here.]

Table 4 reports the impact of the change in the composition of growth on the distribution of compensation and productivity. The log of establishment productivity (TFP) is given by $(1-\nu)\log\widehat{A}$. The log of the manager's wage is given by $\log\widetilde{c}$. The left panel reports the cross-sectional standard deviation, the interquartile range (IQR or 75-th minus 25-th percentiles), and the interdecile range (IDR or 90-th minus 10-th percentiles) for log wages; the right panel does the same for log TFP. The first (last) line shows the values in the initial (final) steady state. The numbers in between are five-year averages computed along the transition path. Small changes in the productivity (or size) distribution cause big changes in the distribution of compensation. The standard deviation of managerial compensation increases by 7.3% in the first 35 years of the transition, similar to what we report later for the increase in within-industry wage dispersion in the data.[16] In the next ten years from 2006–2015, the standard deviation of log wage dispersion is predicted to increase by another 4.5% and the IDR by as much as 11.5%.[17] In sum, the shift towards high-powered incentives leads to a substantial increase in income inequality.

To summarize, in the benchmark version of the calibrated model, the standard deviation of log managerial compensation increases by 11 log points, the IQR by 8 log points, and the IDR by 9 log points over the same period. The IDR increases another 11 log points in the following five years. This compares favorably to the data for workers and managers in Panel A and B in Table 1. Finally, the model produces and increase of 50 log points in the IDR for the largest 500 establishments, 58 log point for the largest 50 establishments (see Table 5). Of course, this number still falls short of the 130 log points increase for top management in the largest 50 firms. In the high portability case, the increase in the IDR is 80 log points. This massive increase in compensation inequality is generated by a modest increase in productivity dispersion. As the right columns show, the standard deviation of productivity increases by only 1.5 percentage points in the first 35 years of the transition. The IQR for increases from 18.3 to 18.4% and the IDR from 29.2% to 31.8% over the same period. Overall, productivity dispersion in our model is somewhat smaller than what is found in the data. Using 1977 US manufacturing data at the 4-digit industry level, Syverson (2004) reports a within-industry IQR of log TFP between 29 and 44%. Increasing log TFP dispersion in the model would give rise to too much reallocation, absent other frictions.

[Table 4 about here.]

[15] We follow Gabaix and Ibragimov (2007) who estimate the Pareto coefficient *b* from a regression of the form log(Rank-1/2)=a-b log(Size).

[16] In the model, unskilled wages are equalized across establishments and do not affect the dispersion.

[17] In the new steady-state, compensation becomes very skewed: the IDR increases so much that the IQR actually decreases.

Table 5 reports the sensitivity of managerial compensation to size for the 500 largest and 50 largest establishments in the model's simulated panel. The top panel looks at the benchmark calibration. We measure the sensitivity of managerial compensation to size by running a separate cross-sectional regression of $\Delta \log c^i$ on $\Delta \log A^i$ in each time period. The slope of that regression is referred to as the pay-performance elasticity. Columns 1 and 5 report the slope coefficients (multiplied by 100) for the 500 and 50 largest firms, respectively. Columns 2 to 4 and 6 to 8 report the dispersion of log compensation for these two samples. For the 500 largest firms, the pay-performance elasticity increases from zero to 5.86. That is, every percent increase in size translates into 0.056 percent increase in compensation. However, for the 50 largest establishments, the elasticity increases from 3.4 to 46. The model makes predictions only about the compensation of the entire management team. In the data, most studies focus exclusively on CEO's. Murphy (1999) finds that the cash compensation elasticity for CEOs of Standard&Poor 500 companies increases from 8.0 in 1972 to 40 in 1996.[18] Our model fails to match this increase in the CEO compensation elasticity, except when we look at the largest establishments.

[Table 5 about here.]

4.4. Labor reallocation, exit, and firm valuation

The right panel of Table 4 summarizes the other main aggregates of interest. The first column shows the excess job reallocation rate. We calibrate the shift in the composition of productivity so as to match the initial steady-state value of 19% as well as the subsequent decline to 12.2% over the ensuing 35 years. The model successfully matches the decline in entry/exit rate (on a steady-state growth path, those are identical). The exit rate starts from 4.3% (chosen to match the sunk costs) and declines to 3.0% by 2001–05. In the data, it declined from 4% to 2.5%. The exit rate is highest in the first ten years of the transition because there is a shake-out of establishments that are no longer profitable under the increased managerial compensation.

The last three columns of Table 4 report valuation ratios. As establishments start to live longer and accumulate more organizational capital, the aggregate value of organizational capital starts to increase. This is the same selection effect: We are only sampling the survivors when computing the market value of matches. Correspondingly, Tobin's q increases from 1.4 in 1971–75 to 1.6 in 2001–05 (column 9). The value of organizational capital as a fraction of value-added $V_t/(Y_t - S_t^a)$ increases from 0.83 to 1.18, a 42% increase (column 10). The increase in the data from 1.54 to 2.41 represents a 45% increase (see Section 4.1).

Managerial workers capture only part of this increase in organizational rents because of the sunk costs and limited portability of organizational capital. The sunk costs create an insensitivity range in which managerial compensation does not respond to productivity shocks. In addition, the discount rate wedge imputes a downward drift to the managerial compensation. As matches live longer, managers end up with a smaller share of the surplus. Managerial wealth declines from 8.3% of value-added to 7.2% (column 7, $M/(Y - S^a)$). The model thus implies a large transfer of wealth from the managers to the owners. However, there is an enormous amount of heterogeneity in the evolution of managerial wealth to value-added ($M/(Y - S^a)$), echoing the increase in managerial compensation dispersion shown earlier. We sort all managers by their final steady-state $M/(Y - S^a)$ ratio. Managers in the 95-th percentile saw a large *increase*, managers

[18] These elasticities are based on annual regressions of $\Delta \log$(*Cash Compensation*) on log(*1+Shareholder Return*). Cash compensation includes salaries, bonuses, and small amounts of other cash compensation. Data prior to 1992 are from Forbes Annual Compensation Surveys; data for 1992 and later are from the Compustat ExecuComp database.

in the 90-th percentile maintained the status quo, while all other managers (especially those in the smaller establishments) suffered a decline in wealth. Managers in the 5-th see their wealth decline from 8.0 to 6.5 times (per capita) value-added.

4.5. Robustness

The degree of portability ϕ governs several key aspects of the model. We studied both a higher value ($\phi = 0.75$) and a lower value ($\phi = 0$) than our benchmark case ($\phi = 0.50$). These results are reported in Table 6 and Table 7. More portability amplifies the dispersion effect of the shift in productivity growth composition, but lowers the increase in the valuation ratios.

The left panel of Table 6 shows the compensation and productivity distribution along the transition for the case in which all of the organizational capital is match-specific ($\phi = 0$). As we expected, the model no longer generates any increase in managerial compensation inequality. Indeed, the managers are fully insured and the owners capture a larger share of the organizational rents. The same results obtain in the case in which managers can fully commit to staying in the match.

This all translates into larger increases in the owners' wealth relative to value-added and in Tobin's q ratio. These results are reported in the left panel of Table 7. Tobin's q goes up from 1.38 to 1.84, a substantially larger increase than in the benchmark case. In sum, the predictions for valuation ratios improve, but the predictions for wage dispersion are counterfactual.

