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Executive Compensation and Matching in the CEO Labor Market

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Executive Compensation and Matching in the CEO Labor Market

by

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I would like to dedicate this work to the community that The Lord has surrounded me with throughout this journey, and especially my parents who began to support me before I was even aware, and who have not stopped since.

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Executive Compensation and Matching in the CEO Labor Market

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This study examines the matching of CEOs to firms and the compensation earned by such managers in a competitive labor market. I first develop a simple competitive equilibrium model and derive predictions regarding the change in wages when an inelastic supply of CEO labor cannot match an increase in demand. The model predicts that the CEO pay-size elasticity increases when more firms compete for a fixed supply of managers. I then empirically test this prediction using industry-level IPO waves as a proxy for increased competition among firms for CEOs. Consistent with the model, I find that pay-size elasticity increases with an increase in an industry's IPO activity. I also find that increased IPO activity leads to a greater likelihood of executive transitions between firms. Overall, the findings point to the substantial role market forces play in the determination of pay in the CEO labor market. I then use a structural model to examine the distortionary effects of frictions in the CEO labor market. I estimate the switching cost to be 20% of the median firm's annual earnings. While reduced-form estimates of the switching cost serve as a lower bound on the reduction in firm value, they underestimate the overall effect which also includes the resulting inefficient firm-CEO matches. Using counterfactual analysis, the switching cost is estimated to decrease the median firm's value by 4.8%, four times larger than the reduced-form estimate.

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Chapter 1

Equilibrium Wage Response to an Increase in CEO Demand

1.1 Introduction

There has been fierce debate regarding the determination of CEO compensation. One school of thought holds that executive pay is the result of rent extraction (Jensen, Murphy and Wruck (2004), Bebchuck and Fried (2003, 2004)). Alternatively, there are those who advocate an efficient contracting view where competitive forces for managerial ability determine CEO pay (Gabaix and Landier (2008), Terviö (2008)). While both explanations likely contribute to the current level of compensation, a snapshot of CEO pay is not particularly informative about the individual merit of either argument or the degree to which it shapes executive compensation. My contribution is to focus on a shock to the demand for managerial talent, which has the clear implication of affecting CEO pay through market forces.

This chapter explores the implications of industry level changes in the demand for CEOs on competitively set wages. Using a simple competitive equilibrium model along the lines of Gabaix and Landier (2008) and Terviö (2008), I examine how a positive shock to the demand for managerial talent affects wages. Not surprisingly, an increase in demand increases the level of CEO pay; a CEO's outside option increases as more firms compete for managerial talent, pushing up wage levels. The more novel prediction, however, is that the elasticity of pay with respect to productive assets also increases. The intuition behind this prediction is that pay elasticity is driven by the differential in ability among CEOs. As more firms enter the labor market, they are forced to go deeper into the pool of potential managers when selecting CEOs, increasing the differential in ability and thereby increasing pay elasticity.

I begin by presenting a frictionless, one-industry model of CEO wages based on Gabaix and Landier (2008) and Terviö (2008). The innovation that I make to this model stems from a change in the competition for managers. After constructing the equilibrium wages, I generate comparative statics by increasing the measure of firms relative to the measure of managers. This allows me to parsimoniously raise the level of competition for CEOs. I show that an increase in the measure of firms participating in the labor market increases both the level of pay and pay-size elasticity. When comparing the wages paid by two firms that differ in their productive assets by a fixed amount, as more firms compete for a fixed supply of managers there is an increase in the relative change in wages between the two CEOs.

The introduction of more firms into the industry leads to a reformation of the CEO-firm matches. Prior to this influx of new firms, smaller, less productive firms may have enjoyed a talented manager. However, following the entrance of new firms seeking a CEO, these firms are no longer able to retain such talented managers, who depart for more productive firms where they receive higher wages. Instead, low productivity firms are each matched with a CEO of a lower quality than under the previous regime. In the model, wages are set in a recursive fashion from the smallest firm upwards. Therefore, while the entry of more productive firms leaves an existing firm with a less talented manager, the entry of some less productive firms drives the wages that the existing firm offers upwards, increasing both the level of pay and the elasticity of pay to firm value. While the model predicts that the level of pay within an industry will increase with demand, the models prediction that the elasticity will increase is much sharper, and I focus primarily on this prediction in my analysis.

In previous work, both Hubbard and Palia (1995) and Crawford, Ezell and Miles (1995) find that deregulation in the banking sector led to an increase in CEO compensation. Cuat and Guadalupe (2009b) extend this analysis while Cuat and Guadalupe (2009a) expand it to the manufacturing sector. Both find an increase in the pay-performance sensitivity of CEOs. However, these papers focus on the effect that changes to the competitive space of a firm have on the level of wages needed to incentivize its manager. In contrast, I examine the market forces that shape CEO pay across firms by focusing on the response of both pay-size elasticity and the reallocation of managerial talent to an increased demand for managers.

There is an extensive literature on the impact of CEOs and the compensation they receive.[1] A long-standing debate in the literature is the source driving the level of CEO compensation to greater and greater heights; either strong CEOs are extracting rents from shareholders or CEO pay is the result of a competitive market for CEO talent. Jensen, Murphy and Wruck (2004) and Bebchuck and Fried (2003, 2004) argue that a CEO plays a considerable role in the structuring of compensation by the board and the resulting level of pay represents rent extraction.[2] Alternatively, there are those who advocate CEO pay as the outcome of an efficient labor market. Gabaix and Landier (2008) and Tervi (2008) each calibrate models where heterogeneous firms and managers are optimally matched and wage contracts are set in competitive equilibrium. I extend this second view by deriving a prediction from such a model which I then test and find empirical support for.

This dissertation also contributes to a second strand of literature which focuses on the importance of CEOs and their value added. Bertrand and Schoar (2003) and Graham, Li and Qiu (2012) examine the CEOs effect on firm performance by focusing on CEOs which transition across multiple firms.[3]

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[1]This is illustrated by the numerous surveys regarding CEO compensation, including earlier works by Rosen (1992), Murphy (1999), Abowd and Kaplan (1999), Core, Guay and Larker(2003), and more recent work by Aggarwal (2008), Bertrand (2009), Edmans and Gabaix (2009) and Frydman and Jenter (2010), among others.

[2]Kuhnen and Zwiebel (2009) take this view to the extreme by modeling executive pay as being directly set by the CEO, whose only deterrent is the risk of being fired. Support has also been argued by a CEO being compensated for luck (Bertrand and Mullainathan (2001)), the asymmetric response of compensation to luck (Garvey and Milbourn (2006)), a breakdown of relative performance evaluation (Gibons and Murphy (1990)), and higher levels of CEO compensation when the CEO also sits on the nominating committee (Core et al (1999)).

[3]Kaplan, Klebanov and Sorensen (2012) map this effect to observable characteristics,

Bennedsen, Perez-Gonzales and Wolfenzon (2012) measure a CEO's impact using the number of days the manager is hospitalized. My dissertation extends this literature by studying the importance a firm places on their CEO in light of changes to the competition for managers.

Finally, this dissertation adds to the literature regarding a firms choice of succession type. Parrino (1997) observes that a firms successor choice is closely tied to the performance of the firm. Cremers and Grinstein (2013) use the percentage of CEO outsiders hired as a measure of firm-specific knowledge, which they find is positively related to the prevalence of compensation benchmarking and pay-for-luck within the industry.[4] I extend these studies by relating a firms successor choice to time-series variation in the firms respective options within and outside the industry.

1.2 The Model

I begin by presenting the CEO labor matching model of both Gabaix and Landier (2008) and Terviö (2008) for a single industry economy, in which I will derive wages under two industry conditions. In the first scenario CEOs

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identifying particular CEO traits that are positively related to future performance. Additionally, Adams, Alemida and Ferreira (2005) find that more powerful CEOs have a stronger impact on the volatility of stock returns, and Carter, Franco and Tuna (2010) and Falito, Li and Milbourn (2013) find that executive compensation is related to observable CEO characteristics.

[4] The decision of hiring a replacement from inside or outside the firm is modeled in Murphy and Zabojnik (2004). In an accompanying work, Murphy and Zabojnik (2007) model a shift from specific to general skills which is linked to trends in outside hires and pay. Additionally, Lasear and Oyer (2004) find that external markets and opportunities affect wage levels at all levels of the firm they study, up to but not including the CEO.

and firms are efficiently matched and wages are determined in competitive equilibrium under normal times. In the second scenario I will introduce an additional measure of firms while holding the measure of managers constant and again determine wages in equilibrium to characterize the effect a positive shock to labor demand has on wage dynamics.

1.2.1 Model Setup and Equilibrium

The economy consists of a continuum of individuals with fully observable, heterogeneous talent levels, $\theta \in [\underline{\theta}, \theta_h]$, each of whom has the ability to manage a firm. All individuals share a common reservation wage, $\underline{w}$. The talent distribution of these individuals follows $f_\theta(\theta)$. Additionally, the economy is populated by a continuum of firms, who differ in their level of productive assets, $A \in \left[\underline{A}, \overline{A}\right]$, governed by $f_s(A)$.

Profits are a function of a firms productive assets, the CEOs talent level and wages paid:

$$\pi = A \cdot \theta - w \tag{1.1}$$

The influence a CEO has on a firms gross profits is modeled as a multiplicative effect. The interpretation is that a superior CEO can make every dollar under her control more productive, relative to a less talented manager, in the spirit of Rosen (1982). This assumption will be important later when deriving the equilibrium wages paid to CEOs.

In this frictionless labor market, there is a perfect rank order correlation between a firms productive assets and the CEOs talent for each matched pair.[5] Therefore, wages are governed by the assignment equation of Sattinger (1979), where each manager earns the wages of a manager marginally less talented then themselves plus their marginal talent increased by factor of the firms productive assets. Define $T(p) \equiv f_\theta^{-1}(p)$, which represents the talent level of the individual in the pth percentile of the talent distribution. Similarly, define $S(p) \equiv f_s^{-1}(p)$, mapping a firms relative ranking in the economy to the size of their productive assets. Then, wages have the following property in equilibrium:

$$W(T(p))' = S(p) \cdot T(p)' \tag{1.2}$$

Thus, the marginal change in wages for a given firm increases in both the local talent differential of managers and the size of the firm.

Up to this point I have said nothing regarding the measure of firms or managers. Let M_θ and M_f denote the measure of managers and firms, respectively. I now make the mild assumption that $M_\theta > M_f$. Simply put, there is a surplus of potential managers in the economy. Let θ_l be such that the measure of CEOs over the interval $[\theta_l, \theta_h]$ equals the measure of firms in the market. Each firm employs exactly one manager, therefore every individual within this interval will be matched with a firm in the labor market. Thus, the talent distribution of employed managers is $\check{f}_\theta(\theta) \equiv f_\theta(\theta) \cdot \frac{M_\theta}{M_f} \forall \theta \in [\theta_l, \theta_h]$,

[5] This assignment outcome is referred to as positive assortative matching. Nickerson (2013) examines the importance of this assumption by quantifying the distortionary effect that a matching friction has on overall social welfare.

and zero otherwise. Define $\check{T}(p) \equiv \check{F}_{\theta}^{-1}(p)$, the quantile function of the new distribution.

Positive assortative matching implies a firm with assets $\underline{A}$ will employ an individual of talent level θ_l. A lack of competition among firms for this manager leads to compensation being set at her reservation wage, $\underline{w}$. From this fixed point and equation 2, competitive wages follow from the following equation:

$$W(S(p)) = \underline{w} + \int_0^p S(u) \cdot \widehat{T}(u)' \, du \tag{1.3}$$

The motivation behind this model is to demonstrate how wages react in abnormal times. Therefore, I apply a perturbation to the industry by introducing an additional measure of new firms, while keeping the distribution of firms fixed. An increase in the measure from M_f to $M_f \cdot (1+g)$ parsimoniously represents an increase in the competition for managers among firms.

Under this second scenario the measure of managers employed also increases from M_f to $M_f \cdot (1+g)$. Because the measure of firms increases while the distribution remains the same, the talent distribution effectively compresses from a firms standpoint, causing every firm but the largest to be paired with a less talented manager. Therefore, there is a decrease in the level of the least talented CEO matched with a firm. Let θ_{ll} be such that the measure of CEOs over the new interval $[\theta_{ll}, \theta_h]$ equals the increased measure of firms in the market, $M_f \cdot (1+g)$. The increase in the measure of firms also requires us to redefine the talent distribution of those managers being employed. The talent distribution of employed managers is now $\tilde{f}_\theta(\theta) \equiv f_\theta(\theta) \cdot \frac{M_\theta}{M_f \cdot (1+g)} \forall \theta \in [\theta_{ll}, \theta_h]$, and zero otherwise. Finally, I define $\tilde{T}(p) \equiv \tilde{F}_\theta^{-1}(p)$, the talent level of an individual in the pth percentile of the new distribution.

Note that while the firm at the upper support continues to employ a manager of talent level θ_h, any other firm in the economy residing in the pth percentile is matched with a manager of lesser ability relative to the first scenario: $\tilde{T}(p) < \check{T}(p)$. Furthermore, because the distribution of firm sizes was not altered, $S(\cdot)$ remains unchanged, giving way to the new wage function:

$$\tilde{W}(S(p)) = \underline{w} + \int_0^p S(u) \cdot \tilde{T}(u)' \, du \tag{1.4}$$

1.2.2 Model Predictions

Given the characterization of equilibrium wages under normal demand in (3) and times of increased demand in (4), the following relationships can be divined.

Proposition 1.2.1. *The wage differential between the largest firm and any other firm is an increasing function with respect to the number of firms in the economy. Let $W(F_s^{-1}(p))$ be the wages paid by a firm in the pth percentile, such that $F_s(s) = p$. Let M be the measure of $F_s(\cdot)$, then:*

$$\frac{\partial}{\partial m}\left[W\left(F_s^{-1}(1)\right) - W\left(F_s^{-1}(p)\right)\right] > 0, \forall p < 1 \tag{1.5}$$

Proof: See Appendix A

Following an increase in the number of firms active in the CEO labor market, the disparity between the wages paid by the largest firm and a firm of any other size also increases. Intuitively, as a new measure of firms is introduced into the economy, every individual in the labor market is matched to a firm with a larger amount of productive assets. Following from (2), this leads to an increase in the wage differential between adjacent managers.[6] It is relatively straightforward to arrive at the effect an increase in competition has on wages paid by the largest firm.

Proposition 1.2.2. *The wages paid by the largest firm is an increasing function with respect to the number of firms in the economy. Let $W\left(F_s^{-1}(1)\right)$ be the wages paid by the largest firm. Let m be the measure of $F_s(\cdot)$, then:*

$$\frac{\partial}{\partial m} W\left(F_s^{-1}(1)\right) > 0 \tag{1.6}$$

Proof: See Appendix A

By assumption, all individuals in the economy share a common reservation wage. This reservation wage provides a fixed point, which when substituted into Proposition 1, yields a model prediction regarding wages paid by the largest firm in the economy.

While the previous propositions place no restrictions on the functional forms on the distributions of either firm size or managerial talent, they fail to illustrate how wages respond locally for firms in the interior of the size distribution. I now refer to the application of the extreme value theorem by

[6] The technical condition that the distributions of firm sizes and managerial talent each have a finite upper support is necessary to ensure that all wages are finite.

Gabaix and Landier (2008), who derive an approximation of $\widehat{T}(\cdot)'$ for a broad class of distributions. Given a tail index of α for the talent distribution $f_\theta(\cdot)$, they show

$$\widehat{T}(p)' = -B \cdot p^{\alpha-1} \tag{1.7}$$

Following the substitution of (XX) into wage equations (XXX) and (XX), I get the following model prediction regarding the local change in wages with respect to firm size following an increase in the demand for CEOs.

Proposition 1.2.3. *The increase in wages associated with an increase in firm size is larger following an increase in the number of firms for all talent distributions with a non-negative tail index. Let α be the tail index of $f_\theta(\cdot)$. Let $f_s(\cdot)$ and $\widehat{f}_s(\cdot)$ be such that $f_s(\cdot) = \widehat{f}_s(\cdot)\,\forall s$, with respective measures $\widehat{m} > m$. Suppose most talented manager has ability $\theta = f_\theta^{-1}(1-\varepsilon)$, for an $\varepsilon > 0$. If $\alpha \geq 0$ and $\widehat{m} > m$, then:*

$$\frac{\partial W\left(\widehat{F}_s^{-1}(p)\right)}{\partial p} > \frac{\partial W\left(F_s^{-1}(p)\right)}{\partial p} \forall 0 \leq p < 1 \tag{1.8}$$

Proof: See Appendix A

Thus, if the tail index of the talent distribution is non-negative, as is the case in the Gaussian, logit, exponential, log-normal, uniform, bounded power law, and Weibull distributions[7], an increase in the number of firms vying for CEOs leads to an increase in wages with respect to firm size regardless of at

[7]See Gabaix, Laibson and Li (2005) for a list of common distributions and their tail indices

which point the derivative is evaluated.[8] Alternatively, following a discretization of both firm size and managerial talent distributions, all of the previous propositions follow through.

1.2.3 Simulation Results

While the previous propositions give an indication of how wages will respond to an increase in the demand for CEO labor, the litmus test by which I will evaluate the models predictions is an empirical one of how pay-size elasticity changes with competition for managers. The propositions set forth thus far do not provide much insight into the magnitude of this response. To provide some intuition, Figure 1 graphs how pays-size elasticity changes following a shock to demand under some common distributions. Panel A reports the equilibrium wages under two scenarios, Normal Demand and Increased Demand, when the distribution of talent follows either a normal distribution (left plot) or a beta distribution (right plot). Under the Normal Demand scenario, I begin by drawing the top 500 firms of an economy from a Zipf distribution and a population of managers from their respective distributions.[9] Next, I assign the top 500 managers to firms in a positive assortative fashion and fix the wages of the smallest firm-CEO pair. Finally, I set wages according to equation (3). For the Increased Demand scenario, I introduce 20% more firms into the econ-

[8]Note that for distributions with a tail index of zero, I must impose an upper bound on the talent level of potential CEOs to ensure that all wages are well defined.

[9]Firm sizes are set to mimic the market capitalization of the largest 500 firms in the compustat universe. See Gabaix (1999) and Luttmer (2007) for a justification of approximating the size distribution of firms using a Zipf distribution.

omy spaced evenly throughout the entire distribution, rematch managers to firms, and again calculate the equilibrium wages. Following the entrance of additional firms, wages respond by increasing along the entire distribution of firm sizes, irrespective of which distribution is considered.

[Figure 1 Approximately Here]

However, it is possible that this result is sensitive to the distribution of talent assumed. To alleviate this concern, Panel B reports pay-size elasticity under eight common distributions for the Normal Demand and Increased Demand scenarios. Pay-size elasticity is calculated by regressing the natural log of CEO compensation on the natural log of firm value and a constant. The parameters of each distribution were chosen in such a way that the pay-size elasticity for the Normal Demand scenario was between .40 and .41. After introducing an additional measure of firms into the economy, pays-size elasticity increases for all distributions considered. In addition, with the exception of uniformly distributed talent, the increase in elasticity is similar across all the distributions.

Chapter 2

Empirical Examination of Model Predictions Using IPO Waves

2.1 Empirical Strategy

To test the models predictions, outlined in the previous chapter, I exploit the increased demand for CEOs arising from the entrance of new firms during industry IPO waves, who compete for a limited supply of managers. As a firm transitions from privately held to publicly traded, the skill set required of its manager changes. This provides a positive shock to the demand for managers who can operate a public firm in the industry. The necessity of a CEO to build up industry-specific human capital prevents an inflow of managers from other industries, resulting in an inelastic supply of managers. This imbalance in the supply and demand of CEO labor increases the elasticity of wages earned by CEOs in competitive equilibrium.

Consistent with the models predictions, I find that the elasticity of pay with respect to firm value is positively correlated with the industrys IPO activity over the preceding three year period. The relation is stronger in industries that require more industry-specific knowledge, in industries which are more unique in their operations, and in well-governed firms. Furthermore, patterns of CEO movement within and across industries are consistent with competition driving a reallocation of CEO talent. Overall, my results suggest that market forces play a key role in the shaping of CEO pay.

Empirically, I use industry level IPO waves to represent the addition of new firms into a pre-existing equilibrium. This allows me to study the entrance of established firms with operations in place into the public equity market. The skill set necessary to efficiently manage a firm changes following the transition from being privately held to publicly traded, increasing the demand for CEOs with such abilities. The use of IPO activity has additional benefits. Large private firms going public have a greater ability to compete with incumbent firms for highly talented CEOs relative to newly formed firms which tend to be smaller in size. In addition, while outside the model presented in the previous chapter, IPO waves could potentially provide a positive shock to the upper tail of productive firms providing an interesting setting in which to study the wage response of very large firms.

Confirming the models prediction, I find that the elasticity of pay with respect to firm value increases by 5.8% relative to the unconditional pay-size elasticity with a one standard deviation increase in industry IPO activity over the preceding three year period. Economically, this equates to an increase in pay of 6.3%, or $412,100 for the average observation in my sample. This result is robust to the measure of CEO pay, with consistent results for both cash and total compensation.

Within the context of the model, the increase in wages is driven by an increase in the number of firms competing for CEOs. Empirically, I represent these new participants in the CEO labor market with firms going public. Supporting this conjecture, I find that the likelihood of a newly public firm hiring an executive exceeds that of formerly established firm by a factor of 5.9.

Through the lens of the model, this competition also results in a reallocation of managers across other firms. This assumption distinguishes the model from hypotheses based on rent extraction or optimal effort inducement. To test the validity of this assumption, I use a competing-risks framework and find the odds of an executive transitioning to a new firm where they receive a higher level of compensation increases by 18% with a one standard deviation increase in the industrys IPO activity.

I then test the cross-sectional magnitude of demand on pay-size elasticity. If wages are being influenced by the competition for managers then there should be a stronger effect when more industry-specific knowledge is needed, resulting in a more inelastic supply of CEOs. I find a larger effect in industries that hire fewer CEOs from outside the industry, in industries with less overlap in sales from firms outside the industry, and in industries whose returns are less correlated with other industries. I posit that these industries are harder to learn, require more industry-specific knowledge, or are more unique in their operations. To test the alternative hypothesis that this effect is being driven by agency problems, I examine how the effect varies with firm governance. Contrary to this principle-agent hypothesis, I find the effect to be more pronounced in well-governed firms.

Finally, in light of these previous findings, I test if IPO activity does in fact reduce the managerial pool available within an industry, thereby affecting a firms choice of successor following CEO turnover. A one standard deviation increase in IPO activity is associated with a 49.5% increase in the odds of selecting a successor from outside the industry relative to an industry insider, conditional on selecting a successor from outside the firm. This result is consistent with IPO waves leading to more competition for top CEOs within an industry, thus bidding up wages.

Overall, increased competition for managers induced by firms going public results in an increase in CEO pay-size elasticity, an effect which is stronger in more specialized or isolated industries. Furthermore, the rise in competition also results in a greater degree of executive transitions as managerial talent is reallocated across firms. This empirical evidence points to the significant part market forces play in the formation of executive compensation.

2.2 Data Description and Variable Construction

To empirically test the models prediction regarding wage elasticity, I use data from Compustat fundamentals, Execucomp, Compustats Historical Segments, BoardEx, IPO dates from Jay Ritters website, industry portfolio performance and composition data from Kenneth Frenchs website, and CEO turnover data from Andrea Eisfeldts website.

2.2.1 Datasets Used

I begin by merging yearly company fundamentals from Compustat with executive compensation data from Execucomp. I exclude any observations with missing values of either total assets (AT), book value of common equity or market value of common equity. Any missing values of deferred taxes are set to zero. The intersection yields 32,466 firm-year observations from 6,358 unique individuals and 3,316 companies over the period of 1993-2011. For each firm, I define the year-end firm value as total assets minus book value of common equity plus year-end market value of common equity minus deferred taxes. My interest is on the largest firms in the economy, where the competition for CEO talent should be the most pronounced. Therefore, I restrict the sample to the largest 2000 firms within each year according to lagged total firm value.[1] Following this restriction 20,355 observations remain. All firms are classified into one of the 48 industries set forth in the scheme by Fama and French (1997).

[1]Additionally, for robustness I also consider the full tenure of any CEO whose firm was ranked in the top 2000 in the year prior to her appointment. This prevents firms from dropping out of the sample after experiencing bad performance, which would possibly bias my results. This also gives the added benefit of having a consistent sample when performing tests related to CEO turnover, while avoiding a possible backfilling bias in the Execucomp sample, documented in Gillan, Hartzell, Koch and Starks (2013), which can bias results related to the structuring of CEO compensation. Results are robust to this alternate restriction on firm size.