In contrast, increasing ϕ to a value of 0.75 gives managers more ownership rights to organizational capital. The right panel of Table 6 shows the compensation and productivity distribution. As a result, not only is initial income dispersion higher (the standard deviation of log wages is 9.6% instead of 0.9% in the initial steady-state), the increase in dispersion is also higher. The standard deviation increases by 15%, the IQR by 8.0% and the IDR by 42% from the initial situation to 2001–05. These increases are much larger than in the benchmark case and fit the increase in *managerial* income inequality in the data better. Some other desirable features of the $\phi = 0.75$ calibration are that (i) Robert's coefficient, which measures the elasticity of managerial compensation to firm size, is 0.32, now matching the data exactly, and (ii) the Pareto coefficient of the firm size distribution is 1.05, also matching the empirical estimates, around 1.0. However, the increase in valuation ratios is only half as big as in the benchmark case.

[Table 6 about here.]

[Table 7 about here.]

5. Additional evidence from the cross-section

This section explores the cross-sectional relationship between managerial compensation dispersion on the one hand and firm valuation on the the other hand, first in the model and then in the data. The empirical evidence for the cross-sectional link between wage dispersion and firm valuation in the data, and the model's ability to generate a similar link, lend further credibility to the organizational capital accumulation mechanism we have put forward. While there are many other potential explanations for cross-sectional differences in firm value, such as external and internal governance, Research&Development, investment opportunities, etc., it is nevertheless important to document that the cross-sectional correlations implied by the model hold up in the data.

Our analysis so far focused on the time-series relationship between the composition of productivity growth, the reallocation rate, and Tobin's q. In the model, these same relationships hold in the cross-section. We use the calibrated model to illustrate this mechanism. We compute 13 different steady-state growth paths for 13 different economies, we label "industries." All parameters are constant across economies except for the vintage-specific growth rate g_θ, which we vary in equally-spaced increments from a low value of 0.00% to a high value of 6.82%. Fig. 9 plots the Tobin's q ratio for each industry against its dispersion of managerial compensation. Reading from the left to the right, as the vintage-specific growth rate declines, the average Tobin's q increases and so does the dispersion in managerial wage dispersion. Recalling Fig.2, a larger mass of firms stays closer to the 45-degree line in such low vintage-specific growth industries.

The sensitivity of the valuations to changes in the reallocation rate is much higher for industries with a low g_θ area. Moving from the point labeled "1" to point "2" on Fig.9, Tobin's q decreases by 50 basis points in response to a 100 log points decrease in the dispersion of compensation. In the data discussed below, estimates of the corresponding decrease in Tobin's q vary between 111 and 70 basis points if we use a broad measure of wage dispersion and between 50 and 80 basis points if we focus only on executive compensation dispersion. The same size increase in g_θ has smaller effects on q and wage dispersion when g_θ is higher.

[Fig. 9 about here.]

In the data, we identify high vintage-specific growth (g_θ) industries, who experience faster depreciation of organizational capital, as those with lower cross-sectional dispersion in managerial compensation. The key question then becomes whether industries characterized by higher dispersion also have lower valuation ratios. We build a panel of 55 industries at the two-digit SIC level covering the 1976–2005 sample. As before, we exclude the financial sector to end up with 47 industries; see Appendices A.2 and A.3 for details. We examine the cross-sectional relationship between compensation dispersion and the average Tobin's q in this panel of 47 industries. We use two different measures for the average Tobin's q. The first measure (Tobin's $q1$) uses total assets less financial assets at book value in the denominator. The second measure (Tobin's $q2$) uses the book value of total assets in the denominator. The numerator in both ratios is the market value of the firm. Appendix A.2 provides more details.

Our first estimation uses the cross-sectional standard deviation of log wages among the establishments within an industry from QWEC. We include fixed effects for time and industry in these regressions. The results are reported in Table 8. Our second estimation uses individual-level wage data for executives from Execucomp to form the wage dispersion in an industry. These results are reported in Table 9. For ease of comparison, we focus on the common sample 1992–2005. The establishment-level data are available at quarterly frequency, while the executive data analysis is at annual frequency. In the latter case, we average Tobin's q across the quarters in a year.

Columns 1 and 3 of Table 8 show that there is a significantly positive covariation between wage dispersion and Tobin's $q1$ and q2 using the establishment-level data. The point estimates imply that a one standard-deviation increase in the wage dispersion of a region (within-region variation) increases Tobin's $q1$ by 0.063 and Tobin's $q2$ by 0.046. A region with a one standard deviation higher wage dispersion (across-region variation), has a Tobin's $q1$ ($q2$) that is 0.417 (0.303) higher. In specifications 2 and 4, we control for intangibles and continue to find strong positive correlation between the wage dispersion in an industry and its q ratio. While the interaction effect is negative, the overall effect of wage dispersion is positive (last row). We find similarly strong effects if we use the interquartile range of log wages instead of the standard deviation (not reported).

[Table 8 about here.]

Table 9 repeats the same analysis using a measure of wage dispersion for executives (See appendix A.5). Wage dispersion is the cross-sectional standard deviation of the log wage among executives within an industry. Executive wage dispersion in an industry is significantly positively related to both measures of Tobin's q (columns 1 and 3). A one standard deviation increase in the within-industry wage dispersion (0.161) translates into a 0.123 increase in Tobin's $q1$ and a 0.076 increase in Tobin's $q2$. The marginal effect of wage dispersion on Tobin's q slightly increases after controlling for the intangibles ratio of the industry (columns 2 and 4). In this specification, the effect of executive wage dispersion on Tobin's q is stronger in industries with a higher intangibles ratio. For example, in column 2, the industry with the average intangible ratio shows a sensitivity to a (within) one standard deviation increase in WDISP of 0.133, whereas that sensitivity increases to 0.143 for an industry with an intangible ratio that is one standard deviation above the average. The results are very similar when using the value of options exercised instead of options granted in the wage definition (not reported). The results using the interquartile range of log wages are also similar (not reported), suggesting a robust correlation between managerial wage dispersion and Tobin's q.

[Table 9 about here.]

To sum up, we find that firms in high wage dispersion, low reallocation industries tend to have higher Tobin's q, as predicted by the model. In these industries, successful firms accumulate more organizational capital.

6. Conclusion

In the last three decades, there has been a marked increase in managerial compensation inequality and in the sensitivity of compensation to performance. This paper argues that both changes can be tied to a compositional change in the nature of productivity growth and the increases in organizational capital that resulted from it. In our model, establishments combine organizational capital, physical capital, and unskilled labor to produce output. The division of organizational rents between the owner and the manager of the establishment is governed by a long-term compensation contract. The well-diversified owner offers insurance to the risk-averse manager, but this insurance is limited by the manager's ability to leave and by the owner's limited liability. Because the manager can transfer a fraction of the organizational capital to a future employer, the increased accumulation of organizational capital improves the outside options of managers in successful firms, and the manager's compensation increases in response to positive performance. In small, unsuccessful firms, compensation is insensitive to performance. The change in the composition of productivity growth allows successful establishments to accumulate more organization capital and grow larger. Together they account for the increase in compensation inequality. In addition, the model generates an increase in firm valuation relative to the physical capital or to output, which reflects the higher value of organizational capital. It is also broadly consistent with trends in labor reallocation, the firm size distribution, and firm exit and entry.

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Table 1
Increasing wage dispersion
All three panels plot the cross-sectional standard deviation, interquartile range, and interdecile range of log wages. Statistics are averaged over 5-year periods. In Panel A, we measure intra-industry, between-establishment wage inequality. The data are from the Quarterly Census of Employment and Wages (QCEW) collected by the Bureau of Labor Statistics (BLS). The unit of observation is an establishment, for which we know the average wage. We calculate the within-industry wage dispersion from a panel of 55 two-digit SIC-code industries, and average across industries. In Panel B, we use individual-level data from the Current Population Survey, March issue. We select only the managerial occupations. Finally, Panel C uses data from Frydman and Saks (2006) for the three highest-paid officers in the largest 50 firms in 1960 and 1990.

	Std	*IQR*	*IDR*
		Panel A: All workers	
1975–1979	21.4	29.1	53.2
1980–1984	22.9	29.3	57.2
1985–1989	24.2	30.8	58.5
1990–1994	25.1	31.6	61.1
1995–1999	26.9	32.8	65.7
2000–2004	28.7	34.5	67.9
		Panel B: All managers	
1975–1979	59.4	72.9	140.8
1980–1984	61.3	79.8	147.5
1985–1989	62.9	82.5	152.7
1990–1994	64.8	83.8	156.6
1995–1999	67.2	83.3	157.7
2000–2004	68.8	84.2	160.4
		Panel C: Top-3 managers	
1975–1979	55.7	74.1	135.1
1980–1984	58.3	74.0	146.7
1985–1989	69.7	90.2	172.6
1990–1994	76.9	100.0	186.8
1995–1999	92.6	124.0	231.7
2000–2004	99.4	149.5	260.9

Table 2
Valuation ratios for U.S. corporate sector
Tobin's q is the ratio of the market value of US corporations V^a divided by the replacement cost of the physical capital stock K. The value-output ratio $(V/(Y - S^a))$ is the market value of US corporations V^a divided by value-added $Y - S^a$ of the non-financial corporate sector.

	(1)	(2)
	Tobin's q	$V/(Y - S^a)$
1965–1969	1.96	1.80
1970–1974	1.49	1.54
1975–1979	0.97	1.13
1980–1984	0.94	1.16
1985–1989	1.33	1.49
1990–1994	1.70	1.82
1995–1999	2.58	2.53
2000–2004	2.33	2.41
2005–2008.I	2.04	2.19

Table 3
Benchmark Calibration
This table lists our benchmark parameter choices. Section 4.2 justifies these choices and Appendix D provides more details on the data we used. NIPA stands for National Income and Products Accounts, CRSP for Center for Research in Securities Prices, DJCBI for Dow Jones Corporate Bond Index, QCEW stands for Quarterly Census of Employment and Wages, and BLS for Bureau of Labor Statistics. The abbreviation "exc. reall. rate" stands for excess reallocation rate in the initial steady state.

Parameter	*Value*	*Source*
ν	0.75	*Atkeson and Kehoe (2005)*
δ	0.06	*NIPA*
α	0.30	$K/Y = 1.77$
r	0.055	*FOF, CRSP, DJCBI*
ρ_o	0.02	
ρ_m	0.03	
γ	1.6	*eq.* (2.8)
g	0.022	*NIPA*
m_s	0.00	
σ_s	19% exc. reall. rate	*Job Reallocation - QCEW BLS*
S	4.3% exit rate	*Entry and Exit*
ϕ	0.5	*Wage Inequality - QCEW BLS*

Table 4
Main results-benchmark calibration
The panel on the left reports the cross-sectional standard deviation (Std), interquartile range (IQR), and the interdecile range (IDR) for log compensation $\log \widetilde{c}$ and log productivity $(1-\nu)\log \widehat{A}$ in percentage points. The panel on the right reports the excess job reallocation rate (EREALL), the entry/exit rate (EXIT), Tobin's q, the ratio of aggregate firm value to output ($V/(Y-S^a)$), and the ratio of managerial wealth to output ($M/(Y-S^a)$). The economy transitions from high vintage-specific growth $g_{\theta,0}$ before 1971 to low vintage-specific growth $g_{\theta,T}$ after 1971. The transition takes place over $T = 20$ years. The results are for the benchmark parameters.

	Log compensation			**Log productivity**			**Aggregates**				
	Std	*IQR*	*IDR*	*Std*	*IQR*	*IDR*	*EREALL*	*EXIT*	*Tobin's q*	$\frac{V}{(Y-S^a)}$	$\frac{M}{(Y-S^a)}$
before	0.94	0.01	0.08	10.69	18.27	29.16	18.96	4.33	1.40	0.83	8.27
1971–1975	1.48	0.01	0.09	10.80	18.32	28.99	17.83	7.74	1.40	0.83	8.04
1976–1980	1.24	0.01	0.08	11.00	18.25	29.13	16.62	6.65	1.43	0.89	7.88
1981–1985	1.75	0.01	0.10	11.09	18.42	29.38	15.30	5.62	1.46	0.93	7.72
1986–1990	2.31	0.02	0.11	11.26	18.32	29.80	13.52	4.08	1.50	1.00	7.51
1991–1995	4.34	0.03	0.13	11.67	18.43	30.76	12.87	3.56	1.54	1.07	7.37
1996–2000	6.41	0.09	11.77	11.79	18.05	30.84	12.70	3.53	1.56	1.12	7.29
2001–2005	8.22	0.13	9.73	12.22	18.36	31.78	12.26	3.05	1.59	1.18	7.22
2006–2010	11.03	8.63	8.94	12.58	18.53	32.58	12.02	2.94	1.62	1.23	7.17
2011–2015	12.78	8.82	21.47	12.57	18.50	32.52	11.90	2.84	1.62	1.22	7.11
after	26.98	0.09	35.07	15.36	21.14	38.98	11.35	1.20	1.64	1.26	6.47

Table 5
Compensation sensitivity in large firms-benchmark calibration
This table reports the sensitivity of compensation to size, the cross-sectional standard deviation (Std), interquartile range (IQR), and the interdecile range (IDR) for log compensation $\log \widetilde{c}$ for the 500 and 50 largest establishments. The economy transitions from high vintage-specific growth $g_{\theta,0}$ before 1971 to low vintage-specific growth $g_{\theta,T}$ after 1971. The transition takes place over $T = 20$ years. The table reports the ratio of market value of the establishment to the aggregate capital stock, at different percentiles of the cross-sectional market value distribution. The results are for the benchmark parameters.

	Top 500				**Top 50**			
	$\Delta c/\Delta A$	*Std*	*IQR*	*IDR*	$\Delta c/\Delta A$	*Std*	*IQR*	*IDR*
1971–1975	−1.68	3.76	0.20	3.51	3.35	8.99	0.39	0.86
1976–1980	0.14	3.55	0.27	0.53	1.08	10.83	0.57	4.79
1981–1985	0.48	4.86	0.41	0.61	6.59	13.71	1.95	27.05
1986–1990	1.03	6.98	0.43	0.65	15.87	16.80	12.83	36.25
1991–1995	1.76	10.36	0.49	3.77	18.86	22.19	28.02	52.99
1996–2000	3.72	13.90	0.49	25.14	37.58	23.88	28.30	54.81
2001–2005	6.08	19.22	2.41	39.25	53.67	25.07	31.83	54.92
2006–2010	5.86	24.12	11.18	52.04	49.89	28.03	32.85	62.17
2011–2015	8.72	29.04	20.97	66.64	46.63	31.11	37.41	86.63

Table 6
Robustness: Compensation and productivity
The panel on the left shows results for $\phi = 0$ (no portability). The panel on the right shows results for $\phi = 0.75$ (high portability). The economy transitions from high vintage-specific growth $g_{\theta,0}$ before 1971 to low vintage-specific growth $g_{\theta,T}$ after 1971. The transition takes place over $T = 20$ years. The table reports the cross-sectional standard deviation (Std), interquartile range (IQR), and the interdecile range (IDR) for log compensation $\log \widetilde{c}$ and log productivity $(1 - \nu) \log \widehat{A}$ in percentage points. The results are for the benchmark parameters.