2.2.2 Measure of IPO Activity

While the data sources outlined thus far have been quite standard, I also need an empirical measure that captures increases in the demand for CEO labor within an industry. I rely on the within industry clustering of IPOs to proxy for times of increased labor demand. For newly public firms to increase the competition for managers, it must be plausible that they could hire away an executive from a firm in the sample. Therefore, I only consider the IPOs of firms whose market value within two fiscal years is within the top 2000 firms.[2] I am left with 1,718 IPOs over the period from 1988 - 2011. However, the use of industry level IPO activity does have its disadvantages. If IPO waves correspond to an increase in the productivity of firms in an industry, a moral hazard view would predict an increase in wages to induce a higher level of effort. However, as I will discuss in more detail later, market value is used to proxy for a firms asset productivity. If a positive shock to asset productivity is also reflected in market values, it is not clear why the elasticity of wages to firm value would change.

As previously mentioned, the driving force behind my test is that human capital must be accumulated over time, creating a slow moving supply of talented executives relative to the increased demand caused by an IPO wave. However, larger industries naturally provide more employment prospects, thereby attracting a greater number of managers. Thus, the supply

[2]To do this, I match IPO dates to the Compustat universe of firms by first using a name matching algorithm, and then verifying by hand.

of potential CEOs in a larger industry is more able to absorb the increased demand induced by a given level of IPO activity. For this reason, the percentage of IPO activity relative to the industry size should be more informative regarding the change in demand for CEO labor. Therefore, each industrys yearly number of IPOs is scaled by the average number of firms within that industry in the prior three year period.

$$ipo_{i,t} = \frac{ipo\, issuance_{i,t}}{\left(n_{i,t-1} + n_{i,t-2} + n_{i,t-3}\right)/3} \tag{2.1}$$

I exclude any industry that averages fewer than 5 firms over the entire sample period to avoid large variations in ipo induced by changes in a small denominator.

[Figure 2 Approximately Here]

Figure 2 plots the time-series for nine industries within my sample chosen at random. Overall, there is considerable variation in industry-level IPO activity across time, with the exception of industry number 31 (Utilities). One possible concern is that an unobservable economy-wide state variable is influencing both wages and IPO activity across the entire economy, leading to correlated IPO activity across industries. While this does not appear to be the case in the figure, this concern will be addressed when presenting the empirical results in the next section.

The theory presented here is that human capital accumulates at a slow pace and managers cannot quickly reallocate themselves to meet the increased demand within an industry. An increase in IPO activity will likely have an effect on wages for multiple years given slow moving human capital. Therefore, to reduce the noise in my measure of CEO demand, I instead sum over the values of ipo for the trailing three year period:

$$IPO\ Activity_{i,t} = \left(ipo_{i,t-1} + ipo_{i,t-2} + ipo_{i,t-3}\right)/3 \tag{2.2}$$

2.3 Increased CEO Labor Demand from IPO Waves

2.3.1 Pay-Size Elasticity and IPO Waves

Empirically, I will be concentrating on pay-size elasticity to test the model predictions presented above. To this end, the reduced-form framework used is as follows:

$$ln\left(Pay_{i,j,t}\right) = \alpha + \beta_1 \cdot ln\left(Size_{t-1}\right) + \beta_2 \cdot ln\left(Size_{t-1}\right) \cdot IPOActivity_{i,t} + \beta_3 \cdot IPOActivity_{i,t} \tag{2.3}$$

For the majority of my tests, I define a CEOs Pay as the natural log of total compensation (TDC1)[3], although I consider other measures of CEO compensation for robustness. EEE is set to the natural log of lagged market value. If a CEO has the ability to affect future cash flows, I believe that market value is a good proxy for productive assets. In addition, if IPO activity is correlated with asset productivity, this shock to productivity should be incorporated in a firms market value. By taking the natural log of both CEO compensation and

[3]TDC1 is the sum of all cash compensation, the total value of restricted stock grants, the Black-Scholes value of option grants, long term incentive payouts and all other compensation.

market value, EEE represents the elasticity of CEO pay to firm value, or the percentage effect on pay associated with a one percent increase in firm value. The interaction of logged market value with IPO Activity represents how pay-size elasticity changes with the level of IPO activity within an industry.

Table presents the results of OLS regressions of CEO compensation and the effects of an increased demand for managers. The primary variable of interest is the coefficient on the interaction between the natural log of market value and IPO Activity. The model presented in the previous section predicts that the pay-size elasticity will increase following the entrance of additional firms competing for CEOs. If this increased competition is correlated with IPO activity within an industry, the model predicts a positive coefficient on the interaction of IPO Activity and logged market value. All variables have been standardized by industry, with the exception of the natural log of firm market value, Ln(Market Value). Thus, the coefficient of Ln(Market Value) represents the elasticity of CEO compensation to firm value.

[Table 1 Approximately Here]

The first specification only controls for differences in average compensation across industries and years with fixed effects. Across the entire sample, the elasticity of pay with respect to firm market value is 0.429, indicating that a ten percent increase in firm value is associated with a 4.29 percent increase in CEO pay. Additionally, the coefficient of 0.0271 (t-stat=4.07) on the interaction term indicates that a one standard deviation increase in the trailing three year IPO activity within an industry leads to a 6.32% increase in pay-size elasticity.[4] Given the non-zero market values for all firms within the sample, if only market value and its interaction with IPO Activity were included in a regression, a positive coefficient would imply that the pay to all CEOs increased following an above average amount of IPOs within an industry. Therefore, IPO Activity is also included without an interaction. This inclusion allows pay-size elasticity to increase without simultaneously requiring the level of pay to also increase, decoupling the two effects. I will examine the effect of IPO activity on the level of CEO pay and discuss one possible interpretation of the negative point estimate on this coefficient shortly. To gauge the economic significance of this effect, the compensation is re-estimated using the point estimates following a one standard deviation increase in IPO Activity, and the average change across all observations is reported in Average Pay Change. With no performance controls, the average level of pay increases by more than $400,000 following a one-standard deviation increase in IPO Activity. Additionally, the effect of IPO Activity evaluated at the mean market value in the sample is statistically significant at the 0.1% level, as reported in the last row.

A broad array of controls for firm performance, including operating return on sales and market returns, and CEO tenure are added in Column 2.[5] Following their addition, there is a decrease in both the overall elasticity

[4] All reported standard errors are clustered at the firm level. For robustness, untabulated tests clustered at the industry, year, industry-year, and CEO spell level, as well as White (1980) heteroskedasticity-adjusted standard errors are also performed, with statistically-significant results.

[5] See Appendix B for a detailed description of the construction of these controls.

of pay to firm size (decreasing to 0.427) and its response to an increase in industry IPO activity (to 0.0232, t-stat=3.16). However, Average Pay Change remains relatively unchanged, decreasing by $2,700 to $404,600 after including performance controls.

While industry fixed effects are included in the first two specifications to account of differences in the average level of CEO compensation between industries, I restrict the pay-size elasticity to be equal across industries. Gabaix and Landier (2008) show that within a competitive wage framework, pay-size elasticity is directly related to the rate of decrease in managerial ability, which may differ across industries. Thus, I relax this constraint in the third specification by interacting a complete set of industry dummy variables with the log of market value. The change has little effect on the interaction between log market value and IPO Activity, decreasing it slightly to 0.0212 while also decreasing in its statistically significant (t-stat=2.86).

Under a framework of competitively set wages, the theory predicts that there should be a response to an increase in CEO demand within an industry. However, it is possible that my industry level measure of labor demand is correlated with overall market conditions which are also driving changes in the pay-size elasticity, biasing my estimates. Therefore, log market value is interacted with a full set of year dummies in Column 4, allowing for the average pay-size elasticity across all firms to vary by year. This inclusion leads to an increase in the sensitivity of pay-size elasticity to IPO activity, with a coefficient on the interaction term of 0.0251 (t-stat=2.94).[6] This represents an increase in pay-size elasticity of 5.88% relative to the average pay-size elasticity across the entire sample.[7] Additionally, the average change in compensation associated with a one standard deviation increase in IPO Activity increases to $412,100, which represents 6.3% of the average compensation in the sample.

All of the specifications considered to this point measure the effect of IPO Activity on a CEOs total compensation. One possibility is that times of increased IPO activity are positively correlated with industry volatility, increasing the value of option grants. To address this concern, Column 5 instead considers the effect on the natural log of cash compensation, defined as yearly salary plus bonus. The magnitude of the effect regarding IPO Activity on pay-size elasticity does decrease with a coefficient of 0.0129 (t-stat=2.14) relative to the analogous specification for total compensation (Column 4). However, the pay-size elasticity across the entire sample also decreases to 0.264. Thus, the effect of one standard deviation increase in IPO Activity now represents an increase in elasticity of 4.89% relative to its baseline value.

When constructing IPO Activity, each years total number of IPOs is scaled by the trailing three year average number of firms in the industry within

[6]To alleviate any concern that the effect of IPO Activity on the change in elasticity is being driven by changes in average compensation levels not adequately controlled for, industry-year fixed effects are included in untabulated results. The coefficient on the interaction term of IPO Activity and the log of market value is 0.0166 (t-stat=2.21).

[7]The interaction of logged market value with industry dummies (Specification 3) and year dummies (Specification 4) allows pay-size elasticity to vary across groups, but also eliminates the unconditional pay-size elasticity. To aid in relative comparisons, the coefficient from Column 2 is reported for both regressions.

the top 2000 firms. Therefore, the effects of IPO Activity on pay-size elasticity could be driven by changes in the denominator and not the number of firms going public. Therefore, Panel A of Table IA I reports the results after scaling the number of IPOs by the full sample average industry size. Additionally, the results in Table 1 use the market value of a firm is used to account for possible changes to firm productivity which would lead to higher levels of CEO compensation under a theory of efficiency wages. However, for robustness both the book value of assets (Panel B) and sales (Panel C) are considered as alternative measures of a firms size. The results remain relatively unchanged.[8]

The theory predicts that the elasticity of managerial wages to a firms productive assets increases with the demand talented managers. In the previous test, I use a firms market value as a proxy for the firms productive assets. However, this value is jointly determined by the firms productive assets and the managers ability.[9] Fortunately the models predictions also extend from a firms productive assets to the rank of such assets relative to other firms. Following the introduction of additional firms, while an increase in equilibrium wages paid should depress market values for all firms, the rank order of the market values of firms in an industry should continue to proxy for the rank order of the firms productive assets. Therefore, Table 2 repeats the previous tests but instead examines the effect of demand on the elasticity of wages to

[8]The interaction of IPO Activity and the natural log of sales becomes statistically insignificant when considering the effect on cash compensation in Column 5 of Panel C.

[9]Gabaix and Landier (2008) show that the contribution of managerial ability to a firms market value is small relative to the firms productive assets, so the results should not be signficianttly affected by using this proxy.

a firms percentile ranking. The results from Table 2 are fully consistent with those of Table 1, suggesting that the effect on market value does not play a significant role.

[Table 2 Approximately Here]

While these results suggest that pay-size elasticity increases following the entrance of new firms into the public equities market, they need not be the result of wages increasing more-so than market values. Alternatively, if pre-existing firms lose market share to firms going public resulting in lower market values, but the wages of managers remain relatively static, such a pattern could be generated.[10] To examine this possible explanation, I now consider a non-parametric approach based on a firms industry ranking. By focusing on a firms industry ranking rather than the firms market value, I remove any effects that a monotonic transformation of market values has on their relation to wages.

[Figure 3 Approximately Here]

Figure 3 presents the average amount of log wages within industry deciles for low and high levels of IPO activity, after controlling for firm performance, year and industry effects. Within each industry, High IPO and Low

[10]An increase in size-wage elasticity would also require that firms drop in market value in a disproportionate but systematic manner, with the smaller firms losing a smaller percentage of their market values.

IPO contain all observations in the top and bottom terciles of IPO Activity, respectively, as previously defined. The shaded bars represent 95% confidence intervals, testing for a difference between each deciles High IPO and Low IPO averages. While wages are systematically larger in times following above average levels of IPO activity, those firms falling into the smallest three deciles have statistically insignificant differences in wages between the High IPO and Low IPO groups. Beginning in the fourth decile, the difference in wages is statistically significant at the 5% confidence level for all remaining deciles. Furthermore, the magnitude of the difference is at its greatest for the top three deciles.

This figure also gives some insight into the negative coefficient of IPO Activity in Table 1. While there is still a positive difference in pay for the smallest size deciles, the pay differential widens as the size decile increases. However, all firms in our sample have large market values. If both series were extrapolated to a firm with a log market value of zero, compensation in the Low IPO group would be larger than that of High IPO. This is consistent with the negative coefficient of the uninteracted IPO Activity variable in Table 1.

2.3.2 Size Varying Effects of IPO Waves on Pay-Size Elasticity

The comparative statics for the model presented in Section II are generated by increasing an additional measure of firms with the same distribution of firm sizes as the incumbent firms. While this is done for parsimony, the empirical tests of this prediction are based on the number of firms becoming publicly traded. Unlike the motivating example, it is unlikely that these firms are equally distributed throughout the size distribution. It is more likely that these firms tend to be smaller in their market value. Furthermore, larger firms going public are more likely to already have a CEO in place capable of running a large company, private or public. Rather, if firms are only introduced in the lower half of the size distribution, the equilibrium response of wages will vary conditional on firm value. For firms below the median market value, where an additional measure of firms is introduced, the change in pay-size elasticity will be similar to the results of Section II. However, the wage response will differ for all firms above the median value, a region in which no new firms are introduced. While wages paid by these firms will increase in their level, the pay-size elasticity in this region will remain unchanged.

If IPOs are concentrated among the smaller firms in the sample and wages are responding to an increase in the competition for managers, the inclusion of larger firms in the sample will attenuate the coefficient on the interaction between log market value and IPO Activity and decrease its statistical significance. Alternatively, CEO compensation could instead represent an efficiency wage required to induce the optimal level of effort. If the number of firms going public is correlated with the productivity of firms within an industry, wages will also increase. To the extent that this increase in productivity is not captured in market values, the interaction of IPO Activity with log market value may capture the effect.[11] However, if IPOs are correlated

[11]However, if this leads to an increase in wages by a common factor across all firms,

with the productivity of firms in an industry, the effect should affect all firms and not be absent in the largest firms.

[Table 3 Approximately Here]

Therefore, Table 3 presents identical model specifications as Columns 4 and 5 of Table 1, while excluding sample observations with the largest market values. For ease of comparability, the first column redundantly reports Column 4 of Table 1. In the second specification, the top 100 ranked firms according to lagged market value for each year are excluded from the sample. Following their expulsion, the effect of a one standard deviation increase in IPO Activity on pay-size elasticity increases both in magnitude, with a coefficient of 0.0357 (compared to 0.0251 in the full sample) and also becomes more statistically significant (t-stat=3.55). Additionally, the average change in compensation also increases to $515,100 following the elimination of the top 100 firms. When the exclusion criteria is extended to remove the largest 250 firms in the third column, the effect again increases to 0.0439 (t-stat=4.27). Therefore, a one standard deviation increase in IPO Activity now increases pay-size elasticity by 9.3% of its full sample average. These results are confirmed in Columns 4 through 6, when examining the effect on only cash compensation.

[Figure 4 Approximately Here]

because the log of total compensation is being considered the effect would be captured in the coefficient of IPO Activity and not its interaction with Ln(Market Value).

Figure 4 illustrates this effect by contrasting a piece-wise form of the regression in Column 1 of Table 3 and the percentage of IPOs within industry rank deciles. The solid squares represent the coefficient of IPO Activity x Logged Market Value, segmented by industry size deciles. Hollow diamonds illustrate the percentage of firms going public which fall into each decile based on market value two years following the IPO. Both the effect of IPO Activity on pay-size elasticity and the percentage of IPOs in the sample are disproportionally concentrated among the smaller size deciles.

Both Table 3 and Figure 4 suggest that the effect that IPO activity has on pay-elasticity is concentrated more-so in smaller firms in the sample, where the majority of firms going public also enter the economy. If CEO compensation is set to induce the optimal level of effort, and IPO activity is correlated with firm productivity, wages would also increase during periods of above average IPO activity. However, it is not immediately clear why the effect would be greater for smaller firms. In contrast, this pattern is consistent with a response of wages to competitive pressures. To further disentangle these two theories, I now turn to the reallocation of managerial talent within industries.

2.3.3 Increased Competition and Executive Transitions

The previous section presents evidence consistent with an increase in the competition for CEO labor following the entrance of new firms, leading to an increase in pay-size elasticity. However, under certain conditions this outcome could also be consistent with a moral hazard setting, where periods of above average IPO activity are associated with an increase in the productivity of assets. While both theories could potentially explain such a relation, within a competitive framework the change in wages is an equilibrium condition associated with the efficient allocation of managers across firms. Therefore, an increase in the competition for managerial effort brought about by the entrance of more firms into the labor market would be accompanied by a greater degree of talent reallocation. Such a prediction is not shared by a moral hazard explanation.

I now seek to test this prediction empirically by examining the transition of executives across firms under a competing-risks survival framework.[12] The use of a competing-risks regression allows me to disentangle executive transitions within industries from transitions to other industries or other events that prevent an executive transition from occurring, thus right-censoring spells. I begin by constructing spells for each of the top 5 executives as reported by Execucomp for every firm within my sample. For each spell, a transition event is classified as taking place if the individual is reported in the top five executives of a second firm within three years following the departure from their previous firm. Additionally, I require that both firms reside in the same industry to ensure that the event captures the reallocation of talent within an industry. I define a competing event as the transition to another industry, or where the individuals spell ends and they do not appear at another firm within three years. Additionally, all spells whereby the individuals previous firm drops out

[12]Specifically, I use the proportional sub-hazards model of Fine and Gray (1999).

of the sample are also classified as competing events, as these instances are not consistent with an executive being hired away. When an individual is reported as being within the top five managers of two firms in the same fiscal year, I first rank each observation based on the annual CEO distinction and then by total compensation received, retaining the first observation for each individual-year.

[Table 4 Approximately Here]

Table 4 presents the results of the competing-risks regression for the top five executives of all firms within the sample. I consider the spells of all five executives as opposed to the CEO alone for two reasons. A transition of a non-CEO between firms is motivated by the additional value the individual adds to the firm they join, consistent with a reallocation of talent in the spirit of the model. In addition, by considering the spells of all five individuals the frequency of transitions is increased, adding power to the test.

The first specification reports the results with only the inclusion of IPO Activity, the standardized trailing three year IPO activity within an industry. Reported are the sub-hazard ratios, similar to the hazard ratio of a Cox proportional-hazard model. Without controlling for any other determinants, IPO Activity is a statistically significant predictor of executive transitions between firms. A one-standard deviation increase in IPO Activity is associated with an increase in the odds of transitioning by 17.9% (z-stat=4.12). The inclusion of controls for firm performance and differences in firm characteristics in Column 2 marginally reduces the coefficient of IPO Activity to 1.169 (z-stat=3.15), indicating a one-standard deviation increase in IPO Activity within an industry is associated with a 16.9% increase in the odds of an executive transitioning to another firm. However, larger firms are more likely to have talented non-CEO executives who are valuable to other firms, making them more likely to be tapped by newly public firms. Therefore, the lagged market value of the firm is also included as a control in Colum 3. Both the coefficient and statistical significance of IPO Activity remain relatively stable. Additionally, this specification confirms that larger firms are more likely to have their top executives transition to other firms.

While the previous specifications indicate that above average IPO activity within an industry is associated with a higher likelihood of executives transitioning between firms, such events may represent individuals being demoted rather than being hired away. Thus, I define an Upward Transition in a similar manner to the previously defined transition event with the additional requirement that the total compensation of the executive increases in the first year following their transition. All transitions not meeting this additional requirement are reclassified as an additional competing event. While this reclassification reduces the statistical significance of each specification, the point estimates remain relatively unchanged with sub-hazard ratios ranging from 1.155 (z-stat=3.05) without any controls to 1.180 (z-stat=2.74) when a complete set of controls are included.

The results in Table 4 present evidence that executives are more likely to transition between firms during times of above average IPO activity. This is supportive evidence for the use of IPO activity as a proxy for the competition among firms for CEOs. However, within the context of the model, pay-size elasticity increases with the number of firms which need to be matched with CEOs. Therefore, I now test the validity of firms going public as a proxy for new firms which require managers.

To begin, I categorize the two firm-years following a firm going public as IPO Eligible observations. I then count the number of executives that transition from a firm in the sample to an IPO Eligible observation. There are 88 such instances within the sample. A random sample is then generated by replacing, without replacement, each IPO Eligible observation with a randomly selected non-IPO Eligible observation from the subset of firms in the same industry and year. I then count the number of transitions from a firm in the sample to this random sample. Figure IA 1 reports the resulting distribution following 10,000 iterations of this process. The median number of executive transitions is 15.[13] Thus, the number of executives which transition to firms recently experiencing an IPO exceeds a randomly selected sample by a factor of 5.9.

Overall, the findings presented in Table 4 and Figure IA 1 indicate that times of increased IPO activity within an industry are associated with greater

[13] The maximum number of transitions over all random samples is 32.

mobility of executives across firms, consistent with the reallocation of talent following an increase in the competition for managerial labor. These results present the first evidence supporting the direct prediction of competitively set wages that when the number of firms competing for an inelastic supply of able CEOs increases, the pay-size elasticity also increases. I now turn to the cross-sectional properties of this effect across industries where CEO labor elasticity differs.

2.4 Cross-Sectional Effects of IPO Waves on Pay-Size Elasticity

The previous sections provide evidence consistent with market forces substantially affecting CEO compensation and the reallocation of talent across firms which cannot be completely explained by theories of rent extraction or efficiency wages. However, while the comparative statics generated from the model are applicable to all industries, if wages are influenced by competitive pressures the magnitude of the effect is likely to differ across firms and across industries. Therefore, to further contrast a theory of competitively set wages from alternative hypotheses, I seek additional evidence in the cross section of industries and firms.

2.4.1 Cross-Sectional Effects across Industries

While the motivating model presented here is of a single industry, it need not be the case that CEOs appointed to very large firms have prior experience within that industry. Additionally, the skills necessary to manage a firm and the necessary amount of human capital a CEO must accumulate likely vary across industries. If the increase in the pay-size elasticity is in response to an increase in CEO demand, this response should be greater in industries that are harder for outsiders to learn, and are more specialized. CEO labor in these industries should be more inelastic, leading to a larger sensitivity of pay-size elasticity to an increase in the competition among firms. Therefore, I construct empirical measures along three dimensions to capture industry uniqueness and skill specialization on the CEOs part.

The first measure I consider is the percentage of an industrys CEOs hired from outside the industry. Industries which require more industry-specific knowledge are likely to have a smaller percentage of CEOs hired with no prior industry experience. I begin by extending the data from Eisfeldt and Kuhnen (2013), classifying each hire in the sample as having prior industry experience by using their employment histories, as reported by BoardEx. I define % Outside Hires as the number of CEO successions within an industry with no prior industry experience divided by the total number of CEO successions in that industry.

While % Outside Hires will correctly classify a CEO as having prior industry experience if all industries are completely segmented, it is not uncommon for two firms to differ in their primary operations but share other lines of business. An example of this is the classification of one company into the 'Food Products' industry while another is placed in the 'Candy & Soda' industry, or alternatively the overlap between the 'Computers' and 'Electronic Equipment' industries. Therefore, to capture the overlap between industries, using data from the previous year I define % Overlapping Segments for industry i at time t as follows:

$$\%Overlapping\ Segments_{i,t} = \frac{\sum_{j \neq i} \sum_{f \in j} s_{f,i,t-1}}{\sum_{j \neq i} n_{j,t-1}} \quad (2.4)$$

where $s_{f,i,t-1}$ is the percent of sales by firm f in industry i for year t-1, and $n_{j,t-1}$ equals the number of firms belonging to industry j in year t-1, as reported in Compustats Historical Segments database. Therefore, a larger value of % Overlapping Segments indicates an industry in which there is more overlap from firms in other industries. Therefore, % Overlapping Segments will capture the exposure of CEOs from other industries with industry i.

Finally, I construct a measure of industry isolation, Industry Return Comovement, for industry i at time t as the following:

$$Industry\ Return\ Comovement_{i,t} = \frac{\sum_{j \neq i} corr\left(r_i, r_j\right)}{47} \quad (2.5)$$

where $corr\left(r_i, r_j\right)$ is the correlation between the value-weighted monthly portfolio returns of industries i and j over the interval t-11 to t-1.[14] Industries whose returns are less correlated with other industries are also more likely to be unique, requiring specialized managerial skills While both % Overlapping

[14] I also consider portfolio returns of equal-weighted industry portfolios in untabulated results, which remain unchanged.

Segments and Industry Return Comovement are constructed using a rolling window of past information, % Outside Hires uses the full sample period when estimating the variable. The full sample period is used to reduce the measurement error in the variable, as the number of CEO successions is quite low in some industries.

[Table 5 Approximately Here]

Table 5 reports the results of OLS regressions of log CEO compensation on the log of firm market value, the interaction of log market value and IPO Activity, and the three-way interaction between log market value, IPO Activity, and standardized forms of each measure of industry uniqueness/CEO importance. This three-way interaction will be used to test for variation in the effect of competition on pay-size elasticity across industries. While the interaction of IPO Activity and log market value represents the effect that an increase in CEO demand has on the pay-size elasticity, this value interacted with industry-level uniqueness measures indicates how the effect of increased demand on pay-size elasticity varies with a one standard-deviation increase in industry uniqueness or CEO importance.

Columns 1 and 2 report the results when considering the interaction with % Outside Hires. The coefficient of -0.014 (t-stat=-1.97) in Column 1 indicates that a one-standard deviation increase in the percentage of CEOs hired from outside the industry reduces the effect of IPO Activity on pay-size elasticity by 150% of its baseline effect.[15] This is supportive of the prediction that the effect of a shock to the competition for CEOs should be greater when an industry is harder to learn and successors cannot be readily drawn from outside the industry. Column 2 includes the full set of performance and firm characteristic controls, with the coefficient on the three-way interaction decreasing slightly to -0.0121 and also decreasing in statistical significance (t-stat=-1.67). However, while the full sample average is used, as I will show later, the increase in demand for CEO talent within an industry may be related to the percentage of CEOs hired from other industries.

Therefore, I now turn to % Segment Overlap, which is estimated on a rolling basis using prior information. Columns 3 and 4 focus on the percentage of sales overlap firms from all other industries have with the industry experiencing a shock to the demand for CEO labor. The coefficient of -0.0427 (t-stat=-1.86) on the interaction term indicates that a change in overlapping sales of an industry has a dramatic influence on the effect of a labor demand shock on pay-size elasticity. Again, after controlling for firm performance in the fourth specification, the results remain quantitatively similar.

While the previous measure captures the overlap that other industries have with the industry experiencing the IPO wave, firms need not have sales in the same industry to be related. Thus, I turn to my third measure based on return correlations across industry portfolios, Industry Return Comovement,

[15] -0.014 / 0.0093 = -150.5%. Likewise, a one-standard deviation decrease in the percentage of outside hires increases the magnitude of the effect by 150%.

in columns 5 and 6. When firm performance is not controlled for in the fifth specification, the negative coefficient of -0.0279 (t-stat=-2.62) indicates that a one-standard deviation increase in the average correlation between an industrys returns and each of the other industries reduces the effect of an IPO wave on pay-size elasticity by 117%. After controlling for firm performance in column 6, the coefficient decreases slightly to -0.0205 with a t-statistic of -1.82. Thus, as an industrys returns become less correlated with other industries the effect of an IPO wave on pay-size elasticity becomes larger.

Finally, because these measures are likely correlated across industries, Columns 7 and 8 include all three measures to assess their joint significance. Without the inclusion of any performance controls, the point estimates for the interactions of both % Outside Hires and Industry Return Comovement remain stable and statistically significant at the 10% level. A Wald test of joint significance among all three variables rejects the null of no effect for any of the three variables with a p-value less than 0.0001. However, when performance controls are included in Column 8, both measures of the elasticity of an industrys labor supply become statistically insignificant at the 10% level. While all three measures are statistically significant when included alone, a test of their joint influence and all of the associated terms required reduces the power to detect each measures individual effect.

Overall, the results in Table 5 indicate that the effect of an industry level shock to the demand for CEO labor has a larger effect on pay-size elasticity in industries where firms are less likely to hire from outside the industry, in industries where there is fewer overlap in sales from firms in other industries, and in industries whose stock returns are less correlated with other industries. However, while this analysis suggests that IPO activity influences pay-size elasticity differently across industries in a way consistent with market pressures influencing CEO pay, there may be other unobservable firm characteristics that differ across industries which could potentially explain these results. Therefore, I now turn to cross-sectional variation at the firm level for additional evidence validating the effect of market pressures on CEO pay.

2.4.2 Cross-Sectional Effects across Firms

Within the context of the model outlined in the previous chapter, the increase in both wages and pay-size elasticity is caused by an increase in the competition for managerial labor. Contrary to this view of competitively set wages, both Jensen, Murphy and Wruck (2004) and Bebchuck and Fried (2003, 2004), among others, argue that the high levels of compensation observed can be explained by rent extraction. Thus, if managers can extract more rents during IPO waves and can do so to a greater extent in larger firms, then pay-size elasticity would be positively related to IPO activity within an industry. Under this hypothesis, the effect of IPO activity on pay-size elasticity should be greater in more poorly governed firms. Alternatively, wages may be determined by a combination of competitive market forces and rent extraction. Under this hypothesis, wages paid by well governed firms should respond more to market pressures, leading to a larger effect of IPO activity on pay-size elasticity in well governed firms. Using firm level governance data, I now seek empirical support regarding these two hypotheses.

To examine the effects of governance, I use two measures of corporate governance. I begin with the G Index of Gompers, Ishii and Metrick (2003) which proxies for the level of shareholder rights along 24 dimensions. In addition, I also consider the E Index set forth in Bebchuk, Cohen and Ferrell (2009), which consists of the six categories of the G Index found to be related to a reduction in firm value.[16]

[Table 6 Approximately Here]

Table 6 presents the results of OLS regressions when interacting the G Index and E Index with the previously defined measure of the sensitivity of pay-size elasticity to IPO activity. The inclusion of governance measures reduces the sample size for two reasons, both reduced coverage in the number of firms relative to Execucomp and governance data that only runs through 2006. The first two specifications present results after standardizing G Index across all observations. Lower values for the G Index indicate highly governed firms. In the first column, after controlling for year and industry fixed effects, a one standard deviation increase in G Index decreases the effect of IPO Activity on pay-size elasticity by 0.0030 (t-stat=-2.52), or 24.6% of its baseline value.

[16]Specifically, the six categories are: staggered boards, limits to shareholder bylaw amendments, poison pills, golden parachutes, and supermajority requirements for mergers and charter amendments.

Furthermore, a one standard deviation increase in G Index is also associated with an increase in the average level of logged CEO compensation of 0.046 (t-stat=2.71). After controlling for firm performance in the second column, the interaction becomes stronger economically with a coefficient of -0.0034 (t-stat=-2.75).

While industry fixed effects are included, these only control for differences in the level of CEO compensation across industries, while I am interested in how the interaction of IPO Activity and pay-size elasticity changes with firm governance. To the extent that governance is correlated within industries, this clustering would not be controlled for with industry fixed effects. Therefore, Columns 3 and 4 present the results after standardizing G Index within each industry. Thus, G Index now represents the governance of a firm relative to its industry average. After controlling for industry level governance, the results remain virtually unchanged with only fixed effect controls (coefficient of -0.0032, t-stat=-2.74) and with firm performance controls (coefficient of -0.0034, t-stat=-2.70). Additionally, when using E Index as a proxy for firm governance in the last four specifications, the results are qualitatively and quantitatively similar both across all firms and within industries and both with and without performance controls.

Table 6 indicates that the effect an increase in the demand for CEO labor has on pay-size elasticity is stronger in more strongly governed firms. This result is consistent with market forces playing a role in the determination of CEO compensation, and inconsistent with compensation being driven solely by the ability of a CEO to extract rents from shareholders. I now seek additional validation that IPO activity within an industry is capturing the depletion of the industrys talent pool thereby raising the outside options of CEOs and increasing their market.

2.4.3 Validation of IPO Waves as a Proxy of Increased Demand for CEOs

The empirical analysis performed in the previous section rests on the effectiveness of IPO waves as a proxy for times of increased demand for CEO labor relative to supply. If IPO activity within an industry does represent a shock to the demand for CEO labor, this shock should affect other decisions of a firm beyond CEO compensation. To this end, I turn my attention to a firms choice of successor following the departure of its incumbent CEO.

While not explicitly modeled here, the intuition behind the effect of an IPO wave falls along the same lines as the "talent pools" described in Cremers and Grinstein (2013). When a firm experiences managerial turnover, it must select a new manager from one of three sources. The firm can choose the successor from within the firm, from another firm within the industry, or they can choose a manager with no prior industry experience. If the talent pool within an industry is effectively drawn down during times of above average IPO activity, the likelihood of choosing an incoming CEO from outside the industry should increase.

Each possible successor type has a potential benefit or drawback. For instance, a firm insider may possess firm-specific knowledge that will improve their performance. Additionally, a firm may have asymmetric information regarding the talent level of a potential inside successor relative to other firms in the industry. Alternatively, potential mangers from inside the industry may have also accumulated industry-specific human capital relative to industry outsiders. Furthermore, the number of potential candidates within the industry is likely much larger than the pool of talent within the firm. Finally, the number of potential candidates outside the industry is larger still, but may not contain the necessary industry or firm-specific knowledge needed to be an effective CEO.

When evaluating the choice between choosing a firm insider and an industry insider, the firm likely has superior knowledge regarding the firm insider while sharing a common knowledge of industry insiders with all other firms, including those going public. This latter group can be viewed as those individuals who have previously demonstrated their abilities. Therefore, newly public firms are likely to be biased towards this pool of individuals in the industry with a prior track record, thereby drawing down on this talent pool. This would lead to an increased probability of a firm choosing its successor from inside the firm. Additionally, when considering the decision between a firm insider and an industry outsider, while IPO activity within an industry would increase the likelihood of a firms first choice within the company being poached by a firm that recently went public, it should have a smaller effect on the pool of CEO talent from outside the industry. Thus, the effect of IPO activity on talent pools should be largest for industry insiders and smallest for industry outsiders, leading to a decreased likelihood of choosing an industry insider and an increased likelihood of choosing a successor from outside the industry.

[Table 7 Approximately Here]

Panel A of Table 7 presents the results of a multinomial logit regression framework used to test this hypothesis. Columns 1 and 2 report the relative risk ratios of a successor being an industry insider or an industry outsider relative to the base case of being chosen from within the firm. The ratio of 0.850 (z-stat=-2.14) in the first column indicates that a one-standard deviation increase in IPO Activity is associated with a 15.0% decrease in the odds of choosing a successor from within the industry over a firm insider. This likelihood also decreases with an increase in the former CEOs tenure, Ln(Tenure). The second column indicates that the likelihood of a firm choosing its next CEO from outside the industry relative to a firm insider increases by 13.4% with a one standard devation increase in IPO Activity, although the effect is only marginally statistically significant with a z-statistic of 1.89. These results remain virtually unchanged after controlling for firm performance (specification 2). To control for the possibility of market conditions driving the results, I take two approaches. As a first step, I construct a measure of market IPO activity for an industry in a similar fashion to IPO Activity. Specifically, Market IPO Activity equals the number of IPOs in all other industries over the same period, scaled by the number of firms in all other industries. The inclusion of this measure of overall IPO activity has no material effect on IPO Activity. Alternatively, year fixed effects are included in Specification 4, leading to a loss of statistical significance regarding IPO Activity. However, given the small number of successions chosen from outside the industry, the inclusion of year fixed effects will reduce the power of the test if there is any clustering of these choices by year.

However, while the previous analysis considers a menu of three possible, the choice of a firm insider may also be influenced by other unobservable firm-specific factors. For example, the commitment of some firms to a tournament structure similar to that of Lazear and Rosen (1981) would lead to the hiring of an insider over either alternative source of CEO talent, increasing the variance of the error term and reducing the power of the test. Therefore, Panel B of Table 7 examines the choice of picking a successor from either inside the industry or outside the industry, conditional on not being a firm insider. Column 1 reports odds ratios of a plain logit regression where the base case is the successor coming from within the industry. The coefficient of 1.373 (z-stat=3.13) indicates that a one-standard deviation increase in IPO Activity increases the odds of choosing the successor from outside the industry by 37.3%. This effect increases to 49.5% (z-stat=3.02) after controlling for firm performance in Column 2. Following the addition of Market IPO Activity in Column 3, the coefficient on IPO Activity both increases to 1.566 and becomes more statistically significant with a z-statistic of 3.32. Similar to Panel A, IPO

Activity becomes insignificant following the inclusion of year fixed effects.

Overall, an increase in the number of firms going public leads to an increase in the likelihood of an established firm choosing a new CEO from outside the industry relative to an industry insider, consistent with increased IPO activity drawing down the industrys talent pool of potential CEOs.

Chapter 3

Effects of a Matching Friction in the CEO Labor Market

3.1 Motivation

The model presented in Chapter 1 and empirically tested in Chapter 2 of this work is built on the work of both Gabaix and Landier (2008) and Terviö (2008). However, an assumption common to both models is socially optimal matching between firms and managers in a frictionless labor market, where matches are formed in a positive assortative nature. In reality, a firm faces an explicit cost when switching managers, which includes severance pay and lost productivity while the new CEO learns the company. Thus, changes to a firms value and overall productivity due to technology shocks, exogenous industry contractions or expansions, and other factors beyond the control of the firm will result in a distortion to positive assortative matching in the cross-section. It is unclear how implications from a model of efficient matching are affected by such a friction. Furthermore, reduced-form methods can establish a lower bound for the economic magnitude of this friction by measuring the decrease in a firms earnings around the turnover of its CEO. However, this estimate understates the true reduction in firm value which also encompasses the value destroyed by an inefficient match between firms and managers as a result of the switching cost.

In this chapter I estimate a dynamic matching model of firms and CEOs with an embedded switching cost that results in inefficient matching in the cross-section. This allows me to re-evaluate the importance of CEO talent while simultaneously estimating the reduction in overall firm value relative to a frictionless economy where firms and CEOs are always optimally matched. In the model, a firm experiences a series of shocks to asset productivity that result in an inefficient match with the incumbent CEO. The firm can elect to replace the existing manager with an optimal replacement from the CEO labor pool but must pay a fixed cost to do so. The decision to retain or replace the incumbent CEO is the outcome of a dynamic programming problem based on the current productivity of the firms assets in place as well as the existing managers talent level.

I estimate this structural model using data on executive compensation and tenure along with firm profitability for large U.S. firms from 1992-2011, gauging the impact of inefficient matching on a firms overall value. I find that the cost of switching managers constitutes a non-negligible percent of a firms annual profits. Using counterfactual analysis, I find that this cost results in a 4.8% decrease in median firm value. While this is partially attributable to the explicit cost paid by the firm when switching managers, I find that the implicit cost from the resulting suboptimal matching scheme constitutes 76.2% of the total reduction in firm value.

The dynamic model presented here is built on the groundwork set forth in Gabaix and Landier (2008). They present a static model in which heterogeneous managers with publicly observable talent and heterogeneous firms which differ in the amount of their productive assets meet in a frictionless labor market. The positive assortative matches formed in equilibrium represent the value optimizing assignment of CEOs to firms. In contrast, this chapters model departs from this static framework by allowing the productivity of a firms assets to vary over time. Each period, a firm receives a positive or negative shock to the productivity of its assets. These shocks reduce the efficiency of the match with the incumbent CEO. Thus, the firm has an incentive to enter the labor market to be optimally matched with a new CEO.

I embed a switching cost in the model that the firm must pay in order to reenter the CEO labor market, discouraging the firm from continually seeking an optimal replacement. This switching cost is meant to represent the search cost to find an adequate replacement, a period of reduced productivity during the transition period, severance pay, and possible firm-specific knowledge that must be acquired by the new manager, among other factors.[1] Therefore, if a firm chooses to retain its incumbent CEO following a shock to productivity due to the switching cost, the resulting match will be an inefficient one relative to a frictionless economy. Furthermore, the inefficiency of this match increases following a series of positive or negative shocks which aggregate together.

The firm effectively chooses how much the productivity of its assets can

[1] Almazan and Suarez (2003) look specifically at severance pay and entrenchment to prevent the replacement of an incumbent CEO with a superior replacement.

change before replacing its manager with a more suitable one. This decision, and hence the degree of inefficiency that can be maintained in equilibrium, is also influenced by the dispersion in CEO talent. If managers are virtually homogenous, a firm has little incentive to replace its existing manager and suffer a switching cost. It is also influenced by the current matches of CEOs as well the anticipated competition from other firms in the labor market, which are endogenously determined in equilibrium.

I estimate this dynamic model to gleam some insight into the importance of CEOs and their contribution to firm value. This also allows me to generate counterfactual scenarios to gauge the destruction in firm value as a result of such frictions in the CEO labor market. I estimate parameters related to the dispersion of managerial talent, the cost associated with changing managers, and the volatility of a firms productive assets using the Simulated Method of Moments (SMM) approach. I identify these parameters using data on the persistence and cross-sectional properties of earnings, earning patterns around CEO turnover, the frequency of these turnover events, relative changes in firm values and executive compensation.

Empirically, I find that CEOs are quite heterogeneous in their ability, with the most talented manager able to generate gross profits greater than the average CEO of the 500 largest firms by a factor of 1.78. I estimate the tail thickness of this managerial distribution to be consistent with the findings of Gabaix and Landier (2008). The cost a firm experiences when switching managers is estimated to be 2.18% of its assets in place, or 20.0% (23.2%) of the median (mean) firms yearly return on assets. However, this decrease in a firms earnings only accounts for one-fourth of the reduction in its value. The remaining reduction in firm value is attributed to the inefficient CEO match the firm tolerates in order to avoid suffering the switching cost on a more frequent basis. Using counterfactual analysis, it is estimated that the median (mean) firms value would increase by 5.06% (4.21%) were it able to replace managers in the absence of a switching cost.

While the structural model used here has as its basis the model of Gabaix and Landier, the two also differ along many avenues. My model endogenizes the distribution of available managers in the labor pool each period. Also, while they take firm value as exogenously given when identifying the talent distribution, in this chapter it is endogenously determined as a function of both manager talent and wages paid. Finally, the two works differ in their scope and focus. Gabaix and Landier explain the rise in CEO compensation over the recent decades using a competitive equilibrium framework. In addition to extending this framework to a dynamic setting, I also seek to examine the implications that inefficient matching between firms and managers has on a firms value.

3.2 Model Setup

I begin by briefly presenting the static matching model of both Gabaix and Landier (2008) and Terviö (2008) and the resulting equilibrium wage function to show the intuition of the equilibrium wages and matching procedure. I will then extend the model into a dynamic framework and discuss the resulting departures from the static equilibrium.

3.2.1 Static Model and Equilibrium

The model environment consists of a continuum of firms with heterogeneous levels of productive assets $A \in \left[\underline{A}, \overline{A}\right]$, whos distribution is characterized by $f_s(A)$. Additionally, the economy is populated with a continuum of managers with fully observable, heterogeneous talent levels, $\theta \in [\underline{\theta}, \theta_{max}]$, whos distribution is governed by $f_\theta(\theta)$. All individuals share a common reservation wage, $\underline{w}$.

Profits are a function of a firms productive assets, the CEOs talent level and wages paid:

$$\pi = A \cdot \theta - w \tag{3.1}$$

Managerial talent is modeled as a multiplicative effect on a firms gross profits. Thus, a superior CEO can make every dollar under her control more productive, relative to a less talented manager. In equilibrium, given observable talent, managers and firms are matched in accordance with the assignment equation of Sattinger (1979), as a result of the following equilibrium wage condition. Define the mapping of a manager in the pth percentile of the talent distribution as $T(p) \equiv f_\theta^{-1}(p)$. Similarly, let $S(p) \equiv f_s^{-1}(p)$, represent the productive assets of a firm in the pth percentile. Then, the equilibrium wages paid to a manager in the pth percentile with talent $T(p)$ have the following property:

$$\frac{\partial W\left(T\left(p\right)\right)}{\partial p}=S\left(p\right)\cdot\frac{\partial T\left(p\right)}{\partial p} \tag{3.2}$$

As a result, each firm is exactly indifferent between the manager it is matched with in equilibrium and a manager with a talent level one epsilon greater, thus preserving positive assortative matching between firms and managers. Furthermore, the smallest firm in the economy with assets $\underline{A}$ will be matched with a manager of talent $\underline{\theta}$, whos wage will be set at her reservation level $\underline{w}$. From this fixed point and (2), competitive wages follow from the following equation:

$$W\left(\theta\right)=\underline{w}+\int_{0}^{F_{\theta}(\theta)}S\left(u\right)\cdot T\left(u\right)'\,du \tag{3.3}$$

However, while the static model gives insight into the formation of wages and the matches between firms and managers in equilibrium, it assumes that there are no frictions preventing the positive assortative matching between CEOs and firms. Therefore, I now present the dynamic model with an embedded switching cost examined in this chapter.

3.2.2 Dynamic Model

Similar to the static model, the dynamic framework consists of a measure one continuum of heterogeneous firms and managers. In contrast to the previous model, firms are modeled as being infinitely lived while managers possess a finite lifespan. Additionally, each firm experiences a shock to its assets, possibly has its CEO retire or fired, and realizes profits within each period. Profits are modeled in a similar fashion to (1) with a few exceptions.

Each periods profits remain a function of the productivity of a firms assets, the talent of the manager, and equilibrium wages paid. However, these profits are also a function of an unobservable idiosyncratic noise component (ε_t), and if applicable a switching cost imposed if a firms incumbent manager is replaced ($c_{replace}$) or retires (c_{retire}):

$$\pi_t = A_t \cdot \left(\theta_t + \varepsilon_t - 1\left(replace\right) \cdot c_{replace} - 1\left(retire\right) \cdot c_{retire}\right) - w_t \qquad (3.4)$$

$$\varepsilon \sim N\left(0, \sigma_{\varepsilon}^2\right)$$

The cost of managerial replacement is modeled as being linear in a firms productive assets. This single factor represents the search cost to find a suitable replacement, the decrease in productivity during the interim period, and other losses incurred by a firm, which likely increase with a firms size.[2] I do not restrict the cost imposed on a firm for managerial retirement, which is also linear in productive assets, to be equivalent to managerial replacement. As a CEO approaches retirement age, the firm is able to seek out a successor in advance to avoid times of reduced productivity during the transition period. In the model, retirement follows an exponential arrival time with probability of δ for estimation feasibility. Finally, an additional idiosyncratic noise component is considered in the dynamic model. While not necessary when estimating a static model, when considering the estimation of a dynamic model this noise component allows for the inclusion of additional time-series moments useful in identification of the models parameters.

[2] Yermack (2006) finds that golden handshakes or severance pay for CEOs increases with firm value.

While firm profits are modeled in a slightly different form in the model considered in this chapter relative to the static model of Gabaix and Landier (2008), the dynamic nature of the model stems from changes to a firms productive assets. These fluctuations encompass changes to a firms assets in place, contractions or expansions to a firms industry, or technology shocks, all of which affect a firms profits. All of these contributing factors are captured in the model by a firms productive assets. However, in reality a firm can choose the level of assets in place. Therefore, the productive assets considered here can be interpreted as the optimal size of the firm given industry and technology conditions, relative to the other firms in the economy. To capture these changes, each period a firm receives a shock to its productive assets, governed by the following processes:

$$\begin{aligned} A_t &= A_{t-1} \cdot x_t \\ x_t &\sim U\left(1-\gamma, 1+\gamma\right) \end{aligned} \tag{3.5}$$

The choice that shocks be drawn from a uniform distribution is made for computational convenience, although the consideration of other distributions is easily done with a concession to the estimation time.

Figure 6 illustrates the timing of the model within each time period. At the onset of the period, the firm experiences a shock to productive assets. While the timing of the shock is modeled at the beginning of the period, it can also be thought of as gradually occurring throughout the length of the previous period, and will now be acted upon. Following this shock, each firm faces the possibility of its CEO retiring, which will occur with probability δ. Immediately following the realization of retirements, all remaining firms must choose to retain the incumbent manager or enter the labor market and be matched with a replacement. If a manager is fired from their current firm they re-enter the labor pool. There, they will be joined by a cohort of newly born CEOs of measure who take the place of the individuals who retired. At this point all firms in need of a CEO, by choice or because their incumbent CEO retired, enter the labor market and are simultaneously matched with a new manager. While broken down into three different steps, these events can be thought of as occurring almost simultaneously at the beginning of the period. Following this matching process, every firm commences production. Finally, profits are realized at the end of the period at which point the process repeats itself.

[Figure 6 Approximately Here]

For simplicity, each periods profits are immediately paid out as a dividend to shareholders. Thus, there are only two sources of variation in the expected value of a firm: changes in a firms productive assets and changes in firm management. There are no other factors that are material to a firms expected dividend stream. While asset productivity and CEO retirement are exogenous in the model, the decision to replace managers is not. Therefore, each period a firm whose manager does not retire chooses $d_t \in \{retain, replace\}$ in a manner that maximizes the total firm value in expectation, V_t:

$$\max_{\{d_s\}_{s=t}^{\infty}} V_t = E_t\left[\sum_{s=t}^{\infty}\beta^{s-t}\pi_s\right] \tag{3.6}$$

where π_s is defined in equation (4) and β is the firms per-period discount rate. The series of the firms decisions that maximizes expected value is arrived at by solving the dynamic programming problem discussed next.

3.2.3 Dynamic Programming Problem

As a firm experiences shocks to its productivity, it must continually decide to either retain its existing manager or replace the CEO with another individual from the labor pool. If the firm has experienced a series of positive shocks, the firm has an incentive to reenter the labor market and be matched with a new manager who has a higher talent level. Conversely, if the firm has experienced a series of negative shocks, the existing manager is more talented than the replacement obtained from the labor market. However, as discussed below, equilibrium wages must be set in such a way that firms who commit to participate in the labor market are matched to managers in a positive assortative manner.[3] This implies that the current manager is relatively too costly relative to a replacement, giving the firm an incentive to switch managers.