	No portability						High portability					
	Log compensation			**Log productivity**			**Log compensation**			**Log productivity**		
	Std	*IQR*	*IDR*	*Std*	*IQR*	*IDR*	*Std*	*IQR*	*IDR*	*Std*	*IQR*	*IDR*
before	0.00	0.00	0.00	10.77	18.52	29.45	9.61	0.46	5.24	13.73	23.33	38.51
1971–1975	0.02	0.00	0.00	10.06	17.46	26.41	14.79	0.51	19.54	13.63	23.57	37.50
1976–1980	0.00	0.00	0.00	9.49	15.85	24.67	12.74	5.47	16.50	13.87	23.61	37.62
1981–1985	0.00	0.00	0.00	9.33	15.12	24.46	13.52	10.74	14.46	14.17	23.58	38.09
1986–1990	1.12	0.00	0.00	9.41	14.87	24.54	14.99	8.60	16.32	14.47	23.48	38.50
1991–1995	2.00	0.00	4.86	9.72	14.24	25.50	19.57	8.27	19.30	14.84	23.88	38.98
1996–2000	3.18	1.83	6.50	10.08	14.38	26.34	23.21	8.29	36.65	15.14	24.04	39.55
2001–2005	3.46	4.57	8.07	10.50	14.64	27.21	25.68	8.37	49.22	15.60	24.20	41.01
2006–2010	4.27	6.43	8.70	10.99	15.17	28.34	29.12	8.69	53.04	16.07	24.75	42.01
2011–2015	4.47	7.68	11.41	11.31	15.54	28.74	31.32	9.29	56.28	16.52	25.27	43.21
after	0.00	0.00	0.00	13.43	16.81	33.17	48.56	29.45	98.49	21.19	32.19	55.35

Table 7
Robustness: Aggregate variables
The panel on the left shows results for $\phi = 0$ (low portability). The panel on the right shows results for $\phi = 0.75$ (high portability). The economy transitions from high vintage-specific growth $g_{\theta,0}$ before 1971 to low vintage-specific growth $g_{\theta,T}$ after 1971. The transition takes place over $T = 20$ years. The table reports the excess job reallocation rate (EREALL), the entry/exit rate (EXIT), Tobin's q, the ratio of aggregate firm value to output ($V/(Y - S^a)$), and the ratio of managerial wealth to output ($M/(Y - S^a)$). The results are for the benchmark parameters.

	Low portability					High portability				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
	EREALL	*EXIT*	*Tobin's q*	$\frac{V}{(Y-S^a)}$	$\frac{M}{(Y-S^a)}$	*EREALL*	*EXIT*	*Tobin's q*	$\frac{V}{(Y-S^a)}$	$\frac{M}{(Y-S^a)}$
Before	18.93	4.32	1.36	0.74	6.02	17.67	3.40	1.37	0.76	4.99
1971–1975	21.78	11.68	1.38	0.82	7.61	18.03	7.14	1.35	0.72	4.48
1976–1980	18.49	9.07	1.43	0.89	7.59	14.94	4.70	1.38	0.76	4.54
1981–1985	16.26	7.06	1.49	1.01	7.51	14.37	4.33	1.40	0.80	4.61
1986–1990	14.59	5.67	1.58	1.16	7.42	12.15	2.46	1.44	0.86	4.58
1991–1995	13.20	4.29	1.66	1.32	7.24	12.27	2.52	1.45	0.88	4.59
1996–2000	12.64	3.85	1.72	1.43	7.12	11.86	2.40	1.46	0.91	4.54
2001–2005	11.92	3.03	1.77	1.52	6.97	11.32	1.74	1.47	0.92	4.49
2006–2010	12.05	3.22	1.81	1.60	6.92	11.63	2.21	1.47	0.92	4.50
2011–2015	11.87	2.98	1.84	1.66	6.84	10.75	1.36	1.48	0.93	4.46
After	11.50	1.48	2.11	2.19	5.77	11.24	0.84	1.45	0.89	4.09

Table 8

Cross-sectional results: Tobin's *q* and establishment-level wage dispersion

* significant at 10%; ** significant at 5%; *** significant at 1%. This table reports fixed-effects estimates of Tobin's *q1* and Tobin's *q2* on wage dispersion (WDISP) for the period 1992–2005. Wage dispersion is measured as the cross-sectional standard deviation of log wages across establishments within an industry. The regressions include year and industry fixed effects. The definition of these variables is detailed in Appendix A.2. Robust standard errors are shown in parentheses.

	(1)	(2)	(3)	(4)
Constant	-0.401 (0.296)	-0.341 (0.293)	0.232 (0.187)***	0.264 (0.185)***
INTAN		0.117 (0.167)		0.086 (0.105)
WDISP	1.113 (0.196)***	1.131 (0.194)***	0.789 (0.123)***	0.801 (0.122)***
*WDISP*INTAN*		-0.275 (0.129)**		-0.174 (0.064)*
Δ *Tobin q* / Δ *WDISP*		0.981 (0.199)***		0.706 (0.125)***
Number of Industries	47			
Observations	2632			

Table 9

Cross-sectional results: Tobin's *q* and executive wage dispersion

* significant at 10%; ** significant at 5%; *** significant at 1%. This table reports fixed effects estimates of Tobin's *q1* and Tobin's *q2* on wage dispersion (WDISP) for the periods 1992–2005. Wage dispersion is measured as the cross-sectional standard deviation of log wages across individual executives within an industry. Wages are the sum of the manager's salary, bonus, restricted stock grants, LTIP payouts, all other annual payments, and value of options granted ("tdc1"). The regressions include year and industry fixed effects. Further detail on the data is in Appendix A.2 and A.5. Robust standard errors are shown in parentheses.

	(1)	(2)	(3)	(4)
Constant	0.627 (0.163)***	0.750 (0.175)***	1.039 (0.101)***	1.117 (0.104)***
INTAN		-0.453 (0.103)***		-0.276 (0.066)***
WDISP	0.765 (0.174)***	0.756 (0.184)***	0.469 (0.108)***	0.459 (0.112)***
*WDISP*INTAN*		0.122 (0.061)**		0.077 (0.045)*
Δ *Tobin q* / Δ *WDISP*		0.823 (0.172)***		0.502 (0.105)***
Number of Industries	46			
Observations	644			

Fig. 1. Optimal Compensation and Size. This figure plots the running maximum of productivity on the horizontal axis, $\widehat{A}_{max,t}$ against current productivity, $\widehat{A}_t$, on the vertical axis. It considers the case in which managers and owners share the same rate of time preference $\rho_m = \rho_o$.

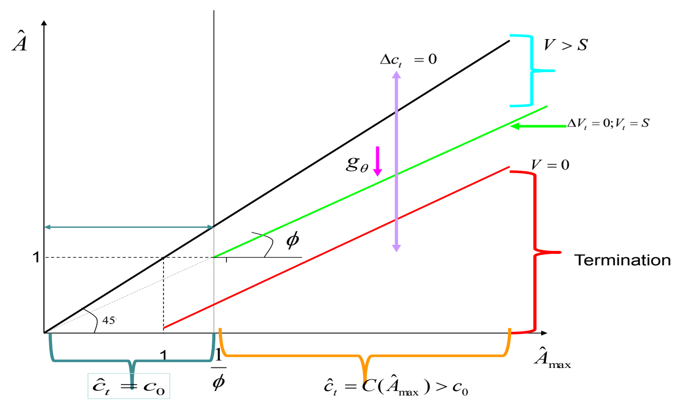


Fig. 2. Optimal Compensation Contract. The left panel plots the current productivity A_t (y-axis) against the running maximum $A_{max,t}$ (x-axis). The right panel figure plots the evolution of the optimal current consumption of the manager $\widetilde{c}$ (dashed line) alongside the evolution of the establishment's organizational capital $\widehat{A}$ (full line). The latter is a measure of size and productivity of the establishment. The two time-series are produced by simulating model for 300 periods (horizontal axis) under the benchmark calibration described below ($\phi = .5$), except that the time discount rates of owners and managers are held equal: $\rho_o = \rho_m$.

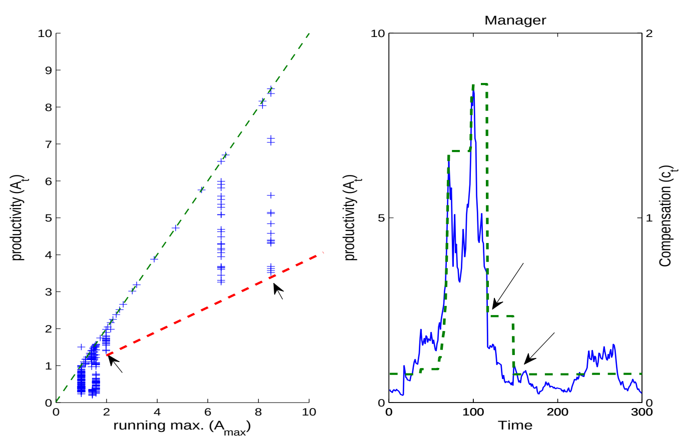


Fig. 3. Payouts to Manager and Owner. The left panel plots the evolution of the optimal current consumption of the manager $\widetilde{c}$ (dashed line, measured against the right axis) alongside the evolution of the establishment's organizational capital $\widehat{A}$ (full line, measured against the left axis). The right panel plots the payouts to the owner $\widetilde{\pi}$. The two time-series are produced by simulating the model for 300 periods (horizontal axis) under the benchmark calibration described below, except that the time discount rates of owners and managers are held equal: $\rho_o = \rho_m$.

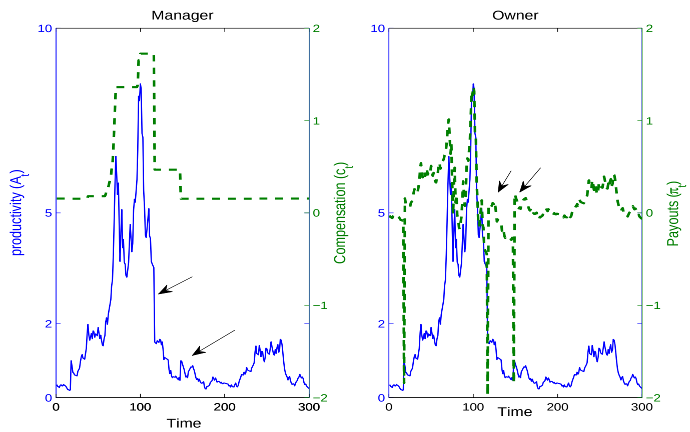


Fig. 4. Payouts to Manager and Owner: Discount Rate Wedge. The left panel plots the evolution of the optimal current consumption of the manager $\widetilde{c}$ (dashed line, measured against the right axis) alongside the evolution of the establishment's organizational capital $\log \widehat{A}$ (full line, measured against the left axis). The right panel plots the payouts to the owner $\widetilde{\pi}$. The two time-series are produced by simulating the model for 300 periods (horizontal axis) under the benchmark calibration described below, except that the time discount rates of owners and managers are held equal: $\rho_o < \rho_m$.

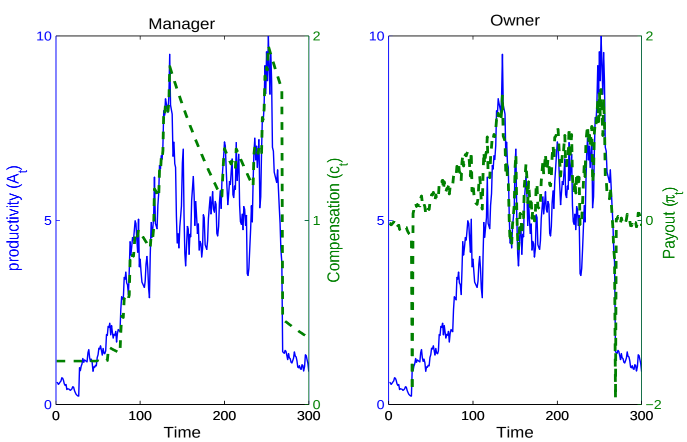


Fig. 5. Excess Reallocation Rate. The dark shaded bars show the excess reallocation rate for the manufacturing sector, constructed by Faberman (2006). The excess job reallocation rate is a direct measure of the cross-sectional dispersion of establishment growth rates. It is defined as the sum of the job creation rate plus the job destruction rate less the net employment growth rate. The Faberman data are extended to 2007.III using BLS data. The light shaded bars show the excess reallocation rate for the private sector (BLS).

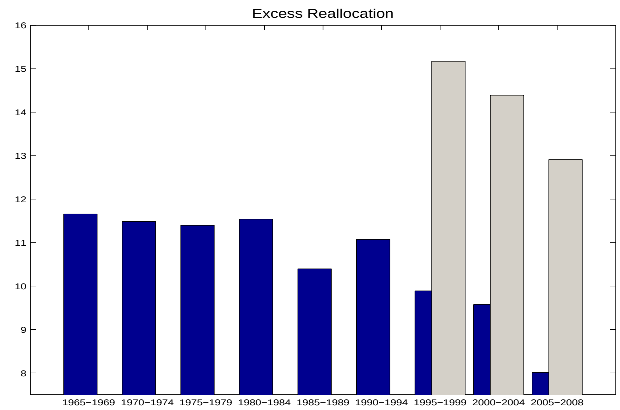


Fig. 6. From Low-Powered to High-Powered Incentives. Plot of log compensation against log size of establishment. The left panel shows the initial steady-state growth path (high vintage-specific growth). The right panel shows the new steady-state growth path (high general productivity growth). The data are generated from the model under its benchmark calibration.