[3]Note, this does not imply that firm and managers in the economy are positive assortatively matched. However, once a firm pays the switching cost to replace their existing manager and enters the labor market, in equilibrium there will be no other firm with a smaller level of productive assets also in the labor market who is matched with a more talented manager. Thus, while the labor market is matched in a positive assortative fashion, the economy as a whole is not.

However, while a firm has the incentive to switch managers, this decision is also accompanied by a switching cost.

Therefore, the firms decision to retain or replace the existing manager can be represented by the following Bellman equation, which is solved for in Appendix C:

$$\begin{aligned} V(\theta, A_t) &= \max_{d_t} \left\{ V(\theta, A_t)^{retain}, V(\theta, A_t)^{replace} \right\} \\ V(\theta, A_t)^{retain} &\equiv A_t \cdot \theta - W(\theta) + \beta \cdot (1-\delta) \cdot E_t \left[V(\theta, A_{t+1}) \right] \\ &\quad + \beta \cdot \delta \cdot E_t \left[V(\theta(A_{t+1}), A_{t+1}) - A_{t+1} \cdot c_{retire} \right] \\ V(\theta, A_t)^{replace} &\equiv V(\theta(A_t), A_t) - A_t \cdot c_{replace} \end{aligned} \tag{3.7}$$

where $W(\theta)$ is the equilibrium wages paid to a manger with talent level θ, and $\theta(A)$ is the talent level of a manager matched to a firm with productive assets A in the labor market. Therefore, a firms decision to retain or replace the incumbent manager depends on the distribution of managers available in the talent pool in addition to the distribution of competing firms who are also seeking a new manger from the talent pool.

If a firm chooses to retain their existing manager, the firms value consists of this periods net profits after paying the mangers wages, plus the discounted expected future value of the firm. This future value equals the weighted average of the firm value conditional on the existing manager retiring or not in the next period. Alternatively, the firm can replace the existing manager by paying a switching cost, thereby allowing the firm to be matched with the optimal manager.

Figure 7 gives some insight into this optimization problem. The first panel compares the firms expected value for both options available, retaining and replacing the current CEO. The figure plots the ratio of the expected firm value conditional on retaining the existing CEO to the firm value conditional on replacing the CEO. Predictably, this ratio is at its greatest level when the firm is already matched with its optimal CEO. At this point, the firms current level of productive assets would result in the firm being matched with a manager from the labor pool of equivalent talent to the incumbent CEO. However, doing so would require the firm to pay the switching cost. As the firm moves away from this point, the incumbent CEO becomes an increasingly inefficient match, offsetting the cost to replace the existing CEO. Furthermore, there are two points where the value of the firm becomes greater if the current CEO is replaced with a manager from the labor pool. This gives rise to an upper and lower level of productive assets, or replacement thresholds denoted by $\overline{A}(\theta)$ and $\underline{A}(\theta)$ respectively, for each CEO talent level. At these thresholds, it becomes optimal for the firm to replace the current manager and participate in the labor market.

[Figure 7 Approximately Here]

Panel B plots these replacement thresholds as a percentage of the firms productive assets when initially matched with the incumbent manager. While a firm with the smallest amount of productive assets requires roughly a 50% increase or 25% decrease in productive assets to replace managers, these switching thresholds increase with a firms productive assets. A firms choice to replace managers is influenced by the distribution of managers in the labor pool. If the dispersion in ability decreases among more talented managers in the labor pool, larger firms would have less of an incentive to replace their incumbent CEO for a replacement from the pool.

3.2.4 Managerial Talent Distribution

As previously noted, the decision to retain or replace an incumbent CEO depends not only on the cost that a firm incurs when changing CEOs, but also on the distributions of firms and managers participating in the labor market. In equilibrium, these distributions must be consistent with the optimal decision rule solving the dynamic programming problem the firm faces. Appendix D generates the stationary distribution of firms and managers in the labor market, endogenously determined as a function of the optimal decision rule.

While the firms choice to participate in the labor market is contingent on the distribution of managers and competing firms in the labor market, these distributions are a function of the overall distribution of managers in the economy. Therefore, while the composition of the talent pool available for higher is endogenously determined in the model, the cross-section of all managers in the economy is exogenously determined.

To characterize this distribution, I rely heavily on the work of Gabaix and Landier (2008) who adapt the extreme value theorem to describe the talent levels of the economys most talented managers. They propose that the change in talent levels for CEOs of the largest U.S. firms can be approximated by the following expression:

$$\theta'(x) = -Bx^{\alpha-1} \tag{3.8}$$

where x denotes the percentile of the talent distribution, with a decrease in ability associated with an increase in x. Therefore, I am able to characterize managerial talent with three parameters, θ_{max}, B and α. θ_{max} represents the ability of the most talented manager in the economy. B serves as a scaling factor that governs the average decrease in talent as you progress through the distribution. α is referred to as the tail-index, and determines the convexity of this decrease.[4]

3.2.5 Equilibrium Wages

While constructed in a similar fashion to the equilibrium wages in the static models of both Gabaix and Landier (2008) and Terviö (2008), their construction differs slightly in the dynamic framework presented here. The intuition behind the static models wage structure described by (2) is that wages must be set in such a way that any firm would be indifferent between being matched with their positive assortative counterpart or being matched with a manager that is marginally more talented but demands a higher wage. Similar intuition holds in the dynamic model considered here, with one difference.

[4]See Gabaix, Laibson and Li (2005) for a list of common distributions and their tail indices

While the wages outlined by (2) make a firm indifferent between two adjacent managers when only the current periods revenue is being considered, the choice of manager has an effect on the wages from multiple periods in a dynamic model. Therefore, wages must be set in such a way that the value of any firm seeking a new manager from the labor market will remain unchanged if they hire a manager marginally more talented than their equilibrium match. Suppose a firm with productive assets A is matched with a manger of talent level $\theta(A)$ in the labor market. Then, equilibrium wages must be set such that:

$$\frac{\partial W(T(p))}{\partial \theta(A)} = \frac{\partial V(\theta(A), A)}{\partial \theta(A)} \tag{3.9}$$

Note that the value of a firm, conditional on participating in the labor market, is a monotonic transformation of the firms productive assets. Therefore, while firms are not positive assortatively matched with managers in the cross section of all firms, all firms and managers participating in the labor market are matched in such a fashion.

3.2.6 Formal Equilibrium Conditions

The optimal decision to replace a suboptimal manager, the distributions of CEOs and firms participating in the labor pool and competitive wages are all jointly determined in equilibrium. Therefore, the general equilibrium is one that satisfies the following conditions:

- Given the distributions $f_s^\star$ and $f_\theta^\star$ and a wage function $W^\star(\cdot)$, the optimal decision rule that solves equation (6) is characterized by $\underline{A}^\star(\theta_i)$, $\overline{A}^\star(\theta_i)$

for all θ_i.

- Given the optimal decision rule $\underline{A}^{\star}(\cdot)$, $\overline{A}^{\star}(\cdot)$ and the distributions $f_s^{\star}$ and $f_{\theta}^{\star}$, all wage offerings that satisfy equation (7) are characterized by the function $W^{\star}(\cdot)$.

- Given the optimal decision rule $\underline{A}^{\star}(\cdot)$, $\overline{A}^{\star}(\cdot)$, the stationary distribution of firm's participating in the labor market is $f_s^{\star}$.

- Given the distribution $f_s^{\star}$ and the optimal decision rule $\underline{A}^{\star}(\cdot)$, $\overline{A}^{\star}(\cdot)$, the stationary distribution of managers in the labor market is $f_{\theta}^{\star}$.

The general equilibrium solution is solved for numerically, as outlined in Appendix E.

3.3 Estimation Approach

3.3.1 Dataset Used

The validity of a structural estimations results rest on two things, the underlying models ability to represent reality and the moments used to identify the model. Therefore, the subset of the economy that the model is applied to must be carefully considered. The model presented herein makes two pivotal assumptions. The first assumption is that the value that a CEO adds is transferable and proportional across companies. Presumably, consistent with the findings of Murphy and Zabojnik (2004, 2007), CEOs of large firms rely more on the ability to manage people effectively and do not require as much firm-specific knowledge from the CEO. Therefore, it is plausible that their managerial ability is transferable across large firms. Additionally, the model also utilizes the extreme value theorem which is very robust in characterizing the tail of a distribution but loses its ability to describe the distribution as you move further towards the interior. For these reasons, the scope of this model should be restricted to large, non-specialized firms.

Therefore, I focus on the largest U.S. firms when estimating the model. I begin with the universe of managers reported in Execucomp from 1992 to 2011, which I merge with Compustat. Given the specific nature of their industries, all financial companies (SIC codes 6000-6999) and utilities (SIC codes 4900-4999) are removed. All CEO successions are identified as a change in the annual CEO flag from one individual to another. Firms are then ranked based on their total market capitalization.[5] Because I seek to study only large firms, I retain only those CEOs whose firm ranking in the year prior to their appointment places them within the top 500 firms. However, such a methodology would under-sample CEOs with long lived tenures that are more likely to have entered their office prior to 1992. To counteract this issue, the terms of all CEOs in the top 500 firms in 1993 are also considered.[6]

Finally, the purpose of the model is to measure the distortionary effect that a switching cost has by preventing a firm from optimally replacing its

[5]Total market capitalization is set equal to Assets Total + Common Shares Outstanding * Price Close (Annual) Common Equity Deferred Taxes

[6]While some firms 1992 fiscal year filings are reported in Execucomp, some firms do not enter the sample until 1993. For this reason, 1993 was chosen instead of 1992.

CEO as the firm experiences shocks to productivity. Nevertheless, I must recognize that in reality other factors come into play regarding a firms decision to change managers. For instance, the model presented in Taylor (2010) focuses on a firms ability to learn about the quality of its manager, which is incorporated into the firing decision. Rather than adding more features to the model, reducing the models tractability in the process, I instead exclude CEO spells where it is unlikely the turnover decision was made because of a change in the firms productive assets. Therefore, I exclude any CEO spell whose tenure is two years or less. To avoid any bias this has when comparing empirical and simulated moments, I also apply this exclusion rule in all simulated spells.

Once the CEO terms are identified, financials of all corresponding firm-years are collected as well as the first fiscal year following the CEOs replacement. Profits are defined as a firms earnings after depreciation divided by the average of lagged and contemporaneous total assets. CEO compensation is set equal to the reported total compensation.[7] All dollar values are converted to 2005 dollars using the GDP deflator. Summary statistics for the final sample are contrasted with the entire universe of Execucomp firms in Table 8. Not surprising, firms in the final sample tend to be larger in both total assets and market capitalization, be more profitable, and have larger executive compensation packages.

[Table 8 Approximately Here]

[7]This corresponds to the Execucomp variable, TDC1, and is the sum of salary, bonus, restricted stock grants, Black-Scholes value of option grants, and LTIP payouts

Finally, I must identify the reason for each CEOs departure. Fortunately, within the context of the model, the dissolution of any match is mutually agreed upon by the firm and manager. The CEO would prefer wages equal to their market value while the firm would prefer a more optimal CEO match. The only classification that must be made is whether a CEO is replaced or retired. Therefore, any CEO who subsequently takes an officer position at another firm is classified as being replaced. For the remainder of the successions, all managers 62 years of age or older at the time of replacement are classified as being retired with the remainder being classified as replaced.

3.3.2 Model Parameters and Estimation

For a given parameter set $\Theta \equiv (\delta, \beta, \theta_{max}, B, \alpha, \gamma, \sigma_{\varepsilon}^2, c_{replace})$, the general equilibrium is computed numerically, as outlined in Appendix E.[8] To illustrate the resulting optimal policy function, Figure 8 plots the life cycle of one simulated firm and its policy function for a reasonable set of parameters. The dotted blue (black) line denotes the upper (lower) threshold of the firms productive assets before the incumbent CEO is replaced. Notice that after the current CEO retires (hollow blue dots) the switching thresholds change. Following a CEOs retirement, the firm re-enters the labor market and is optimally matched. Therefore, because switching thresholds are a function of the incumbent CEO, they change following both CEO retirement and replacement.

[8] In the estimation, I set c_{retire} equal to zero, which is borne out in untabulated empirical results discussed later.

[Figure 8 Approximately Here]

Recall that the first parameters, δ, is the probability that the existing CEO retires. This probability is taken as strictly exogenous in the context of the model, and is estimated using standard reduced-from techniques. In addition, I also abstain from estimating the second parameter, β, used to discount future cash flows because there are models far more suitable than the one presented here able to measure this factor. Therefore, I assume a discount factor of .90, but consider others in untabulated results for robustness sake.

While the first two parameters can be either estimated using a reduced-form approach, or we have reasonable priors regarding their value, the remaining six parameters must be estimated structurally. The first three of these, $(\theta_{max}, B, \alpha)$, jointly describe the distribution of managerial talent in the extreme tail of the population. The thickness of this tail is characterized by the tail index, α. Figure 9 illustrates the convexity of changes in managerial talent within the tail of the distribution.

[Figure 9 Approximately Here]

While Figure 9 illustrates how the distribution of talent changes with α, it is harder to visualize how managerial talent varies with B. Fortunately, given values for θ_{max} and α, there is a one-to-one relationship between B and the average talent level of managers over a given percentile range. Therefore, I instead estimate $\overline{\theta} \equiv \frac{1}{500}\sum_{i=1}^{500}\theta_i$, the average of the 500 most talented individuals. Furthermore, this parameter also encompasses the average productivity of assets in place and should be interpreted as the average talent level scaled by this productivity factor.[9] Prior literature has begun to identify these values (Terviö (2008), Gabaix and Landier (2008)) using CEO compensation within the context of frictionless models. In contrast, if there is a friction whose effect on a firms participation in the labor market is a function of the firms size, the distribution of managers becomes endogenous.

The fourth parameter, γ, captures the magnitude of shocks to a firms productive assets. Additionally, because there is an idiosyncratic noise component embedded in firm profitability, ε, the productivity shocks cannot be estimated using only the variance of a firms profits over time without jointly considering the variance of this noise term. Similarly, the final value of interest, $c_{replace}$, which measures the cost of changing managers depends on the value provided by a more efficient firm-CEO match, making reduced-form analysis problematic. For these reasons, I elect to use a structural model to measure these parameters of interest.

[9]While the difference in talent among CEOs matters for the firms decision to retain or release a manager, the average value does not. The firms optimal policy function will remain unchanged if every CEOs talent level was increased by a constant. However, this parameter is necessary when considering certain model moments.

3.3.3 Simulated Method of Moments

Given model parameters, Appendix E outlines the process to solve for the general equilibrium. However, the task remains to estimate the appropriate model parameters that correspond to empirical evidence. To estimate the model, I rely on the simulated method of moments (SMM), a technique that will be discussed briefly.[10] Given a set of parameters, Θ, rational firm follow an optimal policy function. Therefore, using this decision rule, the actions of a panel of firms within an economy can be simulated through time. From these firm decisions, a set of sample moments can be simulated. The SMM procedure is used to find the parameter set $\Theta^{\star}$ resulting in a set of sample moments that most closely matches the same set of moments measured empirically.

More formally, given a parameter set Θ, N simulations are performed, each of which generates a data panel, $y\left(\Theta\right)_i$. Let $M\left(\mathbf{Z}\right)$ be a vector of moments generated from data $\mathbf{Z}$. The difference between the empirical moments observed and those generated in the simulated economies is defined as follows:

$$\ddot{M}\left(\Theta\right) \equiv M\left(\mathbf{X}\right) - \frac{1}{N}\sum_{i=1}^{N} M\left(y\left(\Theta\right)_i\right) \tag{3.10}$$

where $\mathbf{X}$ is the panel of empirical data. Then the SMM estimator satisfies the following:

$$\Theta^{\star} = \arg\min_{\Theta} Q\left(\mathbf{X}, \Theta\right) \equiv \ddot{M}\left(\Theta\right)' \hat{W} \ddot{M}\left(\Theta\right) \tag{3.11}$$

[10] For a more thorough discussion of SMM see McFadden (1989), Pakes and Pollard (1989), Hennessy and Whited (2005, 2007), Taylor (2010).

where $\hat{W}$ is the efficient weighting matrix, which is set to the inverse of the variance-covariance matrix of the moments in the empirical data.

Following Pakes and Pollard (1989), the parameter standard errors are computed as:

$$\left(1+\frac{1}{N}\right)\left[\left(\frac{\partial \ddot{M}\left(\Theta^{\star}\right)}{\partial \Theta^{\star}}\right)^{\prime} \hat{W}\left(\frac{\partial \ddot{M}\left(\Theta^{\star}\right)}{\partial \Theta^{\star}}\right)\right]^{-1} \tag{3.12}$$

where N is equal to the number of simulations, to adjust for a simulation bias. Conceptually, a parameters standard error is reduced when moments are more sensitive to a change in the parameter, or when the moments are measured more precisely in the empirical data.

While computationally intensive, the minimization process is quite similar to GMM estimation. However, the parameter identification is dependent on the moments specified, and thus great care should be taken when selecting from a group of possible candidates. I now turn my attention to the moments used in the model estimation.

3.3.4 Identifying Moments

An ideal moment candidate has three distinct characteristics. A moment should be strongly correlated with one of the structural parameters. A second feature of the ideal moment is being either uncorrelated or correlated in the opposite direction with other structural parameters. Finally, the ideal moment is one that can be precisely measured in the empirical data. The motivation for this lies in the optimal weighting matrix, which depends on the relative precision with which each moment is estimated. Therefore, an array of moments must be selected that is able to identify the distribution of CEO talent, the magnitude of shocks to productivity, and the switching cost associated with replacing the incumbent CEO. Ultimately, I use a broad spectrum of 15 moments related to CEO tenure length, firm performance around CEO changes, mean, persistence and variability of firm profitability, and changes in relative market values to identify the model parameters.

The first two identifying moments used are based on the length of an average CEO spell. The moments are set equal to the coefficients of α and β_1 in the following model:

$$d_{i,t} = \alpha + \beta_1 \lambda^{(7+)} + \nu_t + \varepsilon_{i,t} \tag{3.13}$$

where $d_{i,t}$ is an binary variable set to unity if CEO i is replaced, and zero otherwise, and $\lambda^{(7+)}$ is a dummy variable that takes on a value of one if the CEOs tenure at time t is greater than or equal to seven years of service, and zero otherwise. Year fixed effects are also included to control for any time trends in CEO turnover, which would only add noise to the estimation process. The coefficients on α and β_1 help to estimate the size of productivity shocks relative to the switching cost. For instance, if the cost to change managers is relatively high and productivity shocks are relatively low, a firm would be less likely to cross the switching thresholds early on in a CEOs tenure, leading to a larger value of β_1. However, if shocks are large relative to the switching cost, it would be more likely that a firm crosses the switching threshold within the first few years of a CEOs spell, leading to a larger value on the coefficient of α. When estimating (11) only those spells in which the CEO is replaced are kept. Neither switching costs nor productivity shocks play a role in the decision to retire in my model, thus all spells where the manager retires are removed from the sample. The frequency of managerial retirement will be estimated in a more traditional way, which will be discussed below.

While these two moments help identify the magnitude of shocks relative to the switching cost, they do not identify productivity shocks independent of other parameters. Therefore, the variance of within-spell firm profitability is also considered. Specifically, the third moment equals the expected variance of the residual estimated from the following pooled linear regression:

$$ROA_{i,t} = \eta_i + \nu_t + \varepsilon_{i,t} \tag{3.14}$$

Because the moment is intended to identify the magnitude of a firms productivity shocks, firm-CEO fixed effects are included to absorb any variance in the profitability measure attributable to differences in CEO ability. Additionally, time fixed effects are included to control for the effects of economy wide shocks. This moment will also help to identify θ_{max},. If assets are generally more productive, θ_{max}, will be larger leading to a larger variance of ROA for a given series of shocks to firm productivity. To further identify θ_{max},, the average return on assets is estimated from the following pooled regression and serves as fourth final moment:

$$ROA_{i,t} = \alpha + \nu_t + \varepsilon_{i,t} \tag{3.15}$$

The next five moments chosen help identify shocks to firm productivity and are based on changes in a firms relative value in the economy. Firms are first ranked according to market value each year, and the annual change in firm ranking is calculated for each firm. Five moments are then generated from the conditional variance of the residual in the following specification:

$$\Delta Rank_{i,t} = \boldsymbol{\lambda} + \boldsymbol{\lambda} \cdot \varepsilon_{i,t} \tag{3.16}$$

where $\boldsymbol{\lambda}$ is a vector of five dummy variables segmenting firms into quintiles based on lagged firm rank and $\Delta Rank_{i,t}$ is the change in a firms ranking with respect to market value. Therefore, the first moment is set to the expected value of ε^2 conditional on having a lagged firm value in the first quintile, and so forth.

While the previous moments help to identify the switching cost relative to productivity shocks, the level of the cost is yet to be identified. For this, I turn to firm performance in the two years around a CEO turnover event. Specifically, four moments are estimated from the following regression:

$$ROA_{i,t} = \beta_1\phi_0^U + \beta_2\phi_{-1}^U + \beta_3\phi_0^D + \beta_4\phi_{-1}^D + \eta_i + \nu_t + \varepsilon_{i,t} \tag{3.17}$$

$ROA_{i,t}$ is set equal to the earnings after depreciation divided by the average of lagged and contemporaneous total assets of the firm at time t. Fixed effects are also included at the year and firm-CEO pair levels. The effects of a managers turnover on profitability in the years surrounding the event are captured with the dummy variables taking on the generic form ϕ_t^s with the two possible superscripts U, and D which stand for up, and down respectively. Up represents the scenario in which the firms relative value has increased over the term of the exiting CEO, represented by an increase in the firms lagged size rank from the CEOs first year to their final year. Similarly, the subscript t, represents the number of years from the turnover event. Thus, in the year immediately preceding a CEO being terminated following a decrease in firm size, ϕ^D_{-1} would take on a value of one. By segregating the turnover event into two mutually exclusive groups, I allow for differing effects on firm profits around the turnover event. For instance, the cost of changing CEOs may be offset to a greater extent by a firm who has grown in size, relative to a firm that has shrunk. This would lead to a more negative coefficient of ϕ^D_{-1} when compared to that of ϕ^U_{-1}.

To identify the model parameters related to the distribution of CEO talent, the next moment is set to the elasticity of total CEO compensation to firm value:

$$ln\left(Pay_{i,t}\right) = \alpha + \beta_1 \cdot ln\left(Size_{i,t}\right) + \nu_t + \varepsilon_{i,t} \tag{3.18}$$

where $ln\left(Size_{i,t}\right)$ equals the market value of firm i at time t. Gabaix and Landier (2008) use this pay-size elasticity to estimate the tail index of CEO ability in a static model. Its inclusion allows for their estimation to be tested in a dynamic setting when firms and CEOs may not be matched in a positive assortative manner.

While other parameters have been discussed, the idiosyncratic component of profitability has yet to be tied to specific moments. For this, one final moment is considered. To identify what portion of a firms profitability in a given period is due to noise and not to productivity shocks, I include the coefficient of lagged profitability from an AR(1) model:

$$ROA_{i,t} = \alpha + \beta_1 \cdot ROA_{i,t-1} + \varepsilon_{i,t} \tag{3.19}$$

3.3.5 Empirical Values of Moments

Each of the moments described above is defined within a reduced-form linear framework. Thus, ordinary least squares regressions provide consistent estimates for their values. The efficient weighting matrix used in the objective function is estimated by applying the seemingly unrelated regressions technique to the moment equations detailed above with error terms clustered on the firm level, and taking the inverse of the corresponding covariance matrix. This weighting matrix puts more weight on matching moments that are precisely measured in the data.

Finally, the probability of a CEO retiring is estimated using a parametric hazard model. Because the model assumes the CEO has an equal likelihood of retiring each year, the underlying hazard function in the estimation process is defined to have an exponential form. The entire history of each CEO included in the sample is first collected. All CEOs who are 62 years or older when they step down and do not take another executive position are assumed to have retired. Furthermore, if a CEO was forced out at a younger age and has since aged to the point where they have effectively left the labor pool, we must consider them to be retired. Therefore, in these cases where the CEO was replaced at a younger age but turns 62 before 2011, the last year observable, they are assumed to have retired when they turned 62. Finally, for all managers who are either still with their firm or have not turned 62 by 2011 the observations are considered to be right censored.

[Table 9 Approximately Here]

The estimation results for each of the sample moments along with the likelihood of retiring are reported in Table 9. The first column estimates the percent of managerial turnover annually. Over the first six years of a managers tenure, the probability of turnover occurring in a given year conditional on surviving up to that point is 4.2%. This probability increases by 2.3% conditional on the spell being at least 7 years in length. The second column reports the moments based on the cross-section of firm profitability. A firms ROA has a cross-sectional mean of 10.31% and exhibits a persistent behavior through time. The third column indicates pay-size elasticity of CEO compensation is 0.42 for the sample considered.