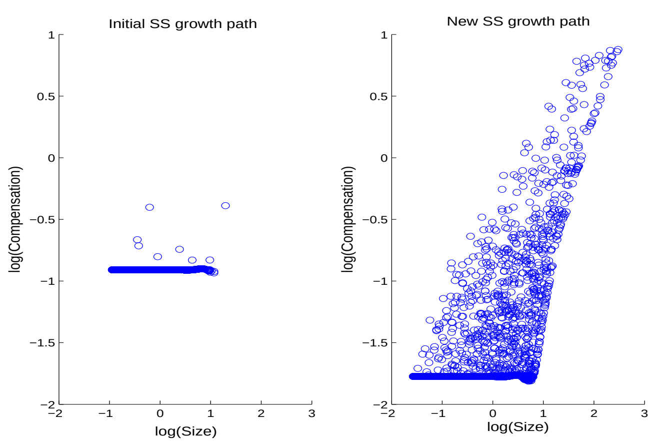


Fig. 7. Compensation and size Distribution on the new steady-state growth path. Histogram of log compensation and log size of establishments. The data are generated by simulating the model's new steady-state growth path(high general productivity growth) under its benchmark calibration.

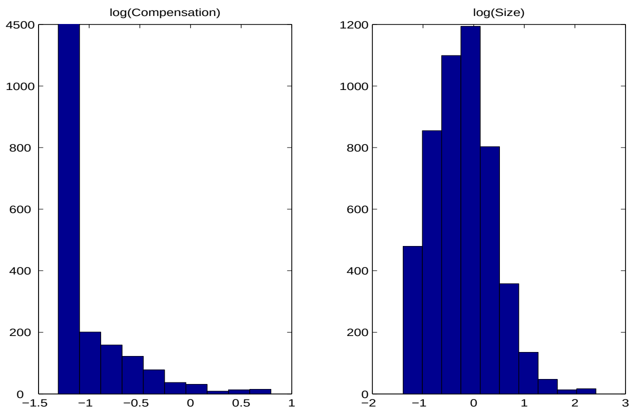


Fig. 8. Size distribution in the new steady state. The figure plots the relationship between the log size of establishments on the horizontal axis and the rank in the distribution log($Rank$ − 0.5) on the vertical axis. The figure is for the new steady-state growth path under our benchmark calibration.

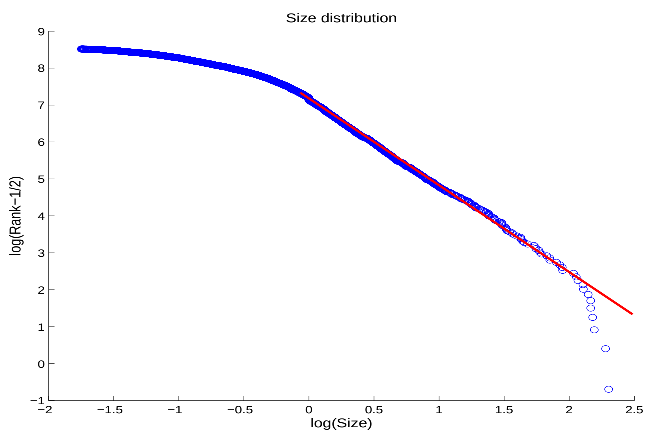
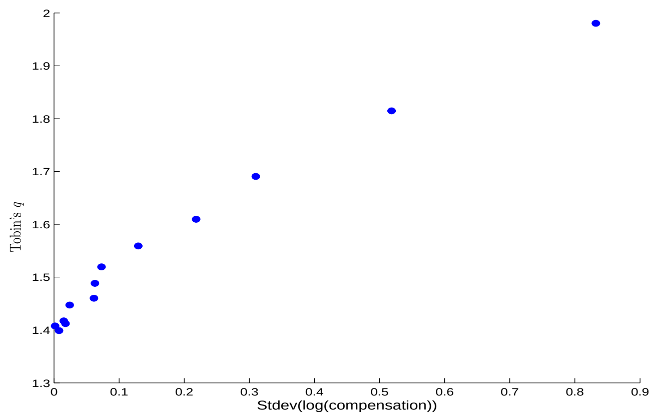


Fig. 9. Cross-section. Scatter plot of steady-state growth path Tobin's q against the standard deviation of log compensation for 13 industries with g_θ varying from low (0.00%) on the right side to high (6.82%) on the left side. The results are for the benchmark parameters.



A. Data Appendix

A.1. Using Flow of Funds data

The computation of firm value returns is based on Hall (2001). The data to construct our measure of returns on firm value were obtained from the Federal Flow of Funds, henceforth FOF. We use the (seasonally-unadjusted) flow tables for the non-farm, non-financial corporate sector, in file UTABS 102D. We calculate the market value of the corporate sector V^a as the market value of equity (item 1031640030) plus net financial liabilities. Net financial liabilities are defined as financial liabilities (item 144190005) minus financial assets (item 144090005). Because outstanding bonds (a part of financial liabilities) are valued at book value, we transform them into a market value using the Dow Jones Corporate Bond Index (DJCBI). We construct the levels from the flows by adding them up, except for the Market Value of Equity. This series is downloaded directly from the Balance series BTABS 102D. (item 103164003). Net (aggregate corporate) pay-outs is measured as dividends (item 10612005) plus the interest paid on debt (from the NIPA Table 1.14 on the Gross Product of Non-financial, Corporate Business, line 25) less the net issuance of equity (item 103164003) less the increase in net financial liabilities (item 10419005). The same NIPA Table 1.14 is used to obtain gross value-added (line 17), $Y_t - S_t^a$. Finally, capital expenditures (item 105050005) are obtained from the Flow of Funds.

Tobin's q for the non-financial sector is constructed as the ratio of the market value of the corporate sector V^a and the replacement cost of physical capital (K). We construct the replacement cost of physical capital using the perpetual inventory method with FOF investment data (item 105013003) and inventory data (item 10502005). To deflate the series, we use the implicit deflator for fixed non-residential investment from NIPA, Table 7.1. The depreciation rate is set to 2.6% per quarter.

A.2. Using Compustat data

We use annual and quarterly data from Compustat. If an item from Compustat is not available quarterly, we use its annual figure for each quarter, dividing by four if it is a flow variable. For each industry, the **net payout ratio** is defined as the ratio of payouts to security holders over payouts to workers plus security holders.

Payouts. Payouts to security holders are computed as the sum of interest expense (item 22), dividends from preferred stock (item 24), dividends from common stock (item 20), and equity repurchases, computed as the difference between the purchase (annual item 115) and the sale (annual item 108) of common and preferred stock. If there is no information available on the purchase and sale of stock, we assume that it is zero.

Payouts to workers are computed as the product of number of employees (Compustat, annual item 29) and wages per employee (see Appendix A.3 below). We only include those firms for which the payouts to security holders is less than the firm assets (annual item 6).

The intangibles ratio is defined as the ratio of intangibles (annual item 33) to net property, plant, and equipment (PPE, annual item 8). We filter out those firms whose intangibles ratio is greater than 1000. The intangibles ratio for each industry is then computed as the total intangibles over the total PPE for each industry.

Tobin's q. The variable q_1 is computed first for all firms having the following items available from Compustat: *DATA1* (Cash and Short-Term Investments), *DATA2* (Receivables - Total), *DATA6* (Assets - Total), *DATA9* (Long-Term Debt - Total), *DATA34* (Debt in Current Liabilities), *DATA56* (Preferred Stock - Redemption Value), *DATA68* (Current Assets - Other), and the following items available from the Center for Research on Securities Prices (CRSP): *PRC* (Closing Price of Bid/Ask average), *SHROUT* (Number of shares outstanding). For each firm, Tobin's q is defined as follows

$$q_1 = \frac{\text{totalvaluefirm}}{\text{DATA6 - fin\_assets}},$$

where:

$$totalvaluefirm = mcap + totaldebt - fin\_assets$$
$$totaldebt = DATA9 + DATA34 + DATA56$$
$$fin\_assets = DATA1 + DATA2 + DATA68$$
$$mcap = PRC * SHROUT/1000.$$

We select only those firms for which $0 < q_1 < 100$. For the selected firms, we compute industry I's Tobin's q as:

$$q_{1,agg} = \frac{\sum_{i\in I} \text{totalvaluefirm}_i}{\sum_{i\in I} \text{DATA6}_i - \text{fin\_assets}_i}.$$

We use a second definition of Tobin's q. The variable q_2 is defined as :

$$q_2 = \frac{\text{firm\_value}}{\text{DATA6}},$$

where

$$firm\_value = mcap + DATA6 - DATA60 - DATA74$$
$$mcap = PRC * SHROUT/1000,$$

and computed for all firms having the necessary items available in Compustat. We select only those firms for which $0 < q_2 < 100$. For the selected firms, we compute industry I's average q as:

$$q_{2,agg} = \frac{\sum_{i\in I} \text{firm\_value}_i}{\sum_{i\in I} \text{DATA6}_i}.$$

A.3. Labor reallocation

We use data from the Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW) program. This program reports monthly employment and quarterly wages data at the SIC code level from 1975 to 2000, and at the North American Industry Classification System (NAICS) code level from 1990 to 2005. Since there is no one-to-one correspondence between SIC and NAICS codes, we form industries at the 2-digit SIC code level that match industries at the three-digit NAICS code level. We finally end up with 55 different industries, that match to only 47 different Compustat industries. We exclude the financial sector from our calculations. The employment data from the QCEW program are spliced in 1992. We first compute the change in employment from month to month at the SIC and NAICS code level. If it is positive, it is recorded as Job Creation, otherwise it corresponds to Job Destruction. We then aggregate Job Creation, Job Destruction, and Employment by quarter, and deseasonalize each of these series separately using the X12-arima adjusted figures from the Census Bureau. Job Reallocation is then computed as the sum of Job Creation and Job Destruction, divided by Employment. Excess Job Reallocation is computed as the sum of Job Creation and Job Destruction minus the absolute change in Employment, divided by Employment.

A.4. Managerial Wage Data from Current Population Survey

We use the Integrated Public Use Microdata Series-Current Population Survey data on respondents' annual wage earnings from 1971–2006. Managerial occupations are defined as follows: for 1971-82, (previous year) occupation codes 220–246 except 221 and 226; for 1983–1991, codes 003–019; for 1992–2002, codes 003–022; and codes 001–043 after 2002. We restrict the sample to managers who were over 21 years old, were employed in the private sector, and who were full-time workers in the previous year (i.e., they averaged at least 35 hours per week). We drop observations with annual earnings less than $2,000 in 1983$. Finally, because wages are subject to top-coding, we follow Autor et al. (2008) and multiply top-codes by 1.5 (this adjustment only affects the reported standard deviations, not the IQR or IDR). The final sample size is about 3,000 managers in the 1970s and grows to around 6,000 managers in the 2000s.

A.5. Managerial wage data from Execucomp

We use the Compustat Executive Compensation (Execucomp) data, which contain annual compensation for top executives of over 2,500 companies from 1992 to 2005, to compute the dispersion in managerial pay within industries. Compensation is measured using Execucomp's tdc1 and tdc2 variables. Both are the sum of the manager's salary, bonus, restricted stock grants, Long Term Incentive Plan payouts, all other annual payments, and value of options. The difference between the two compensation measures is in what they use for the last term in the sum. Tdc1 uses the value of options grants, while tdc2 uses the value of options exercised. We compute the standard deviation of the logs of these two compensation measures within each industry-year in our data. This is then matched to our data set on industries' Tobin's q and intangible ratios. We are left with a total of 644 observations (46 industries over 14 years).

B. Steady-state growth path

Proof of Proposition 2. The first-order condition implies that compensation $\widetilde{c}$ is constant as long as the participation constraint does not bind. When a new match is formed, the normalized promised utility $\widetilde{v}$ starts off at $\widetilde{v}_0 = \omega(\widehat{A}_t)$. The dynamics of the optimal wage contract can be characterized by setting up the Lagrangian. Let μ denote the multiplier on the promised utility constraint and let $\lambda(\widehat{A}')$ denote the multiplier on the participation constraint in state $\widehat{A}'$. We assume $\widehat{V}(\cdot)$ is strictly concave and twice continuously differentiable. Note that the non-differentiability introduced by the max operator in $\widetilde{V}(\cdot)$ is integrated out by averaging over the idiosyncratic shocks to construct $\widetilde{V}$ (see eq. 2.14). When the participation constraint $\widehat{A}'$ does not bind ($\lambda(\widehat{A}') = 0$), conditional on continuation of the relationship ($\beta = 1$), the law of motion for the promised utility in efficiency units $\widetilde{v}$ satisfies the first-order condition:

$$\mu = \frac{-\partial \widehat{V}(\widehat{A}', \widetilde{v}')}{\partial \widetilde{v}'}.$$

The left-hand side is the cost to the owner of increasing the manager's compensation today. It equals μ, the shadow price of a dollar today, from the envelope condition. From the first-order condition for consumption we know that $\mu = 1/u_c(\widetilde{c})$. The right-hand side is the cost of increasing the manager's compensation tomorrow, from the first-order condition for $\widetilde{v}'$. From the envelope condition, this equals $\mu' = 1/u_c(\widetilde{c}')$. So, the first-order condition implies that consumption $\widetilde{c}$ must be constant over time, as long as the manager's participation constraint does not bind. As a result, actual managerial compensation c grows at the rate of output growth g on the steady-state growth path. When the participation constraint does bind, the following inequality obtains:

$$\mu < \frac{-\partial \widehat{V}(\widehat{A}', \widetilde{v}')}{\partial \widetilde{v}'}.$$

The utility cost of increasing the manager's compensation to the owner increases. From the concavity of $u(\cdot)$, it follows that the manager's promised utility and current compensation (in efficiency units) increase when the participation constraint binds. When the constraint does bind, we increase $\widetilde{c}$ to make sure the constraint holds with equality. This is optimal (see Kuhn-Tucker conditions).

This suggests a simple consumption rule is optimal. We conjecture the optimal consumption function $C\left(\widetilde{v}, \widehat{A}\right)$ such that:

$$C\left(\widetilde{v}, \widehat{A}\right) = u_c^{-1}\left(1/\mu\right),$$

where $\mu = \frac{-\partial \widehat{V}(\widehat{A}, \widetilde{v})}{\partial \widetilde{v}}$. Define the running maximum of $\widehat{A}$ as $\widehat{A}_{max,t} = max\{\widehat{A}_\tau, \tau \leq t\}$. In addition, let T denote the random stopping time when the match gets terminated because of zero surplus:

$$T = inf\{\tau \geq 0 : \widehat{V}(\widehat{A}_\tau, \widetilde{v}_\tau) = 0\}.$$

Compensation is determined by the running maximum of productivity for all $0 < t < T$:

$$c_t = c(\widehat{A}_{max,t}) = max\left\{c_0, C\left(\omega(\widehat{A}_{max,t}), \widehat{A}_{max,t}\right)\right\}.$$

This consumption function satisfies the necessary and sufficient Kuhn-Tucker conditions if the continuation probability β is non-increasing in $\widehat{A}$. This being the case, the participation constraint only binds if $\widehat{A}$ exceeds its previous maximum. It is easy to verify that β is indeed non-increasing in $\widehat{A}$ given this consumption function.