In the fourth column, there is evidence for a change in firm profitability around a CEOs departure. Interestingly, while firm profits are lower in the year preceding a turnover event whenever the firm has decreased in size, although not significant at any traditional confidence level, the same is not true if the firm has increased in size. In addition, while profits are lower in both of these groups when managerial turnover occurs, the point estimate is more negative for firms whose market capitalization has decreased over the CEOs tenure. In untabulated results, CEO retirement has no statistically significant effects on firm profits in the years surrounding the retirement date. For this reason, I set the switching cost following a CEOs retirement to zero to reduce the number of free parameters that must be estimated.

The fifth column reports the variance of the change in firm rank with respect to market value conditional on lagged firm rank. Firms with a larger lagged market value exhibit a lower variance in their ranking within the economy. Finally, the final column reports the average probability of a CEO retiring in a given year. Thus, when solving the model, the probability of a manager retiring EEE is set equal to .0574.

3.4 Estimation Results

The model is estimated using a simulated annealing algorithm, with the methodology used to compute the simulated moments detailed in Appendix F. The resulting parameter estimations are presented in Panel A of Table 10, along with their respective standard errors. The first parameter of particular interest is the cost that a firm incurs when replacing its CEO. The estimate indicates that if a firm were to change managers, they would effectively be paying a penalty equal to 2.18% of their assets in place. Relative to the median firms annual return on assets, this represents a decrease of 20.0% which corresponds to a dollar cost of $81.8 million in the sample.[11] Using detailed

[11] With respect to the mean return on assets, this represents 23.2% of annual ROA, or in dollar terms, a $94.2 million loss.

information on CEOs in Denmark between 1992 and 2003, Bennedsen, Perez-Gonzales and Wolfenzon (2012) find a CEOs death is associated with an 18% decline in operating return on assets. However, this finding is slightly larger than the estimate of Taylor (2010) who evaluates the cost to be 1.33% of a firms assets. When considering the decreased productivity a firm possibly faces when changing management, as well as the severance packages paid to executives among other costs, this cost is reasonable. While this estimate gives a sense of the contemporaneous cost a firm faces, it does not represent the overall impact on the economy. To examine the distortionary effect of this cost, in the next section I will generate a counterfactual economy free of this friction where talent can be optimally allocated.

[Table 10 Approximately Here]

Beyond this switching cost, the distribution of talent among the top managers is also estimated. The parameters indicate there is considerable dispersion in managerial ability. When benchmarked against the average level of talent among all managers, 0.17, the most talented manager with ability, 0.30, can generate gross revenues that are larger by a factor of approximately 1.77. While these parameters give a sense of the disparity in talent at the extreme, it does not characterize how quickly talent diminishes at the tail of the distribution. This rate of decrease is captured by the parameter α. The point estimate of 0.72 is very similar to the value of 0.66 that Gabaix and Landier (2008) estimate when using only executive compensation. However, it is hard to assign an economic value to the surplus managers provide based strictly on these estimates. In the next section, I will address this question more thoroughly using counterfactuals.

The estimate of the parameter γ indicates that the annual shock to a firm's productive assets is bounded by a 30.8% increase or decrease. Combining this with the uniform nature of the shock distribution, this parameter represents a standard deviation in a firm's productive assets of 17.78%.[12] In addition to this persistent shock to asset productivity, firm profitability is affected by a non-persistent, idiosyncratic component with a standard deviation of 0.0263.

While every parameter estimated is very statistically significant, this is not a sufficient indicator of their ability to replicate all the moments observed in the data. This hypothesis can be formally assessed using a χ^2 test, similar to over-identifying test presented in Hansen (1982) used in GMM estimations:

$$\frac{S}{1+S} N \cdot Q\left(\mathbf{X}, \Theta^{\star}\right) \tag{3.20}$$

where Q is the objective function being minimized in (9), N is the number of observations in the sample, and S is the number of simulations performed. Under the null that all J moments generated from a model with K parameters are equal to their empirically observed analogs, (18) follows a χ^2 distribution with $J - K$ degrees of freedom. As Panel B of Table 10 reports, the null that

[12] Using the formula for standard deviation of a uniform distribution: $\frac{b-a}{\sqrt{12}} = \frac{2 \cdot 30.8\%}{\sqrt{12}} =$ 17.78%

the model can replicate all 15 moments is rejected at the .01% confidence level. This model is asked to explain many different features of the data including the time-series variance and persistence of firm profitability within CEO spells, the average amount of CEO turnover, changes in relative firm value, and cross-sectional patterns in CEO compensation; therefore the result is not wholly surprising. However, before discussing the models economic implications, I examine where the model breaks down in its ability to replicate particular moments. Panel C reports the 15 moments estimated empirically and in the simulated data and a t-test of their differences.

CEOs in the simulated economy have an increased probability of experiencing turnover after their sixth year, similar to the pattern observed empirically. However, the model tends to over-estimate the turnover in the first six years, and slightly under-estimate the likelihood of turnover in later years. There is a statistically significant difference in the turnover rate in the first six years of a CEOs tenure but not in terms greater than six years.

When attempting to match moments related to firm profitability, the model fares considerably better. Both the average and persistence of a firms return on assets is similar in the model relative to their empirical counterparts. However, the model tends to underestimate the with-spell variance of firm profitability.

Interestingly, the equilibrium wages the model yields results in an elasticity of CEO pay to firm value within 0.05 of the estimated elasticity from Execucomp. The difference between the two values cannot be rejected at the

5% confidence level.

The results are mixed when the model attempts to mimic the array of moments related to profitability around CEO turnover events. While only one moment out of six is rejected at the .1% confidence level, the model does fail to replicate other patterns among these moments. Empirically, the decrease in profitability tends to be larger for years when turnover occurs compared to the year prior. While a similar pattern is generated in the model, the simulations tend to under-estimate the cost following an increase in firm value and over-estimate the cost following a decrease in firm value.

Finally, when evaluated on its performance in matching changes to a firms relative ranking within the economy, the model tends to under-state the variability of these changes in value. The one exception is the fourth quintile corresponding to relatively small firms in the economy. The model tends to over-state the change in firm ranking for firms whose lagged ranking qualifies them for this quintile.

3.5 Distortionary Effects of a Switching Cost

While the estimated parameters values presented in the previous section give some insight into the cost of changing managers and the degree to which a better manager adds value, their economic magnitudes are still unclear. To better understand how this friction affects the matching of firms and managers, I perform a counterfactual that measures the distortionary effects that a switching cost has on the optimal allocation of talent across firms.

As discussed in the previous section, the estimation results imply that whenever a firm replaces its manager it incurs a one-time cost of 2.18% of total firm assets. While interesting, this does not represent the complete cost this inefficiency imposes on the economy. By multiplying this estimated switching cost by the likelihood of replacing a manager in a given year and evaluating it as an annuity of annual costs one can obtain a back-of-the-envelope estimate, which serves as a lower bound on the decrease in firm value. However, this understates the extent of the distortionary effect as it does not incorporate the implicit cost of being inefficiently matched with a suboptimal manager following a shock to productivity. For this reason, I compare the expected value of firms in my model to those in a counterfactual economy absent any switching costs.

The optimal policy function associated with the parameter estimates from the previous section serves as a base case, denoted as Matching Friction. Alternatively, a second economy is considered that is free of any switching costs, denoted as Optimal Matching. In this case, the firms optimal decision is to always enter the labor market and be re-matched with a CEO.[13] As an estimate of total firm value in each scenario, I start the economy and allow 150 periods to pass to establish a steady-state. At this point I assign a size rank to each firm. 75 periods are then simulated, wherein firms assets experience periodic shocks, managerial replacement occurs according to the

[13]If a firm has not experienced a change in rankings since the previous period, they will be re-matched with the CEO that had in the previous period

corresponding policy function, and profits are realized in each period. For each firm, this series of 75 cash flow realizations is then discounted back to the period when firms were initially ranked. Therefore, the discounted value of the cash flow series represents an estimate of total firm value. This simulation is repeated 100,000 times and the present value calculations are averaged across all simulations to form an expected firm value for each size ranking.

[Figure 10 Approximately Here]

Panel A of Figure 10 plots the ratio of a firms value under the Optimal Matching scenario relative to the Matching Friction case. There is little differentiation in expected firm value for larger firms, while the difference increases as firm size becomes smaller. The distortion to firm value caused by the switching cost reaches its greatest point slightly after the median firm. Recall that the moment estimates from the previous section indicate that there is less volatility in the size rankings of large firms relative to small firms, both in the model and empirically. Thus, productivity shocks are less likely to affect the relative ranking of a large firm in the economy. This reduces the difference in ability between their incumbent CEO and a replacement they could obtain in the labor market. Ultimately, firms in the frictionless economy who are able to replace their CEOs free of a switching cost have a median (mean) value 5.06

While the previous two scenarios capture the overall difference in firm value caused by the matching friction, they do not quantify what portion of this distortion is the inefficiency of the manager-firm match and what portion is the cost experienced when replacing managers. To address this question, a third scenario is considered in which each firm experiences a series of switching costs identical to the Matching Friction scenario, but is also efficiently matched with managers in every period. Thus, the difference in a firms value under this scenario, denoted Switching Cost, and Matching Friction represents the economic magnitude of the inefficient match. The reduction in value solely attributable to the inefficient matching of firms and managers exhibits a similar pattern to the overall decrease in firm value. At its greatest point, optimal matching results in an increase in firm value of 2.73%. For the overall economy, the median (mean) firm value increases by 1.84% (1.72%) when managers and firms are optimally matched but still experience the same switching cost.

Panel B of Figure 10 contrasts the cost of suboptimal matching to the overall decrease in firm value. For each firm, the ratio of the decrease in firm value associated with inefficient matching to the decrease in value associated with both inefficient matching and the explicit switching cost is reported. While the economys largest firms experience productivity shocks that lead to inefficient matches, these shocks seldom result in the optimal decision to replace managers. Thus, the implicit cost associated with an inefficient match dominates the explicit cost of switching managers for these firms. While the contribution of this implicit cost to the overall destruction in firm value decreases when considering smaller firms, at its minimum point it still represents two-thirds of the overall effect. Overall, suboptimal matching represents 76.2

While the existence of a switching cost does lead to the inefficient matching between firms and managers, it is still unclear how equilibrium wages change in a dynamic setting relative to prior static model. Contrasting the wages from the model presented here with a static framework will give insight into how sensitive the predictions of Gabaix and Landier (2008) and Tervi (2008) are to a multi-period setting. Therefore, I take the estimated model parameters and construct the one-period equilibrium wages from (3).

[Figure 11 Approximately Here]

Figure 11 plots the ratio of equilibrium wages from the dynamic model to these static wages. Overall, equilibrium wages are larger in the dynamic framework relative to a one-period model. This disparity is largest for the lowest ranked firms in the economy.[14] However, the average increase in wages in the dynamic model is only 3.10%. Therefore, it is unlikely that the predictions from a static model would be materially influenced by the construction of wages from a dynamic framework.

3.6 Conclusion

This dissertation examines the implications of a competitive labor market for CEOs on equilibrium wages and firm-CEO matches. Specifically, I examine the change in wages following an increase in the demand for managers

[14]This could be attributed to the technical requirement that a firms productive assets be bounded for a stationary distribution to be reached. Therefore, small firms would be more likely to grow, increasing the premium for managers in this region of the distribution.

who possess the skills necessary to run a public company coupled with a relatively inelastic supply of such individuals. I use the sudden influx of additional firms associated with industry-level IPO activity to represent these times of increased CEO labor demand. Consistent with the predictions of simple competitive equilibrium models of CEO compensation, I find that the elasticity of pay with respect to firm value increases by 5.8% following a one-standard deviation increase in industry IPO activity over the preceding three year period. Economically, this represents an average increase in pay of 6.3%, or $412,100 for the observations within my sample. This result is robust to my measure of CEO pay.

In addition, I find that the effect of demand on pay elasticity is stronger in industries that are harder to learn or require more industry-specific knowledge and industries which are more unique in their operations. Specifically, I find the effect to be larger in industries that hire fewer CEOs from outside the industry, industries with less overlap in sales from firms in other industries, and industries whose returns are less correlated with other industries. Furthermore, I find the effect to also be stronger in well-governed firms, suggesting that poorly-governed firms are more susceptible to rent extraction while market forces are a stronger determinant of pay in firms with stronger governance.

To disentangle the competitive equilibrium from competing hypotheses of efficiency wages or rent extraction, I also examine the effects of IPO activity on executive transitions within an industry, a prediction unique to the model presented in this work. Using a competing-risks hazard model, I find that executives are 19% more likely to transition between firms and 18% more likely to take a position for higher pay with a one standard deviation increase in IPO activity.

The examination of equilibrium wages is based on a frictionless matching model. However, firms and industries continually receive shocks to the productivity of their assets. In a frictionless economy, as a firm grows in prominence they should be optimally matched with a more talented manager. However, while firms grow and shrink in size, empirically they do not replace existing managers in a manner consistent with a frictionless labor market. If there is a friction in the matching process, how do predictions from a static model change? Furthermore, how much firm value is destroyed due to this friction?

To answer these questions, I also estimate a dynamic competitive equilibrium model with time-varying firm productivity and a switching cost that must be paid when replacing an existing CEO. The model is estimated using SMM, yielding an interesting set of findings. Firms experience a switching cost equal to 2.18% of their assets in place. Ultimately, this friction prevents the optimal re-matching of CEOs and firms in a dynamic setting. Using counterfactual analysis, it is estimated that the median (mean) firms value would increase by 5.06% (4.21%) when able to replace managers free of any such switching cost. Furthermore, the lions share of this value destruction is due to the inefficiency of firm-CEO matches in the cross-section and not the explicit cost when switching managers.

While the model estimated here is relatively straightforward as firms are able to observe the ability of managers, the overall cost they experience due to factors such as lost productivity, severance pay, and search costs negatively impacts firm value in a substantial way. Furthermore, reduced-form estimates of this cost will understate the overall impact to firm value, as they do not account for the cost of a suboptimal match between firms and CEOs.

Table 1: CEO Pay-Size Elasticity and Increased Labor Demand

	Ln(Total Compensation)				Cash Pay
	(1)	(2)	(3)	(4)	(5)
Ln(Market Value)	0.429	0.427	0.427	0.427	0.264
	(32.87)	(31.32)	(31.32)	(31.32)	(28.63)
Ln(Market Value) x IPO Activity	0.0271	0.0232	0.0212	0.0251	0.0129
	(4.07)	(3.16)	(2.86)	(2.94)	(2.14)
IPO Activity	-0.198	-0.161	-0.149	-0.178	-0.0910
	(-3.38)	(-2.50)	(-2.27)	(-2.39)	(-1.72)
Excess Return		0.078	0.078	0.075	0.029
		(5.96)	(6.02)	(5.86)	(3.65)
Median Return		0.052	0.053	0.054	0.041
		(4.68)	(4.69)	(4.76)	(4.94)
Excess OROS		0.385	0.406	0.370	0.003
		(1.85)	(1.93)	(1.71)	(0.02)
Median OROS		-0.042	-0.035	-0.039	-0.068
		(-1.76)	(-1.43)	(-1.61)	(-3.38)
Ln(Tenure)		0.043	0.044	0.043	0.084
		(3.08)	(3.13)	(3.09)	(7.90)
Intercept	3.810	4.539	3.571	5.260	4.804
	(28.37)	(19.39)	(7.24)	(14.92)	(20.17)
Year FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Performance Controls	No	Yes	Yes	Yes	Yes
Industry Level Elasticity	No	No	Yes	No	No
Year Level Elasticity	No	No	No	Yes	Yes
N	19710	18372	18372	18372	18368
Adj. R-sq	0.419	0.427	0.433	0.429	0.359
Average Pay Change ($, thousands)	407.3	404.6	358.6	412.1	211.5
p-value	0.0003	0.0001	<0.0001	0.0002	0.0243

Table 2: CEO Pay-Percentile Elasticity and Increased Labor Demand

	Ln(Total Compensation)				Cash Pay
	(1)	(2)	(3)	(4)	(5)
Ln(Market Value)	0.383	0.357	0.357	0.357	0.234
	(11.86)	(10.25)	(10.25)	(10.25)	(10.14)
Percentile Rank	0.215	0.320	0.320	0.320	0.141
	(1.88)	(2.64)	(2.64)	(2.64)	(1.72)
Percentile Rank x IPO Activity	0.097	0.093	0.084	0.098	0.074
	(3.49)	(3.24)	(2.93)	(2.94)	(3.26)
IPO Activity	-0.001	-0.005	-0.005	-0.008	-0.016
	(-0.60)	(-0.28)	(-0.28)	(-0.43)	(-1.18)
Excess Return		0.079	0.080	0.076	0.029
		(6.04)	(6.13)	(5.93)	(3.68)
Median Return		0.055	0.057	0.057	0.043
		(4.95)	(5.02)	(5.01)	(5.08)
Excess OROS		0.393	0.427	0.379	0.006
		(1.89)	(2.13)	(1.75)	(0.04)
Median OROS		-0.036	-0.026	-0.032	-0.066
		(-1.50)	(-1.04)	(-1.35)	(-3.26)
Ln(Tenure)		0.042	0.043	0.042	0.084
		(3.01)	(3.04)	(3.02)	(7.86)
Intercept	4.081	4.950	4.251	5.556	4.920
	(17.70)	(15.28)	(7.65)	(15.11)	(19.27)
Year FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Performance Controls	No	Yes	Yes	Yes	Yes
Industry Level Elasticity	No	No	Yes	No	No
Year Level Elasticity	No	No	No	Yes	Yes
N	19710	18372	18372	18372	18368
Adj. R-sq	0.419	0.428	0.434	0.430	0.359

This table reports the results of OLS regressions. The dependent variable is denoted in the column header. *Ln(Market Value)* is the natural log of market value of assets. *Percentile Rank* is the firm's percentile rank in the industry in a given year. *Percentile Rank x IPO Activity* is the interaction of industry percentile rank and the three year trailing industry average number of IPOs, standardized by industry. *Excess OROS* is industry-adjusted operating return over sales. *Excess Return* is the industry-adjusted log return on equity. *Ln(Tenure)* is the natural log of a CEO's tenure within her current spell. *Performance Controls* indicates the inclusion of other firm performance related variables, detailed in Appendix II. *Industry Level Elasticity* indicates an interaction between *Ln(Market Value)* and a full set of industry dummy variables. *Year Level Elasticity* indicates an interaction between *Ln(Market Value)* and a full set of year dummy variables. Firms are classified into Fama French 48 industries. Reported are t-statistics in parentheses, clustered at the firm level.

Table 3: Demand Effects on Pay-Size Elasticity Across Firm Sizes

	Ln(Total Compensation)			Cash Pay		
	Full Sample	Rank > 100	Rank > 250	Full Sample	Rank > 100	Rank > 250
Ln(Market Value)	0.427	0.456	0.472	0.264	0.268	0.271
	(31.32)	(38.29)	(34.77)	(28.63)	(29.34)	(26.50)
Ln(Market Value) x IPO Activity	0.0251	0.0357	0.0439	0.0129	0.0188	0.0234
	(2.94)	(3.55)	(4.27)	(2.14)	(2.84)	(3.02)
IPO Activity	-0.178	-0.265	-0.332	-0.091	-0.140	-0.177
	(-2.39)	(-3.08)	(-3.81)	(-1.72)	(-2.46)	(-2.73)
Excess Return	0.075	0.066	0.061	0.029	0.027	0.024
	(5.86)	(5.22)	(4.84)	(3.65)	(3.44)	(3.07)
Median Return	0.054	0.054	0.048	0.041	0.042	0.041
	(4.76)	(4.55)	(3.85)	(4.94)	(4.87)	(4.66)
Excess OROS	0.370	0.354	0.354	0.004	0.010	0.019
	(1.71)	(1.67)	(1.67)	(0.02)	(0.07)	(0.14)
Median OROS	-0.039	-0.054	-0.077	-0.068	-0.069	-0.086
	(-1.61)	(-2.16)	(-2.74)	(-3.38)	(-3.28)	(-3.67)
Ln(Tenure)	0.043	0.039	0.030	0.084	0.087	0.086
	(3.09)	(2.75)	(2.06)	(7.90)	(8.03)	(7.77)
Intercept	5.260	4.553	4.186	4.804	4.589	4.414
	(14.92)	(11.68)	(8.56)	(20.17)	(17.47)	(13.84)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Performance Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year Level Elasticity	Yes	Yes	Yes	Yes	Yes	Yes
N	18372	17628	16183	18368	17637	16214
Adj. R-sq	0.429	0.416	0.394	0.359	0.327	0.295
Average Pay Change ($, thousands)	412.1	515.1	599.6	211.5	263.8	311.9
p-value	0.0002	<0.0001	<0.0001	0.0243	0.0010	0.0061

This table reports the results of OLS regressions. The dependent variable is denoted in the column header. *Ln(Market Value)* is the natural log of market value of assets. *Ln(Market Value) x IPO Activity* is the interaction of log market value and the three year trailing industry average number of IPOs, standardized by industry. *Excess OROS* is industry-adjusted operating return over sales. *Excess Return* is the industry-adjusted log return on equity. *Ln(Tenure)* is the natural log of a CEO's tenure within her current spell. *Performance Controls* indicates the inclusion of other firm performance related variables, detailed in Appendix II. *Year Level Elasticity* indicates an interaction between *Ln(Market Value)* and a full set of year dummy variables. *Average Pay Change* is the mean change in compensation for a one standard deviation change in *IPO Activity* for a firm in the sample. *p-value* reports the p-value of the test of zero change in pay, evaluated at the mean firm market value in the sample. Firms are classified into Fama French 48 industries. Reported are t-statistics in parentheses, clustered at the firm level.

Table 4: Within-Industry Executive Transitions

	All Transitions			Upward Transition		
	(1)	(2)	(3)	(4)	(5)	(6)
IPO Activity	1.179	1.169	1.190	1.155	1.162	1.180
	(4.12)	(3.15)	(3.41)	(3.05)	(2.54)	(2.74)
Ln(Market Value)			1.150			1.129
			(4.31)			(3.18)
Excess Return		1.037	1.038		0.985	0.986
		(0.66)	(0.68)		(-0.26)	(-0.24)
Median Return		1.120	1.117		1.085	1.083
		(2.81)	(2.78)		(1.84)	(1.82)
Performance Controls	No	Yes	Yes	No	Yes	Yes
Number Transitions	523	500	500	386	370	370
Time at Risk	132,927	121,486	121,486	132,927	121,486	121,486
Wald Chi-Sq	16.99	97.03	109.80	9.321	62.62	70.62
P-value	< 0.0001	< 0.0001	< 0.0001	0.0022	< 0.0001	< 0.0001

This table reports the results of competing risk hazard models. The failure event is denoted in the column headers. *All Transitions* includes all executives who leave a firm within the sample and appear in the top five executives of another firm within the industry within two years. *Upward Transition* requires the executive's total compensation to increase following the transition. The competing risks are defined as: a transition to a different industry, the firm's exit from Execucomp, and for *Upward Transition* a decrease in total compensation. *IPO Activity* is the three year trailing industry average number of IPOs, standardized by industry. *Ln(Market Value)* is the natural log of market value of assets. *Excess Return* is the industry-adjusted log return on equity. *Excess OROS* is industry-adjusted operating return over sales. *Performance Controls* indicates the inclusion of other firm performance related controls, detailed in Appendix II. Firms are classified into Fama French 48 industries. Reported are sub-hazard ratios with z-statistics in parentheses, clustered at the industry-year level.

Table 5: Demand Effect on Pay-Size Elasticity across Industries

	Ln(Total Compensation)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln(Size)	0.399	0.346	0.406	0.354	0.411	0.366	0.408	0.365
	(12.91)	(10.94)	(13.42)	(11.35)	(11.30)	(9.91)	(11.22)	(9.94)
Ln(Size) x IPO Activity	0.0093	0.0154	0.0125	0.0160	0.0239	0.0224	0.0148	0.0167
	(1.12)	(1.76)	(1.51)	(1.80)	(2.64)	(2.38)	(1.47)	(1.61)
x % Outside Hires	-0.0140	-0.0121					-0.0110	-0.0073
	(-1.97)	(-1.67)					(-1.73)	(-1.07)
x % Segment Overlap			-0.0427	-0.0403			-0.0292	-0.0324
			(-1.86)	(-1.69)			(-1.30)	(-1.39)
x Ind. Comovement					-0.0279	-0.0205	-0.0256	-0.0159
					(-2.62)	(-1.82)	(-2.37)	(-1.42)
IPO Activity	-0.060	-0.107	-0.083	-0.111	-0.172	-0.150	-0.100	-0.115
	(-0.83)	(-1.40)	(-1.15)	(-1.44)	(-2.13)	(-1.79)	(-1.13)	(-1.25)
Intercept	4.605	5.329	3.586	4.704	3.476	4.543	4.223	4.890
	(7.18)	(7.69)	(10.01)	(11.32)	(8.98)	(10.32)	(6.84)	(7.36)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Performance Controls	No	Yes	No	Yes	No	Yes	No	Yes
Year Level Elasticity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	19776	18438	19803	18465	19803	18465	19776	18438
Adj. R-sq	0.421	0.429	0.420	0.429	0.420	0.429	0.422	0.430

This table reports the results of OLS regressions. The dependent variable is the natural log of total CEO compensation. *Ln(Size)* is the natural log of market value of assets. *Ln(Size) x IPO Activity* is the interaction of log market value and the three year trailing industry average number of IPOs, standardized by industry. *x % Outside Hires* is the interaction of Ln(Size) x IPO Activity and the percentage of an industry's CEOs hired from outside the industry. *x % Segment Overlap* is the interaction of Ln(Size) x IPO Activity and the average percentage of sales a firm from a different industry has in the industry considered. *x Ind. Comovement* is the interaction of Ln(Size) x IPO Activity and the average correlation between the industry's returns and all other industries. All other un-interacted terms are not reported for brevity. *Performance Controls* indicates the inclusion of other firm performance related controls, detailed in Appendix II. *Year Level Elasticity* indicates an interaction between *Ln(Size)* and a full set of year dummy variables. Firms are classified into Fama French 48 industries. Reported are t-statistics in parentheses, clustered at the firm level.

Table 6: Demand Sensitivity of Pay-Size Elasticity and Firm Governance

	G-Index				E-Index			
	Across Industries		Within Industry		Across Industries		Within Industry	
Ln(Size)	0.410	0.375	0.410	0.375	0.410	0.369	0.409	0.367
	(9.29)	(8.08)	(9.28)	(8.05)	(9.05)	(7.69)	(9.04)	(7.63)
IPO Activity	-0.070	-0.096	-0.068	-0.096	-0.052	-0.073	-0.052	-0.078
	(-0.77)	(-0.96)	(-0.75)	(-0.96)	(-0.56)	(-0.70)	(-0.55)	(-0.76)
Ln(Size) x IPO Activity	0.0122	0.0136	0.0119	0.0135	0.0102	0.0109	0.0100	0.011
	(1.18)	(1.20)	(1.15)	(1.18)	(0.96)	(0.93)	(0.94)	(0.97)
x Governance	-0.0030	-0.0034	-0.0032	-0.0034	-0.0030	-0.0037	-0.0032	-0.0035
	(-2.52)	(-2.75)	(-2.74)	(-2.70)	(-2.48)	(-2.92)	(-2.72)	(-2.88)
Governance	0.046	0.049	0.041	0.044	0.074	0.081	0.073	0.079
	(2.71)	(2.90)	(2.50)	(2.63)	(3.89)	(4.18)	(4.01)	(4.30)
Excess Return		0.104		0.105		0.104		0.104
		(5.44)		(5.46)		(5.25)		(5.25)
Median Return		0.050		0.050		0.060		0.060
		(3.27)		(3.31)		(3.78)		(3.79)
Excess OROS		0.0704		0.0711		0.100		0.101
		(0.90)		(0.91)		(1.32)		(1.31)
Median OROS		-0.038		-0.036		-0.027		-0.023
		(-1.02)		(-0.95)		(-0.72)		(-0.60)
Ln(Tenure)		0.049		0.049		0.055		0.055
		(2.69)		(2.68)		(2.97)		(2.97)
Intercept	3.990	5.100	3.997	5.106	4.042	5.226	4.051	5.229
	(9.66)	(8.19)	(9.67)	(8.20)	(9.51)	(8.10)	(9.55)	(8.10)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Performance Controls	No	Yes	No	Yes	No	Yes	No	Yes
Year Level Elasticity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	10662	10018	10662	10018	9777	9157	9777	9157
Adj. R-sq	0.409	0.417	0.409	0.417	0.423	0.431	0.423	0.431

This table reports the results of OLS regressions. The dependent variable is the natural log of total CEO compensation. The column header indicates the governance variable being considered, either standardized across the pooled sample (*Across Industries*) or within each industry (*Within Industry*). *Ln(Size)* is the natural log of market value of assets. *Ln(Size) x IPO Activity* is the interaction of log market value and the three year trailing industry average number of IPOs, standardized by industry. *x Governance* is the interaction of Ln(Size) x IPO Activity and the governance variable indicated in the column header. *Governance* is the governance variable indicated in the header. *Performance Controls* indicates the inclusion of other firm performance related controls, detailed in Appendix II. *Year Level Elasticity* indicates an interaction between *Ln(Size)* and a full set of year dummy variables. Firms are classified into Fama French 48 industries. Reported are t-statistics in parentheses, clustered at the firm level.

Table 7: Successor Choice and Talent Pool Depth

Panel A: Multinomial Logit, Base Case = Firm Insider

	(1)		(2)		(3)		(4)	
Successor Industry:	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
IPO Activity	0.850	1.134	0.817	1.155	0.795	1.151	0.923	1.061
	(-2.14)	(1.89)	(-2.34)	(1.79)	(-2.65)	(1.75)	(-0.82)	(0.52)
Ln(Market Value)	0.969	0.916	0.942	0.967	0.995	0.956	0.910	0.968
	(-0.60)	(-1.61)	(-1.02)	(-0.55)	(-0.09)	(-0.68)	(-1.52)	(-0.51)
Ln(Tenure)	0.772	0.699	0.838	0.705	0.821	0.708	0.731	0.746
	(-2.82)	(-3.91)	(-1.74)	(-3.63)	(-1.93)	(-3.55)	(-2.71)	(-2.63)
Excess Return			0.633	0.834	0.637	0.835	0.814	0.814
			(-3.28)	(-1.14)	(-3.28)	(-1.13)	(-1.17)	(-1.17)
Median Return			0.938	1.018	0.942	1.020	0.883	0.883
			(-0.78)	(0.23)	(-0.74)	(0.25)	(-0.92)	(-0.92)
Market IPO Activity					0.843	1.010		
					(-3.13)	(0.41)		
Year FE	No		No		No		Yes	
Performance Controls	No		Yes		Yes		Yes	
N	1846		1738		1737		1738	
Pseudo R-Sq	0.013		0.064		0.068		0.090	

Panel B: Plain Logit, Base Case = Industry Insider

	(1)	(2)	(3)	(4)
Successor Industry:	Outside	Outside	Outside	Outside
IPO Activity	1.373	1.495	1.566	1.205
	(3.13)	(3.02)	(3.32)	(1.06)
Ln(Market Value)	0.939	1.011	0.921	1.133
	(-0.87)	(0.13)	(-0.87)	(1.18)
Ln(Tenure)	0.859	0.780	0.787	0.934
	(-1.18)	(-1.66)	(-1.56)	(-0.36)
Excess Return		1.217	1.215	1.201
		(1.69)	(1.69)	(1.51)
Median Return		1.110	1.094	1.037
		(0.92)	(0.79)	(0.18)
Market IPO Activity			1.264	
			(3.13)	
Year FE	No	No	No	Yes
Performance Controls	No	Yes	Yes	Yes
N	476	451	451	451
Pseudo R-sq	0.019	0.163	0.180	0.246

This table shows multinomial logistic results with a base case of hiring a firm insider (Panel A) and a plain logit ordered with a base case of hiring from within the industry (Panel B). The alternative choice is denoted in the second column header. *IPO Activity* is the three year trailing industry average number of IPOs, standardized by industry. *Ln(Market Value)* is the natural log of market value of assets. *Ln(Tenure)* is the natural log of a CEO's tenure within her current spell. *Excess Return* is the industry-adjusted year-end log return. *Excess OROA* is industry-adjusted operating return over book value of assets. *Market IPO* is the three year trailing average total number of IPOs excluding the firm's industry. *Performance Controls* indicates the inclusion of other firm performance related controls, detailed in Appendix II. Reported are relative risk ratios (Panel A) and odds ratios (Panel B) with White (1980) heteroskedasticity-adjusted z-statistics in parentheses.

Table 8: Summary Statistics Structural Estimation

	Execucomp		Non-Financial		Final Sample	
	Mean	N	Mean	N	Mean	N
Operating Income ($M)	683.95	33,339	529.00	26,454	1,439.03	8,214
Assets – Total ($M)	9,986.4	45,124	4,370.3	38,232	15,161.2	8,215
Return on Assets	8.60%	31,054	9.33%	24,957	11.53%	8,180
Total Market Capitalization ($M)	12,950.1	44,943	7,361.4	38,089	26,422.5	8,177
Total Executive Compensation ($M)	4.754	32,831	4.727	25,991	8.068	7,956

This table reports summary statistics for the entire universe of Execucomp observations, all non-financial firms, and the final sample used when computing empirical moments.

Table 9: Moment Coefficients

	Turnover	ROA	Ln(Pay)	ROA	Var(Δ Rank)	Retire
Intercept	0.042					
	(13.36)					
7+ Years Tenure	0.023					
	(3.33)					
Mean		0.1031				
		(41.13)				
Lagged ROA		0.8527				
		(62.97)				
Variance		0.0027				
		(13.05)				
Ln(Market Value)			0.4217			
			(14.23)			
Turnover (Up, -1)				0.0006		
				(0.16)		
Turnover (Up, 0)				-0.0084		
				(-2.05)		
Turnover (Down, -1)				-0.0065		
				(-1.26)		
Turnover (Down, 0)				-0.0116		
				(-2.08)		
Lagged Rank Q1					266.21	
					(6.20)	
Lagged Rank Q2					1349.92	
					(8.37)	
Lagged Rank Q3					2407.13	
					(15.16)	
Lagged Rank Q4					3452.38	
					(19.57)	
Lagged Rank Q5					3509.87	
					(11.40)	
Prob. Hazard						0.057
						(73.95)

This table reports sample moment estimates using OLS regressions. *Turnover (Up, t)* is a dummy variable taking a value of one when a firm experiences CEO turnover at time *t* conditional of the firm's market value ranking increasing over the CEO's tenure. *Lagged Rank Q1* is a dummy variable taking on a value of one when the firm's lagged size ranking places it in the quintile of firms with the largest market value in the sample. Reported are *t*-statistics with standard errors clustered at the firm level.

Table 10: Estimation Results

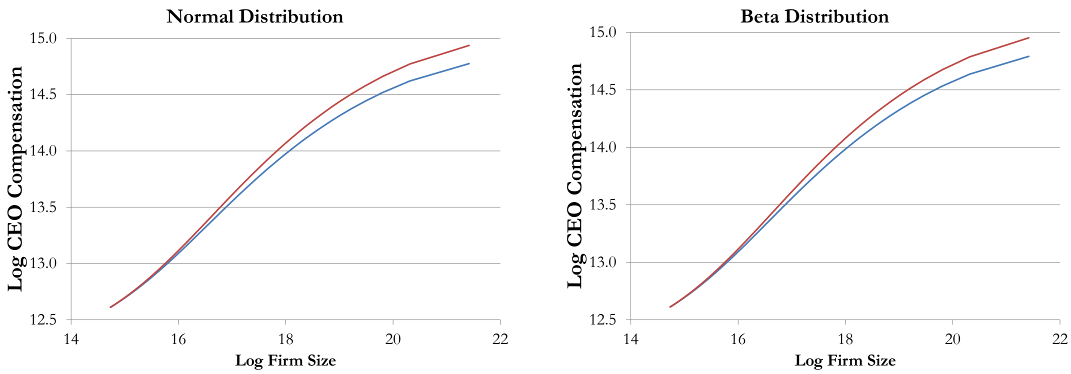
Panel A: Parameter Estimates						
	Switching Cost (c)	Maximum Talent (θ_{max})	Average Talent ($\bar{\theta}$)	Tail Index ($\propto$)	Shock Bounds (γ)	Idiosyncratic Noise (σ_{ε}^{2})
Point Estimate	0.0218	0.3014	0.1698	0.7204	0.3084	0.0007
Standard Error	(0.0005)	(0.0005)	(0.0011)	(0.0030)	(0.0010)	(0.0035)

Panel B: Over-Identification Test	
	$\chi_{(9)}$
Test Statistic	100.03
p-value	<.0001

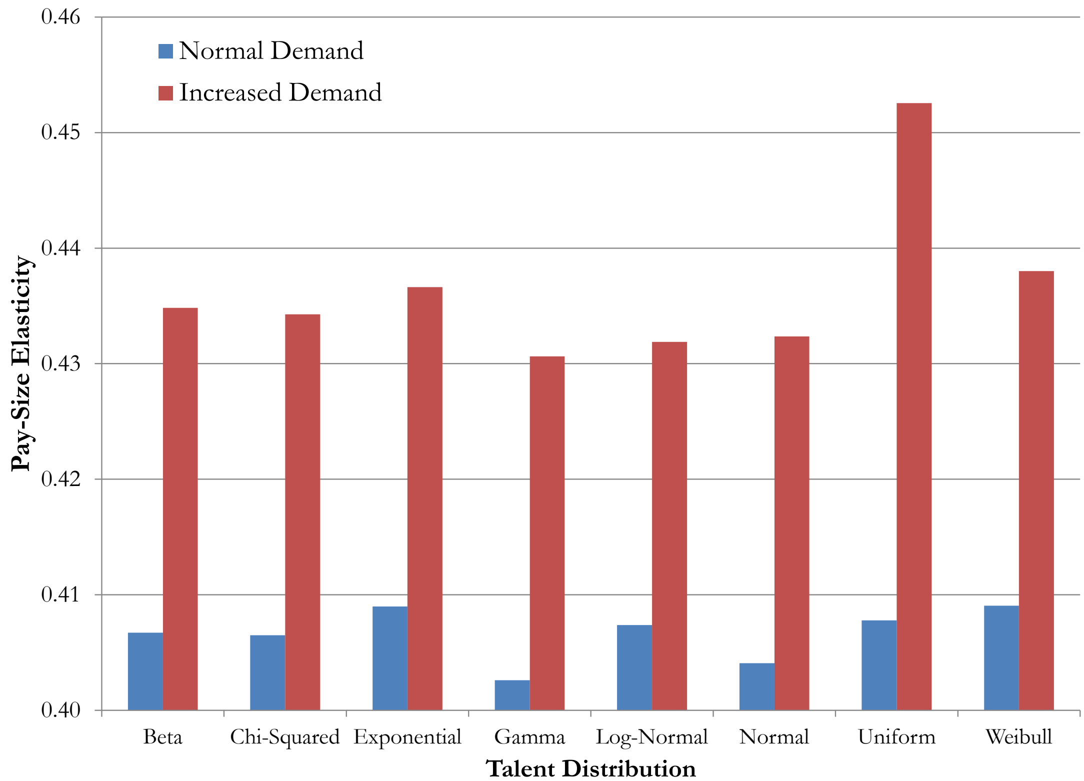
Panel C: Individual Moment Fits			
	Empirical Moment	Simulated Moment	p-value
Turnover Intercept	0.0423	0.0532	0.0004
7+ Years Tenure	0.0230	0.0175	0.4400
Average ROA	0.1031	0.1014	0.4083
ROA Persistence	0.8527	0.8530	0.9815
ROA Var., within spell	0.0027	0.0019	< 0.0001
Pay-Size Elasticity	0.4217	0.3763	0.0955
Turnover (Up, -1)	0.00063	0.0129	0.0178
Turnover (Up, 0)	-0.0084	0.0064	0.0466
Turnover (Down, -1)	-0.0065	-0.0119	0.3157
Turnover (Down, 0)	-0.0116	-0.0342	< 0.0001
Var(Δ Rank), Q1	266.21	88.07	< 0.0001
Var(Δ Rank), Q2	1349.92	639.95	< 0.0001
Var(Δ Rank), Q3	2407.13	1826.00	0.0001
Var(Δ Rank), Q4	3452.38	3848.89	0.0213
Var(Δ Rank), Q5	3509.87	3081.12	0.1540

This table reports parameter estimates (Panel A), a test of over-identification (Panel B), and a test of equality between empirical and simulated moments (Panel C). Parameter estimate standard errors are reported in parentheses.

Figure 1: Wage Response to Increased Demand

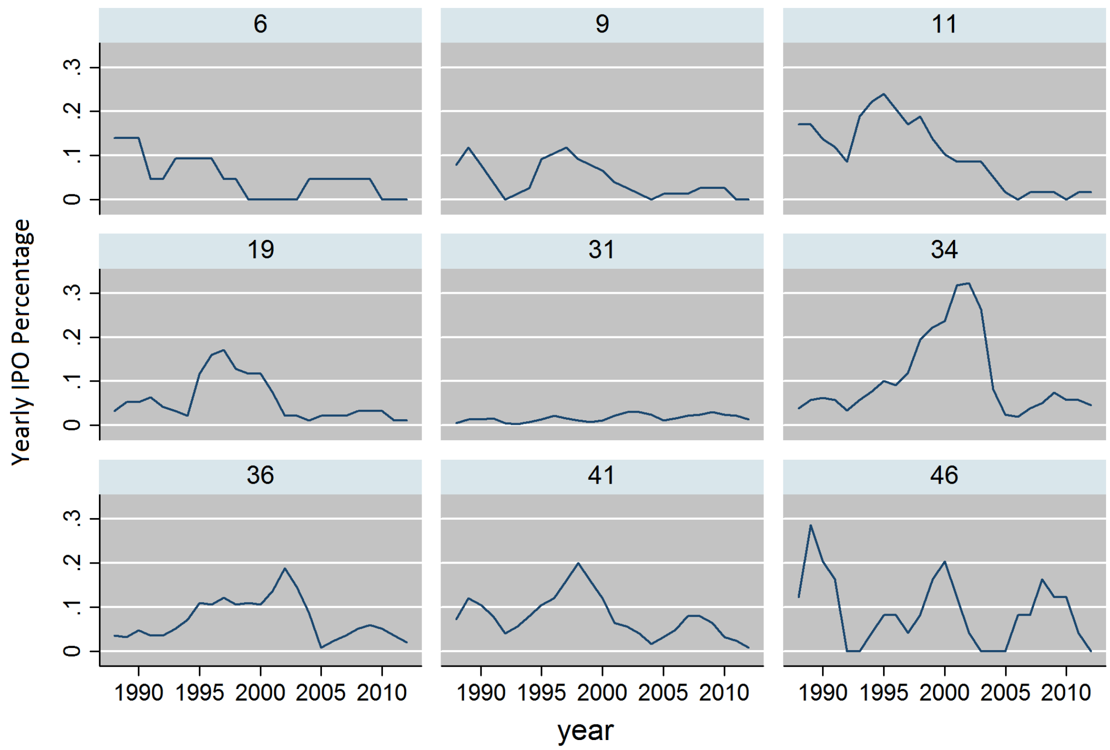


This figure illustrates the change in CEO compensation in competitive equilibrium (Panel A) and the elasticity of CEO pay to firm size for multiple distributions of talent (Panel B) following an increase in the number of firms. Increased Demand represents the entrance of 20% more firms into the economy. Pay-Size Elasticity is the point estimate of OLS regressions of log CEO pay on log firm size and a constant.



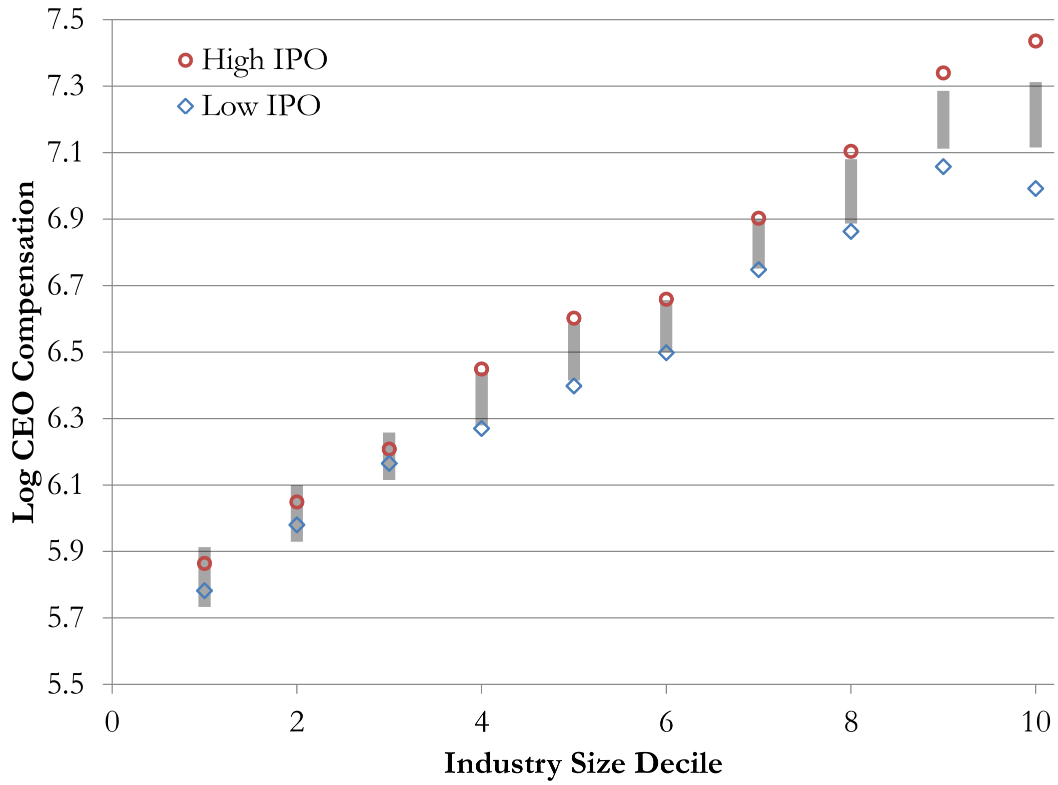
0.46
0.45
0.44
0.43
0.42
0.41
0.40
Normal Demand
Increased Demand
Pay-Size Elasticity
Beta
Chi-Squared
Exponential
Gamma
Log-Normal
Normal
Uniform
Weibull
Talent Distribution

Figure 2: Yearly IPO Activity by Fama-French 48 Industry



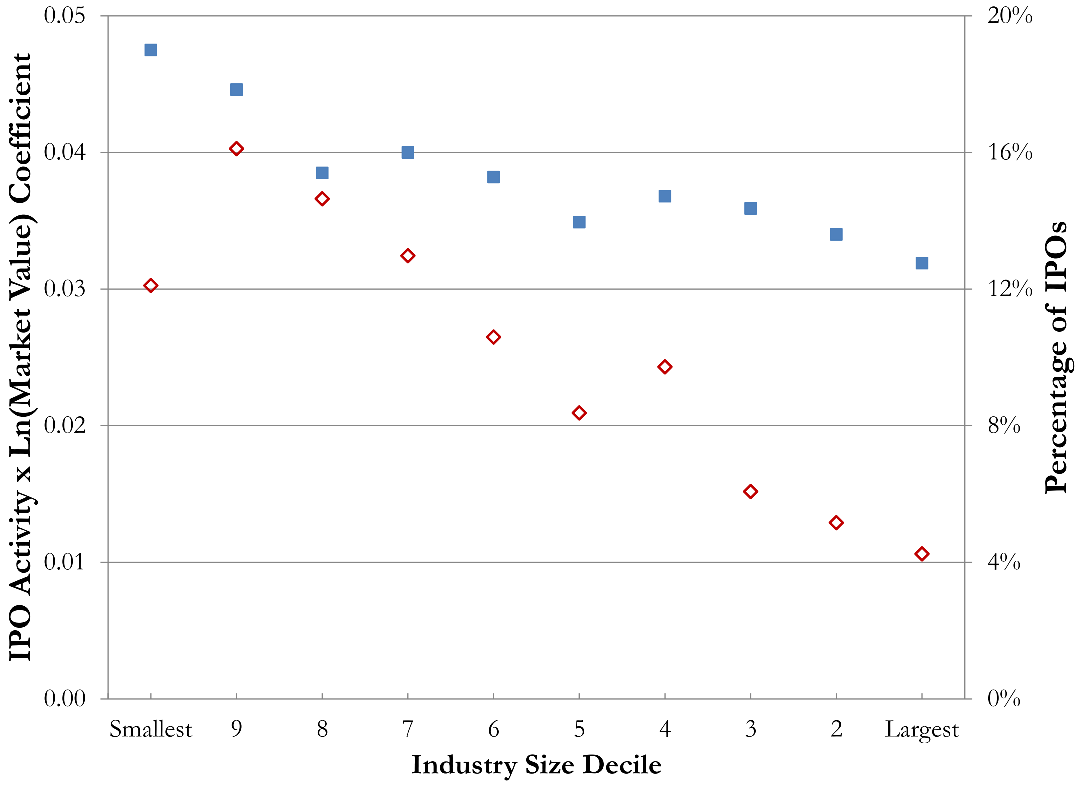
This figure graphs the yearly number of IPOs per industry scaled by the industries average size across the entire sample period. Only the top 2000 firms, ranked by total firm value, are considered in the sample.