Proof of Proposition 3. The discount rate wedge induces a downward drift in the manager's consumption and promised utility. When the participation constraint does not bind, the envelope condition and the first-order condition for $\widetilde{v}'$ imply the following:

$$\frac{-\partial \widehat{V}(\widehat{A}, \widetilde{v})}{\partial \widetilde{v}} = \mu = e^{(\rho_m - \rho_o)} \frac{-\partial \widehat{V}(\widehat{A}', \widetilde{v}'')}{\partial \widetilde{v}'}.$$

Because $e^{\rho_m - \rho_o} > 1$, the owner's utility cost of providing compensation tomorrow is lower than μ, the cost today. As a result, the optimal promised utility is decreasing over time. Because $\mu = u_c^{-1}(\widetilde{c})$, this also implies that current consumption drifts down. By construction, this consumption policy satisfies the necessary and sufficient first-order conditions for optimality.

C. Transition experiment

Definition 4. *A constant-discount rate transition between two steady-state growth paths is defined as a path for which the productivity of the newest vintage grows at rate $g_{t,\theta}$, the economy-wide productivity-level grows at a rate $g_{z,t}$, and all aggregate variables $\{Y_t, K_t, w_t, C_t\}_{t=0,T}$ have a constant trend growth rate*

$$g = \left((1 + g_z)(1 + g_\theta)^{1-\nu}\right)^{\frac{1}{1-\alpha\nu}}.$$

The rental rate on capital R_t and the discount rate r_t are constant. The measure over promised utilities and establishment productivity satisfies (2.10) and (2.11) during the transition. At $t = T$, this economy reaches *its new steady-state growth path. So for $i > 1$:*

$$\Psi_{T+i,s}(A, v) = \Psi_{T+i-1,s}\left(\frac{A}{1+g_\theta}, v\right) \tag{C.1}$$

$$\lambda_{T+i,s}(A, v) = \lambda_{T+i-1,s}\left(\frac{A}{1+g_\theta}, v\right). \tag{C.2}$$

Output deviates from its trend growth path during the transition because the average establishment productivity level deviates from its initial steady-state growth path $\{\overline{A}_{old,t}\}$. The average productivity level changes, because the joint measure over establishment-specific productivity and promised utility is changing. Along the transition path, we check that the rental rate for physical capital is constant:

$$R_t = \alpha v \widetilde{K}_{new,t}^{\alpha v - 1} = \alpha v \left(\widetilde{K}_{old,t}\right)^{\alpha v - 1},$$

where $\widetilde{K}_t = \frac{K_t}{\overline{A}_t^{\frac{1-v}{1-\alpha v}} z_t^{\frac{1}{1-\alpha v}}}$ denotes the capital stock in *adjusted* efficiency units. The aggregate capital stock is adjusted such that

$$\varphi_t = \frac{\widehat{K}_{new,t}}{\widehat{K}_{old,t}} = \left(\frac{\overline{A}_{new,t}}{\overline{A}_{old,t}}\right)^{\frac{1-v}{1-\alpha v}}.$$

Capital is supplied perfectly elastically at a constant interest rate. Along the transition path, all aggregate variables $\{Y_{new,t}, K_{new,t}, W_{new,t}, C_{new,t}\}_{t=0,T}$ are scaled up by φ_t. This is the productivity adjustment relative to the old steady-state growth path. Once we have computed $\{\varphi_t\}$, we can back out the transition path for all the other variables.

Reverse shooting algorithm. The objective is to compute the transition for the value function, aggregate productivity, the outside option function, and the joint measure over promised consumption and productivity $\{V_t, \overline{A}_t, \omega_t, \Psi_{t,s}, \lambda_{t,s}\}$. We start in the new steady state with the new vintage-specific growth rate $g_{\theta,T}$ at T, and the "stationary" joint measure $\Psi_{T,s}$ over organizational capital and promised consumption, which satisfy the conditions in eq. (C.2). We conjecture a $\{\varphi_t\}_{t=0}^T$ sequence. Because we know $\widehat{V}_T$, the owner's value of an establishment at the beginning of period t can be constructed recursively, starting in $i = 1$:

$$\widehat{V}_{T-i}(\widehat{A}, \widetilde{v}; s) = \max_{\widetilde{c}, \widetilde{v}'_t(\cdot)} \left[\begin{array}{c} \widetilde{y}_{T-i+1} - W - R\widetilde{k}_{T-i+1} - \widetilde{c}_{T-i+1} \\ +R^{-1}(1+g) \int \widetilde{V}_{T-i+1}(\widehat{A}', \widetilde{v}'; s+1)\, Q_{s'}(\varepsilon') d\varepsilon' \end{array} \right],$$

subject to the law of motion for capital in (2.13), the promised consumption constraint in (2.15), and a series of participation constraints:

$$\widetilde{v}' \geq \widetilde{\omega}_{T-i+1}(A'),$$

and, finally, the value of the firm is defined as:

$$\widetilde{V}_{T-i}(\widehat{A}, \widetilde{v}) = \max\left[\widehat{V}_{T-i}(\widehat{A}, \widetilde{v}), 0\right].$$

We solve for $\{V_t, \overline{A}_t, \omega_t, \Psi_{t,s}, \lambda_{t,s}\}_{t=1}^T$ starting in the last period T.

Simulating forward. Next, we simulate this economy forward, starting at the initial values for $\left(V_0, \overline{A}_0, \omega_0, \Psi_{0,s}, \lambda_{0,s}\right)$ in the old steady-state growth path, using our solution for the transition path $\{V_t, \overline{A}_t, \omega_t, \Psi_{t,s}, \lambda_{t,s}\}_{t=1}^T$. We use a sample of $N = 5,000$ establishments. This gives us a new guess for the aggregate establishment productivity series and hence for $\{\varphi'_t\}_{t=0}^T$. We continue iterating until we achieve convergence.

D. Calibration details

To calibrate the depreciation rate, the tax rate, and the capital share $\alpha\nu$, we used mostly NIPA data. Let CFC denote the consumption of fixed capital. Let K_{INV} denote the stock of inventories, obtained from NIPA Table 5.7.5B. (Private Inventories and Domestic Final Sales by Industry). Let K_{ES} denote fixed assets, obtained from NIPA Table 6.1. (Current-Cost Net Stock of Private Fixed Assets by Industry Group and Legal Form of Organization). The depreciation rate is computed as

$$\delta = CFC/(K_{ES} + K_{INV}).$$

The average tax rate τ_c is computed as follows. Let CT denote corporate taxes, let NP denote net product, let ST denote sales taxes, and let $SLPTR$ denote state and local taxes. The tax rate is computed as

$$\tau_c = CT/(NP - CE - ST),$$

where we compute ST as $CT - RATIO \times SLPTR$ and $RATIO$ is the average ratio of fixed assets held by non-farm, non-financial corporations to total fixed assets.

To compute the average cost of capital r, we computed the weighted-average of the average return on equity and the average return on corporate bonds over the period 1950–2005. The average return on corporate bonds was computed using the DJCBI. The average return on equity is computed from the log price/dividend ratio and a constant real growth rate for dividends of 1.8%, the average growth rate over the sample. The dividend series and the price/dividend ratio from CRSP are adjusted for repurchases. The weights in the average are based on the aggregate market value of equity and corporate bonds. The resulting average cost of capital is 5.5%.