Figure 3: CEO Compensation and IPO Activity by Size Decile



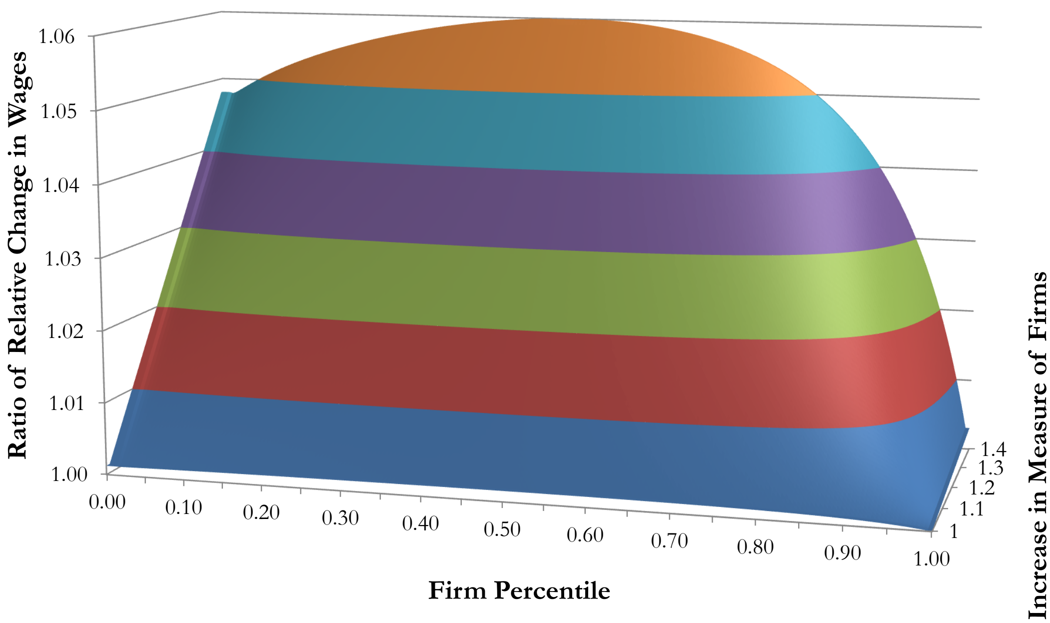
This figure graphs the average level of the log of total CEO compensation by size. Size deciles are computed within each industry-year and lagged by one year. High IPO represent years in the top tercile of an industrys IPO Activity. Low IPO represent years in the bottom tercile of an industrys IPO Activity. Shaded areas represent the 95% confidence interval of the difference between the High IPO and Low IPO groups. IPO Activity is the 3-year moving average within the industry. Included are controls for excess firm performance outlined in Appendix II, industry fixed effects, and year fixed effects. Only CEOs tenures which began while their firm ranked in the top 2000 firms, with respect to total firm value, are considered in the sample. All firms within two years of their initial public offering are excluded.

Figure 4: Sensitivity of Pay-Size Elasticity and IPO Activity Concentration



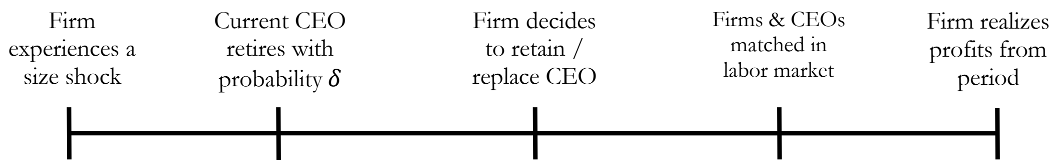
This figure graphs the effect of demand on pay-size elasticity (solid squares) and percentage of IPOs within the sample (hollow diamonds) by industry size decile. The effect of demand on pay-size elasticity is calculated as the piece-wise coefficient of logged total compensation on the interaction of logged firm value and IPO Activity for industry size deciles. IPO Activity is the standardized, 3-year moving average within the industry. Included are controls for excess firm performance outlined in Appendix II, industry fixed effects, and year fixed effects. All firms within two years of their initial public offering are excluded.

Figure 5: Change in Relative Wages for Increase in Demand for Managers



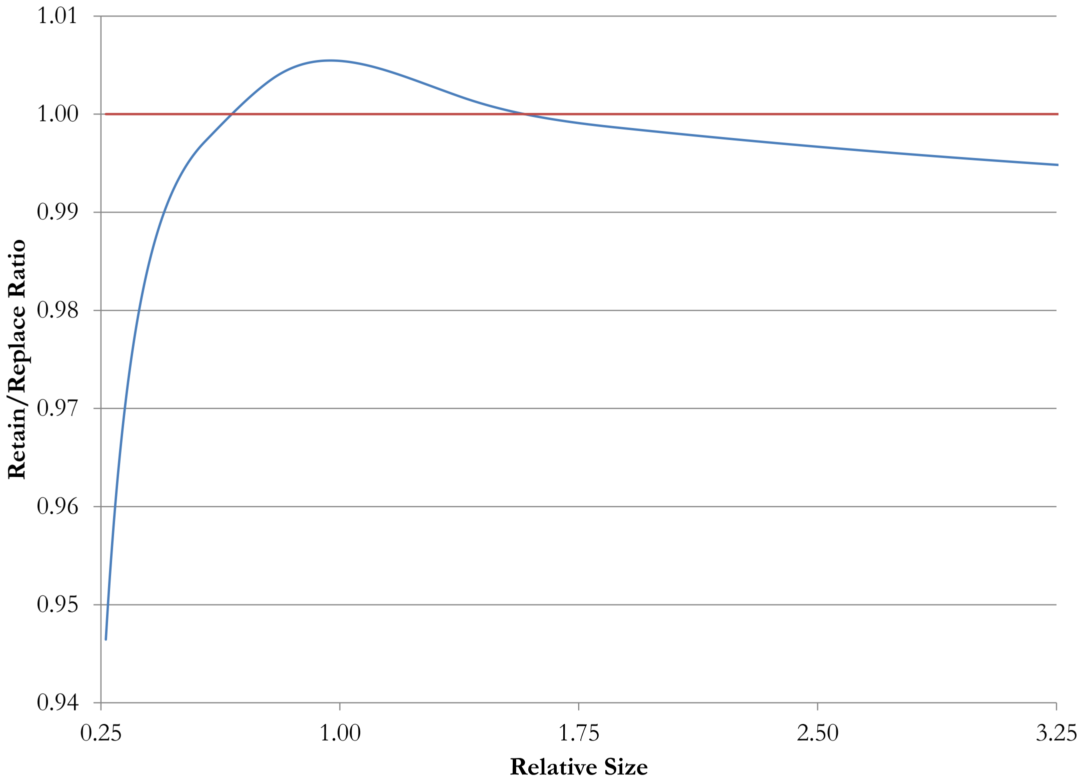
This figure plots the ratio of the relative change in wages following an increase in the measure of firms in the the economy over the relative change in wages prior to the increase in firm measure. Firm size is assumed to follow Zipfs Law with A set equal to 1000, and managerial talent is assumed to follow a bounded exponential distribution with lambda equal to unity. The initial measure of firms relative to managers is set to 0.1 and the reservation wage is set to 100. See Appendix I for details.

Figure 6: Timing of Model

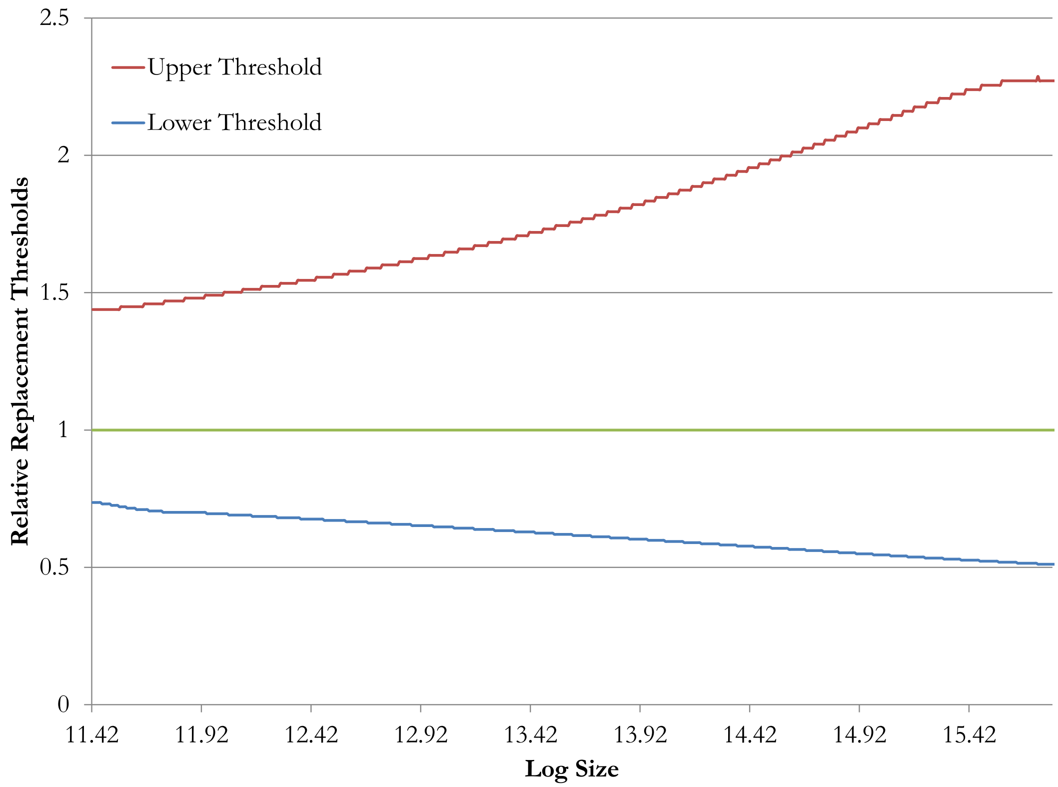


This figure depicts the timeline of events within each period of the dynamic model.

Figure 7: Value of Retaining versus Replacing Managers

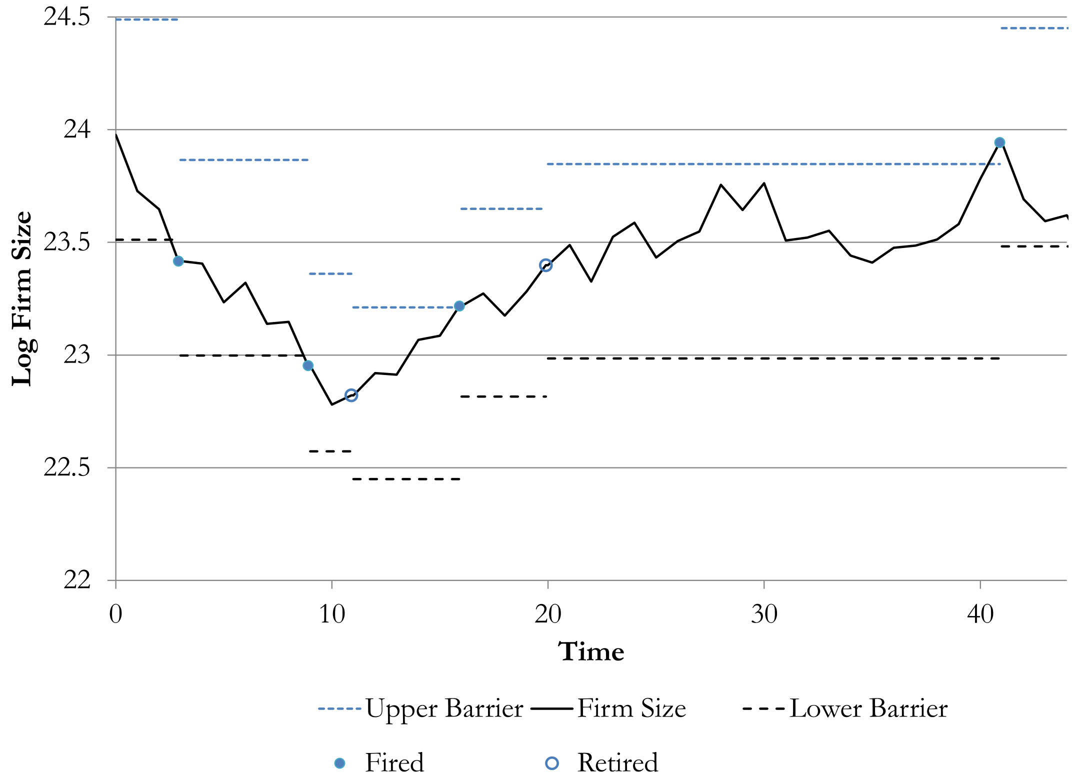


This figure illustrates a firms expected value given the retention or replacement of the incumbent CEO. The y-axis represents the expected firm value when retaining the existing manager to the expected firm value when replacing the incumbent manager. The x-axis represents the ratio of the firms current level of productive assets to level of productive assets when the incumbent manager was hired. The two points at which the blue line crosses 1.00 represent the switching thresholds where the firm finds it optimal to replace the existing manager. Panel B illustrates how these optimal switching thresholds vary with the level of productive assets at which point the incumbent CEO was hired.



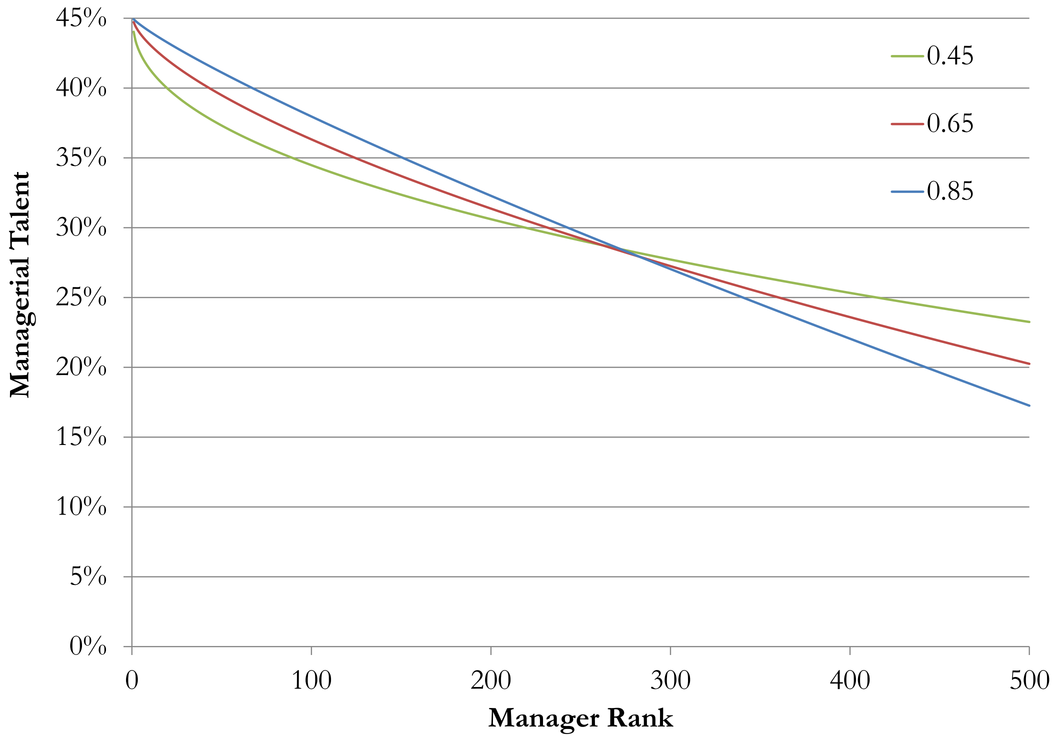
Upper Threshold
Lower Threshold
Relative Replacement Thresholds
Log Size
2.5
2
1.5
1
0.5
0
11.42
11.92
12.42
12.92
13.42
13.92
14.42
14.92
15.42

Figure 8: Simulated Path of One Firm



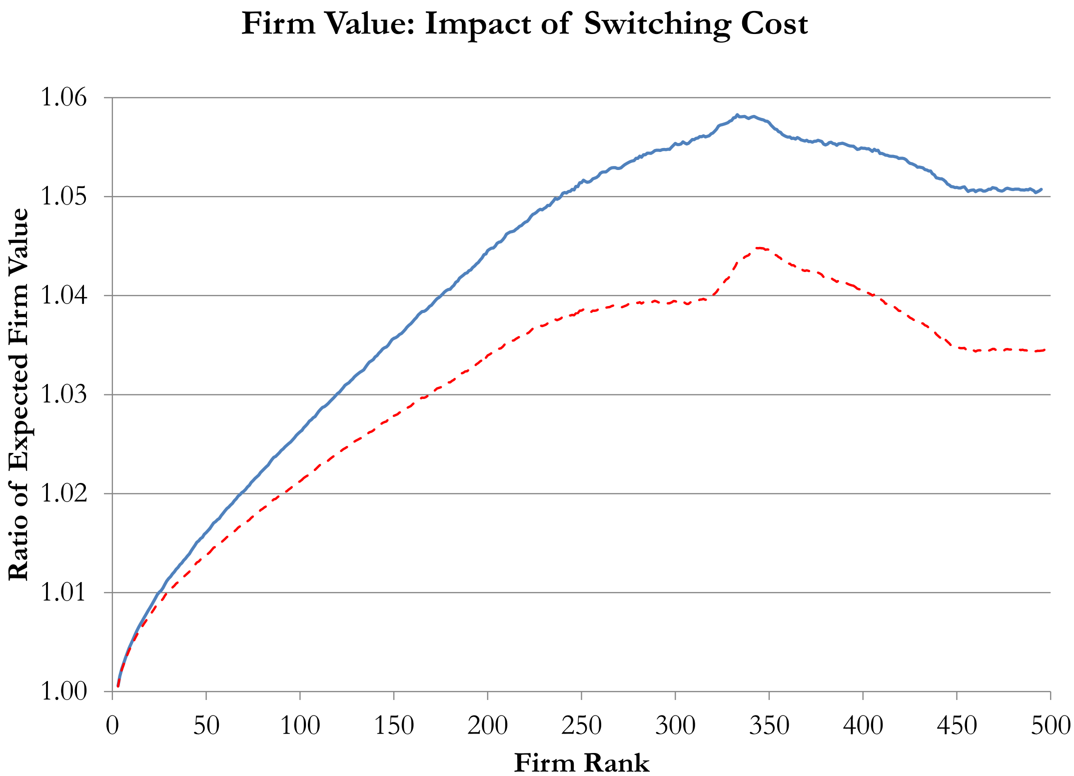
This figure depicts the actions of one simulated firm through time. The solid black line represents the level of the firms productive assets for each point in time. The dashed black (blue) line illustrates the optimal lower (upper) replacement threshold for the firm. Solid blue markers represent instances where the current CEO was replaced, while hollow blue markers represent periods where the incumbent CEO retired.

Figure 9: Talent Distribution



This figure illustrates how the convexity of the talent distribution varies with the tail index. The green, red and blue lines plot the talent level of the top 500 most talented mangers for tail indices of 0.45, 0.65, and 0.85 respectively.

Figure 10: Distortionary Effects of a Switching Cost



This figure illustrates relative expected firm values for a given size ranking under three scenarios (Panel A) and the proportion of value reduction due to suboptimal matching (Panel B). Optimal Matching represents an economy with a frictionless labor market. Matching Friction represents an economy with a switching cost which leads to the sub-optimal matching of firms and managers. Switching Cost represents an economy where firms experience an identical series of explicit switching costs as Matching Friction, but are also optimally matched with managers in each period. Panel A reports the three firm moving average of the ratio of expected firm value for the Optimal Matching and Switching Cost scenarios relative to the Matching Friction scenario. Panel B reports the ratio of the decrease in firm value when firms are sub-optimally matched with managers but do not pay the switching cost to the Switching Cost scenario.

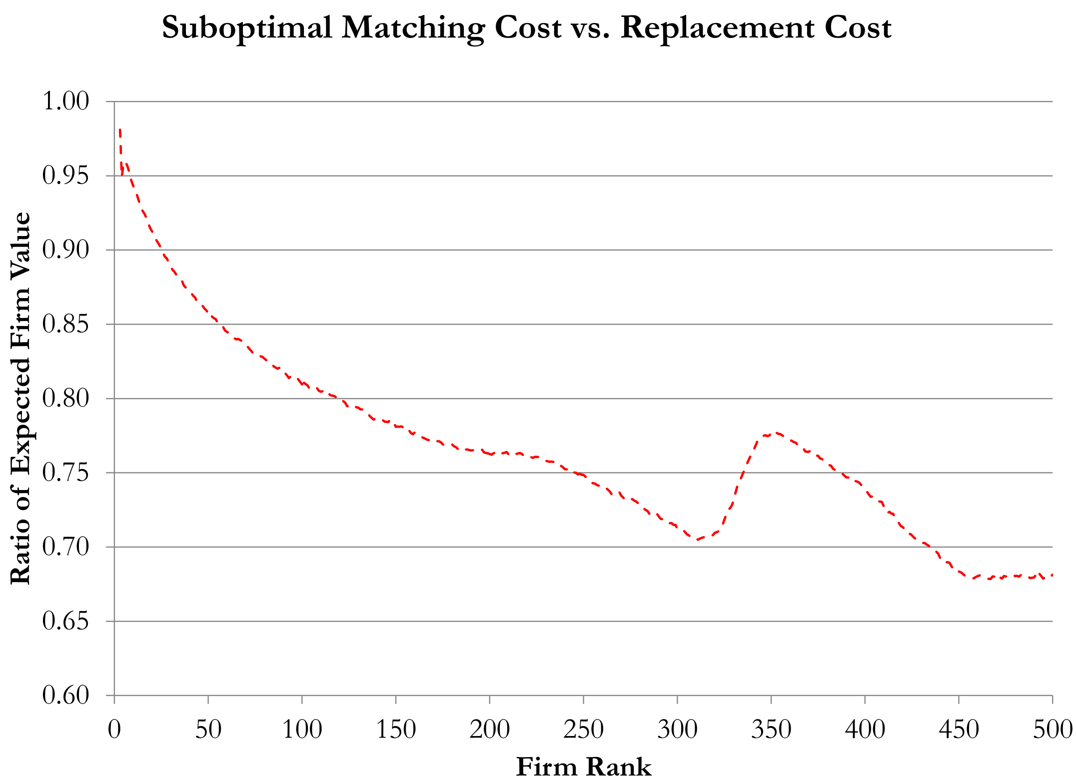
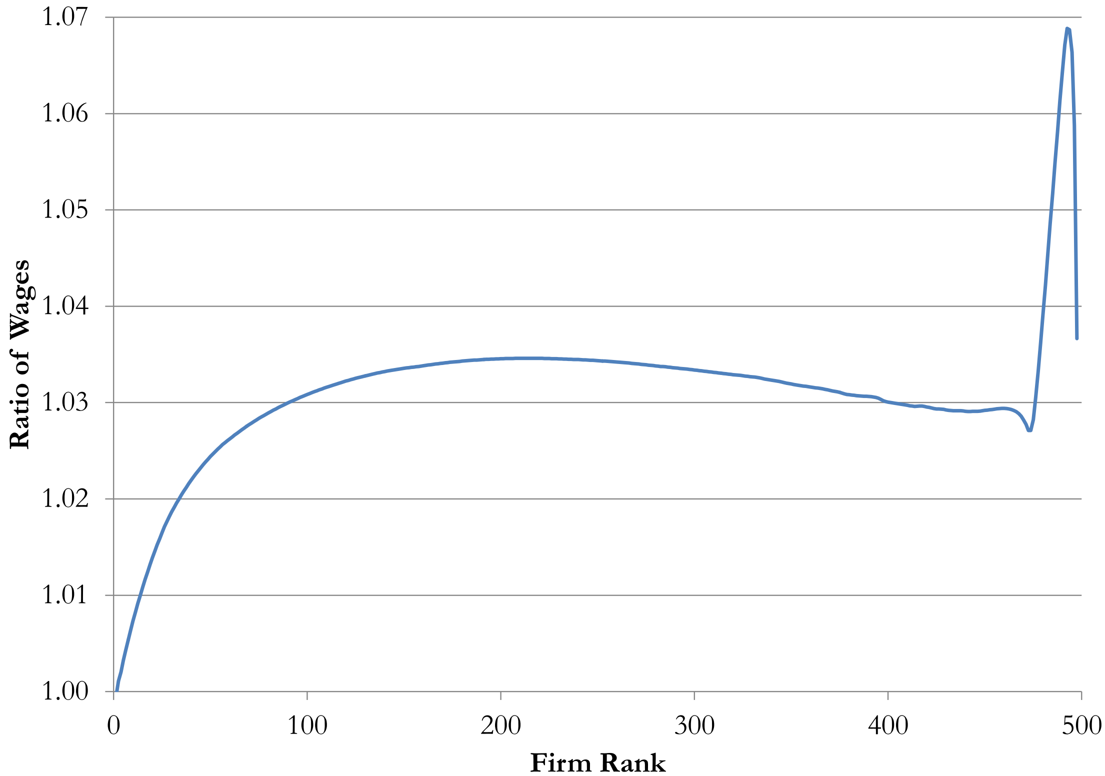

Suboptimal Matching Cost vs. Replacement Cost
Ratio of Expected Firm Value
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0
50
100
150
200
250
300
350
400
450
500
Firm Rank

Figure 11: Equilibrium Wages Within a Dynamic and Static Framework



This figure illustrates ratio of equilibrium wages in the dynamic model to the wages within a static framework, using the final estimates of the model parameters. The y-axis reports the ratio of wages under the two models. The x-axis represents the size ranking of the firm being considered, ranked in descending order of total firm value.

Appendices

Appendix A

Theoretical Proofs

Proof of Proposition 1: Let $W\left(F_s^{-1}(p)\right)$ be the wages paid by a firm with size s, such that $F_s(s) = p$. Let m_s and m_θ be the measure of firms and managers, such that $m_s < m_\theta$. Define $\boldsymbol{m} = \frac{m_s}{m_\theta}$. Denote the wages paid by the largest firm in the economy, $W\left(F_s^{-1}(1)\right)$, as $\overline{w}$. Denote the quantile functions $F_s^{-1}(p)$ and $F_\theta^{-1}(p)$ by $S(p)$ and $T(p)$, respectively. In equilibrium, by positive assortative matching, a manager with talent level $T(u)$ is matched with a firm of size $S\left(\frac{u-(1-\boldsymbol{m})}{\boldsymbol{m}}\right)$ for all $u > 1 - \boldsymbol{m}$. Then, given the wages of the largest firm, the wage function is characterized as follows:

$$W\left(F_s^{-1}(p)\right) = \overline{w} - \int_{1-(1-p)\cdot\boldsymbol{m}}^{1} S\left(\frac{u-(1-\boldsymbol{m})}{\boldsymbol{m}}\right) \cdot T(u)'\, du \tag{A1}$$

Now consider a second economy with firm size characterized by $\hat{f}_s(\cdot)$ such that $f_s(s) = \hat{f}_s(s)\ \forall\ s$, with measure $\widehat{m}_s = m_s \cdot x$ for some $x > 1$. Denote the wages paid by the largest firm in this economy as $\overline{\overline{w}}$. In equilibrium, a manager with talent level $T(u)$ is now matched with a firm of size $S\left(\frac{u-(1-\boldsymbol{m}\cdot x)}{\boldsymbol{m}\cdot x}\right)$ for all $u > 1 - \boldsymbol{m} \cdot x$. In similar fashion to Equation A1, equilibrium wages can be characterized by the following:

$$W\left(\hat{F}_s^{-1}(p)\right) = \overline{\overline{w}} - \int_{1-(1-p)\cdot\boldsymbol{m}\cdot x}^{1} S\left(\frac{u-(1-\boldsymbol{m}\cdot x)}{\boldsymbol{m}\cdot x}\right) \cdot T(u)'\, du \tag{A2}$$

Note, that Equation A2 can be re-written as:

$$W\left(\hat{F}_s^{-1}(p)\right) = \bar{\bar{w}} - \int_{1-(1-p)\cdot\boldsymbol{m}\cdot x}^{1-(1-p)\cdot\boldsymbol{m}} S\left(\frac{u-(1-\boldsymbol{m}\cdot x)}{\boldsymbol{m}\cdot x}\right)\cdot\, T(u)'\,du$$

$$- \int_{1-(1-p)\cdot\boldsymbol{m}}^{1} S\left(\frac{u-(1-\boldsymbol{m}\cdot x)}{\boldsymbol{m}\cdot x}\right)\cdot\, T(u)'\,du \qquad \text{(A3)}$$

Thus, by (A1) and (A3), the difference in equilibrium wages for a firm of in the p[th] percentile can be written as follows:

$$W\left(\hat{F}_s^{-1}(p)\right) - W\left(F_s^{-1}(p)\right)$$

$$= \bar{\bar{w}} - \bar{w} - \int_{1-(1-p)\cdot\boldsymbol{m}\cdot x}^{1-(1-p)\cdot\boldsymbol{m}} S\left(\frac{u-(1-\boldsymbol{m}\cdot x)}{\boldsymbol{m}\cdot x}\right)\cdot\, T(u)'\,du \qquad \text{(A4)}$$

$$- \int_{1-(1-p)\cdot\boldsymbol{m}}^{1} \left[S\left(\frac{u-(1-\boldsymbol{m}\cdot x)}{\boldsymbol{m}\cdot x}\right) - S\left(\frac{u-(1-\boldsymbol{m})}{\boldsymbol{m}}\right)\right]\cdot\, T(u)'\,du$$

By rearranging terms:

$$\left\{\bar{\bar{w}} - W\left(\hat{F}_s^{-1}(p)\right)\right\} - \left\{\bar{w} - W\left(F_s^{-1}(p)\right)\right\}$$

$$= \int_{1-(1-p)\cdot\boldsymbol{m}\cdot x}^{1-(1-p)\cdot\boldsymbol{m}} S\left(\frac{u-(1-\boldsymbol{m}\cdot x)}{\boldsymbol{m}\cdot x}\right)\cdot\, T(u)'\,du \qquad \text{(A4)}$$

$$+ \int_{1-(1-p)\cdot\boldsymbol{m}}^{1} \left[S\left(\frac{u-(1-\boldsymbol{m}\cdot x)}{\boldsymbol{m}\cdot x}\right) - S\left(\frac{u-(1-\boldsymbol{m})}{\boldsymbol{m}}\right)\right]\cdot\, T(u)'\,du$$

Note that for all $p < 1$ the first integral is strictly positive, given $S(\cdot), T(\cdot)' > 0$. In addition, it follows that:

$$\frac{u-(1-\boldsymbol{m}\cdot x)}{\boldsymbol{m}\cdot x}-\frac{u-(1-\boldsymbol{m})}{\boldsymbol{m}} = \frac{u-1}{\boldsymbol{m}\cdot x}-\frac{u-1}{\boldsymbol{m}} = \frac{u-1}{\boldsymbol{m}}\cdot\left(\frac{1}{x}-1\right)$$

Therefore,

$$\frac{u-(1-\boldsymbol{m}\cdot x)}{\boldsymbol{m}\cdot x} > \frac{u-(1-\boldsymbol{m})}{\boldsymbol{m}} \text{ for all } u<1, x>1$$

Thus,

$$S\left(\frac{u-(1-\boldsymbol{m}\cdot x)}{\boldsymbol{m}\cdot x}\right)-S\left(\frac{u-(1-\boldsymbol{m})}{\boldsymbol{m}}\right)>0$$

Implying that the second integral is also strictly positive for all $u<1$. Then for all $\{f_S(\cdot),\hat{f}_S(\cdot),f_\theta(\cdot)\}$ with finite upper support such that $f_S(s)=\hat{f}_S(s)\ \forall\ s$, if $\widehat{m}>m$, then:

$$\left[W\left(\hat{F}_S^{-1}(1)\right)-W\left(\hat{F}_S^{-1}(p)\right)\right]-\left[W\left(F_S^{-1}(1)\right)-W\left(F_S^{-1}(p)\right)\right]>0\ \forall\ 0\ \leq x<1 \tag{A5}$$

Therefore:

$$\frac{\partial}{\partial m}\left[W\left(F_S^{-1}(1)\right)-W\left(F_S^{-1}(p)\right)\right]>0, \forall\ p$$

Proof of Proposition 2: By assumption, the manager of the smallest firm earns their reservation wage, $\underline{w}$. Therefore, $W\left(\hat{F}_S^{-1}(0)\right)=W\left(F_S^{-1}(0)\right)=\underline{w}$. By Proposition 1, equation (A5), we have that for all $\{f_S(\cdot),\hat{f}_S(\cdot),f_\theta(\cdot)\}$ with finite upper support such that $f_S(s)=\hat{f}_S(s)\ \forall\ s$ and $\widehat{m}>m$: $W\left(\hat{F}_S^{-1}(1)\right)-W\left(\hat{F}_S^{-1}(x)\right)>W\left(F_S^{-1}(1)\right)-W\left(F_S^{-1}(x)\right)\ \forall\ 0\ \leq x<1$. Consider the case when $x=0$:

$$W\left(\hat{F}_s^{-1}(1)\right) - W\left(\hat{F}_s^{-1}(0)\right) > W\left(F_s^{-1}(1)\right) - W\left(F_s^{-1}(0)\right)$$

$$\Rightarrow\ W\left(\hat{F}_s^{-1}(1)\right) - \underline{w} > W\left(F_s^{-1}(1)\right) - \underline{w}$$

$$\Rightarrow\ W\left(\hat{F}_s^{-1}(1)\right) > W\left(F_s^{-1}(1)\right)$$

Thus, for all $\{f_s(\cdot), \hat{f}_s(\cdot), f_\theta(\cdot)\}$ with finite upper support such that $f_s(s) = \hat{f}_s(s)\ \forall\ s$: If $\widehat{m} > m$ then $W\left(\hat{F}_s^{-1}(1)\right) > W\left(F_s^{-1}(1)\right)$. Therefore:

$$\frac{\partial}{\partial m} W\left(F_s^{-1}(1)\right) > 0$$

Proof of Proposition 3: Denote the counter cumulative distributions of firm size and manager talent as $\bar{F}_s(s)$ and $\bar{F}_\theta(\theta)$, respectively. Define the quantile functions $\bar{F}_s^{-1}(p)$ and $\bar{F}_\theta^{-1}(p)$ by $\bar{S}(p)$ and $\bar{T}(p)$, respectively. Thus, $\bar{S}(0) = \bar{s}$, $\bar{S}(\cdot)' < 0$. In order to ensure that talent is bounded, suppose that there exists an $\varepsilon > 0$ such that $\overline{\theta} = \bar{T}(\varepsilon)$, and $\bar{T}(\cdot)' < 0$. Let m_s and m_θ be the measure of firms and managers, such that $m_s < m_\theta$. Define $\boldsymbol{m} = \frac{m_s}{m_\theta}$. Then, by positive assortative matching, a firm of size $\bar{S}(p)$ will now be matched with a manager of talent $\bar{T}(\varepsilon + p \cdot \boldsymbol{m})$. By positive assortative matching, a firm of size $\bar{S}(p)$ will be matched with a manager of talent $\bar{T}(p \cdot \boldsymbol{m})$. Following Gabaix and Landier (2008), we have the following:

$$\frac{\partial}{\partial p} W\left(\bar{F}_s^{-1}(p)\right) = \bar{S}(p) \cdot \frac{\partial}{\partial p} \bar{T}(\varepsilon + p \cdot \boldsymbol{m}) = \bar{S}(p) \cdot \bar{T}'(\varepsilon + p \cdot \boldsymbol{m}) \cdot \boldsymbol{m} \qquad \text{(A6)}$$

Consider a second economy with firm sizes drawn from the distribution $\hat{f}_s(\cdot)$, such that $f_s(s) = \hat{f}_s(s)\ \forall\ s$, with measure $\widehat{m}_s = m_s \cdot x$ for some $x > 1$. Note that the counter cumulative distribution and quantile functions are identical to $f_s(\cdot)$. In equilibrium, a firm of size $\bar{S}(p)$ is now matched to a manager with talent level $\bar{T}(\varepsilon + p \cdot \boldsymbol{m} \cdot x)$. Furthermore, the derivative of wages is as follows:

$$\frac{\partial}{\partial p}\widehat{W}\left(\bar{F}_s^{-1}(p)\right) = \bar{S}(p) \cdot \frac{\partial}{\partial p}\bar{T}(\varepsilon + p \cdot \boldsymbol{m} \cdot x) = \bar{S}(p) \cdot \bar{T}'(\varepsilon + p \cdot \boldsymbol{m} \cdot x) \cdot \boldsymbol{m} \cdot x \quad \text{(A7)}$$

The elasticity of wages to firm size at the p[th] percentile is greater in the economy with a greater measure of firms when the derivative in (A7) is larger than that of (A6). Rearranging terms yields:

$$\bar{T}'(\varepsilon + p \cdot \boldsymbol{m} \cdot x) \cdot x > \bar{T}'(\varepsilon + p \cdot \boldsymbol{m}) \quad \text{(A8)}$$

I now refer to the application of the extreme value theorem by Gabaix and Landier (2008), who derive an approximation of $\bar{T}'(\cdot)$, which holds exactly under certain assumptions. Given a tail index of α for the talent distribution $f_\theta(\cdot)$:

$$\bar{T}'(p) = -B \cdot p^{\alpha-1} \quad \text{(A9)}$$

Substituting (A9) into (A8) and simplifying yields:

$$\frac{(\varepsilon + p \cdot \boldsymbol{m})^{\alpha-1}}{(\varepsilon + p \cdot \boldsymbol{m} \cdot x)^{\alpha-1}} < x$$

Equivalently,

$$(\varepsilon + p \cdot \boldsymbol{m} \cdot x)^{1-\alpha} < x \cdot (\varepsilon + p \cdot \boldsymbol{m})^{1-\alpha} \quad \text{(A10)}$$

Given $\varepsilon > 0$ and $p < 1$, (A10) holds for all $\alpha \geq 0$, for any region of the talent distribution where the tail index is an exact characterization of the distribution: If $\alpha \geq 0$ and $\widehat{m} > m$ then

$$\frac{\partial\, W\left(\widehat{F}_s^{-1}(p)\right)}{\partial p} > \frac{\partial\, W\left(F_s^{-1}(p)\right)}{\partial p} \;\forall\; 0 \leq p < 1$$

Example of Increased Pay-Size Elasticity: While Proposition 3 proves that the local increase in wages at any firm size is an increasing function of the number of firms in the economy, this does not imply that pay-size elasticity also increases at every point. More specifically, because pay-size elasticity is a function of the level of wages in addition to the change of wages at a point, if the increase in the level of equilibrium wages at a point outpaces the increase in the change in wages at that point, pay-size elasticity will decrease. Thus, I the theory requires that

$$\frac{\frac{\partial}{\partial p} W\left(\bar{F}_s^{-1}(p)\right)}{W\left(\bar{F}_s^{-1}(p)\right)} \tag{A7}$$

is an increasing function in the measure of firms in the economy.

I will demonstrate that this is the case for talent characterized by an exponential distribution, which has a closed form quantile function allowing for an analytical representation of equilibrium wages at any point. Recall that equilibrium wages paid by a firm ranked in the p[th] percentile of the economy are characterized by the following:

$$W(p) = \int_0^p S(u) \cdot \hat{T}(u)'\, du + \underline{w} \tag{A8}$$

I will also assume that firm sizes follow Zipf's law (Gabaix and Landier (2008) provide empirical support for this assumption) with some scaling factor A:

$$S(p) = A \cdot (1-p)^{-1} \tag{A9}$$

Assuming an exponential talent distribution for some parameter lambda with a fixed upper support following Proposition 3, the quantile function of the talent distribution matched in an economy with measure m firms is:

$$\hat{T}(p) = F_{\theta}^{-1}(p) = \frac{\ln(1-(1-\varepsilon)\cdot m\cdot p)}{-\lambda} \tag{A10}$$

Thus, equilibrium wages paid by a firm in the p[th] percentile is:

$$\begin{aligned} W(p) &= \int_0^p A\cdot(1-u)^{-1}\cdot\frac{\partial}{\partial u}\frac{\ln(1-(1-\varepsilon)\cdot m\cdot u)}{-\lambda}\,du + \underline{w} \\ &= \int_0^p A\cdot(1-u)^{-1}\cdot\frac{\frac{1-\varepsilon}{\lambda}}{1-(1-\varepsilon)\cdot m\cdot u}\,du + \underline{w} \\ &= \underline{w} + \frac{A\cdot(1-\varepsilon)}{\lambda}\cdot\left[\frac{ln(1-(1-\varepsilon)\cdot m\cdot u)-ln(1-u)}{1+(1-\varepsilon)\cdot m}\right]\Bigg|_{u=0}^{p} \end{aligned} \tag{A11}$$

I will now focus on the counter cumulative distributions of firms and managers. Now, a lower value of p denotes a larger firm and a more talented manager. Following this transformation, the local relative change in wages of a firm in the p[th] percentile is:

$$\frac{\frac{A}{(1-p)}\cdot\frac{m}{-\lambda\cdot(\varepsilon+m\cdot p)}}{\underline{w}+\frac{A\cdot(1-\varepsilon)}{\lambda}\cdot\left[\frac{ln(1-(1-\varepsilon)\cdot m\cdot u)-ln(1-u)}{1+(1-\varepsilon)\cdot m}\right]\Bigg|_{u=0}^{1-p}} \tag{A12}$$

However, it remains to show that the absolute value of (A12) is increasing in the measure of firms in the economy.[1] Figure AII.1 illustrates the ratio of (A12) following an increase in the measure of firms relative to the previous value of (A12). The figure plots the ratio for differing values of *p*, denoting the firm at which the ratio is computed, as well as differing values of *x* which denotes the magnitude of the increase in the measure of firms in the economy (see Proposition 3 for the formal interpretation of *x*).

All ratios within the surface plot are greater than unity, indicating that the local pay-size elasticity is increasing in the measure of firms in the economy for all firms in the

[1] Following the switch in notation to the counter cumulative function, an increase in percentile will result in a decrease in wages. Therefore, an increase in the relative change in wages is realized when equation (A12) becomes more negative. If pay-size elasticity does with the measure of firms, then the absolute value of (A12) is an increasing function of the measure of firms.

economy. This result has been verified for differing values of $(\lambda, \varepsilon, m, A, \underline{w})$ and is robust to all values of these parameters.

Appendix B

Empirical Performance Controls

Prior performance and differences in firm characteristics are controlled for using standard accounting information obtained from Compustat. Both the firm value in excess of the industry median (Fama French 48) and median industry value are included.

Variable	Description
OROA	Ratio of net income (NI) to the book value of assets (AT).
OROS	Ratio of net income (NI) to sales (SALE).
ROE	Ratio of net income (NI) to the book value of common equity (CEQ).
Capex	Ratio of capital expenditures (CAPX) to the book value of assets (AT).
Leverage	Ratio of long term debt (DLTT) plus debt in current liabilities (LCT) to the book value of assets (AT).
Cash	Ratio of cash holdings (CH) to the book value of assets (AT).
Dividend	Ratio of dividends paid out (DVT) to the book value of assets (AT).
R&D	Ratio of research and development expenditures (XRD) to the book value of assets (AT).
Cash Flow	Ratio of earnings before extraordinary items (IB) plus depreciation expenses (DPC) to the book value of assets (AT).
Stock Return	Natural log of annual return on equity (fiscal year-end).

Appendix C

Dynamic Programming Problem

Solution to the Dynamic Programming Problem

This appendix solves the dynamic programming problem faced by the firm. I begin by introducing some notation. Let f_s be the probability distribution of firms participating in the labor market with respect to their level of productive assets. Let f_θ be the probability distribution of talent for managers participating in the labor market. Define A_t, θ_t, and $W(\theta_t)$ to be the productive assets of a firm, the talent level of its incumbent manager, and its wages paid at time *t*. Finally, let $\theta(A_t) \equiv F_\theta^{-1}(F_s(A_t))$, indicating the talent level of the manager a firm with productive asset A_t would be matched with in the labor market.

Now, I re-examine the value maximization problem faced by a firm. Each firm maximizes expected value through its firing decision:

$$V(\theta_{t-1}, A_t) \equiv \max_{\{d_s\}_{s=t}^{\infty}} E_t\left[\sum_{s=t}^{\infty} \beta^{s-t}\pi_s\right] \qquad \text{(AI.1)}$$

where θ_{t-1} is the talent level of the incumbent manager at the close of the previous period. Furthermore, because all agents are risk-neutral and the idiosyncratic component of profitability in equation (4) has mean zero, the solution to (AI.1) can be found by excluding this term altogether. Therefore, by substituting (4) into (AI.1) and separating out the current period's dividend, I get the following:

$$V(\theta_{t-1}, A_t) \equiv \max_{\{d_s\}_{s=t}^{\infty}} A_t \cdot \left(\theta_t - d_t \cdot c_{replace}\right) - W(\theta_t) + E_t\left[\sum_{s=t+1}^{\infty} \beta^{s-t}\pi_s\right] \qquad \text{(AI.2)}$$

$$\equiv \max_{d_t} \begin{cases} \left(A_t\theta_t - W(\theta_t) + \max_{\{d_s\}_{s=t+1}^{\infty}} E_t\left[\sum_{s=t+1}^{\infty} \beta^{s-t}\pi_s\right] \middle| \theta_t = \theta_{t-1}\right), \\ \left(A_t \cdot (\theta_t - c_{replace}) - W(\theta_t) + \max_{\{d_s\}_{s=t+1}^{\infty}} E_t\left[\sum_{s=t+1}^{\infty} \beta^{s-t}\pi_s\right] \middle| \theta_t = \theta(A_t)\right) \end{cases} \tag{AI.3}$$

I now focus on the first value in (AI.3), which corresponds to the case when the firm retains their current CEO. While the firm has chosen to retain the incumbent manager, she will retire with probability δ at the end of the period after the profits have been realized. Therefore, the value of the firm conditional on retaining the existing manager is:

$$\begin{aligned} V(\theta_{t-1}, A_t)^{retain} &= A_t\theta_{t-1} - W(\theta_{t-1}) \\ &+ (1-\delta) \cdot \left(\max_{\{d_s\}_{s=t+1}^{\infty}} E_t\left[\sum_{s=t+1}^{\infty} \beta^{s-t}\pi_s\right] \middle| \theta_t = \theta_{t-1}\right) \\ &+ \delta \\ &\cdot \left(\max_{\{d_s\}_{s=t+1}^{\infty}} E_t\left[\sum_{s=t+1}^{\infty} [\beta^{s-t}\pi_s] - \beta \cdot c_{retire} \cdot A_{t+1}\right] \middle| \theta_{t+1} = \theta(A_{t+1})\right) \end{aligned} \tag{AI.4}$$

By factoring out a β term from both summations, and given the distribution of size shocks, f_x, the switching cost can be separated out by conditioning on the firm's current level of assets, yielding:

$$V(\theta_{t-1}, A_t)^{retain} = A_t\theta_{t-1} - W(\theta_{t-1})$$
$$+ \beta(1-\delta)$$
$$\cdot \int \left(\max_{\{d_s\}_{s=t+1}^{\infty}} E_t \left[\sum_{s=t+1}^{\infty} \beta^{s-t-1}\pi_s \right] \middle| \theta_t = \theta_{t-1},\ A_{t+1} = A_t x \right) f_x\, dx + \beta\delta$$
$$\cdot \int \left(\max_{\{d_s\}_{s=t+1}^{\infty}} E_t \left[\sum_{s=t+1}^{\infty} \beta^{s-t-1}\pi_s \right] \middle| \theta_{t+1} = \theta(A_{t+1}),\ A_{t+1} = A_t x \right) f_x\, dx \qquad \text{(AI.5)}$$
$$- \beta\delta \cdot \int c_{retire} \cdot (A_t x) \cdot f_x\, dx$$

Note that first integrand is represents (AI.1) one period into the future. Furthermore, the second integrand is of the same form with one exception. The firm no longer has any choice over retaining or replacing the incumbent CEO in period *t+1* following their retirement at the end of time *t*. However, a manager with talent level $\theta(A_{t+1})$ at the end of time *t* is, by definition, the optimal match at time *t+1*, thereby satisfying equation (AI.1). Therefore, (AI.5) can be simplified to the following:

$$V(\theta_{t-1}, A_t)^{retain} = A_t\theta_{t-1} - W(\theta_{t-1}) + \beta(1-\delta) \cdot \int V(\theta_{t-1},\ A_t x) f_x\, dx$$
$$+ \beta\delta \cdot \left[\int V(\theta(\ A_t x),\ A_t x) f_x\, dx - \int c_{retire} \cdot (\ A_t x) f_x\, dx \right] \qquad \text{(AI.6)}$$

$$= A_t\theta_{t-1} - W(\theta_{t-1}) + \beta \cdot \left[(1-\delta) \cdot E_t[V(\theta_{t-1}, A_{t+1})] + \delta \cdot E_t[V(\theta(A_{t+1}), A_{t+1}) - c_{retire} \cdot A_{t+1}] \right] \qquad \text{(AI.7)}$$

$$= A_t\theta_{t-1} - W(\theta_{t-1}) + \beta$$
$$\cdot E_t\left[(1-\delta) \cdot V(\theta_{t-1}, A_{t+1}) + \delta \cdot [V(\theta(A_{t+1}), A_{t+1}) - c_{retire} \cdot A_{t+1}] \right] \qquad \text{(AI.8)}$$

Intuitively, (AI.8) can be broken down into three parts. The first term represents the dividends earned in the current period if the manager is retained. The second component represents the discounted expected value of the firm next period conditional on the manager not retiring. The last element is the discounted expected value of the firm if the current manager does retire.

Alternatively, the firm's other option is to replace the current manager. Fortunately, this case can be represented much more concisely, while still remaining intuitive. Recall that if the firm replaces its current manager, its value can be represented by the following expression:

$$V(\theta_{t-1}, A_t)^{replace} = A_t\theta(A_t) - W\big(\theta(A_t)\big) + \left(\max_{\{d_s\}_{s=t+1}^{\infty}} E_t\left[\sum_{s=t+1}^{\infty} \beta^{s-t}\pi_s\right]\middle|\theta_t = \theta(A_t)\right) - A_t \cdot c_{replace} \qquad \text{(AI.9)}$$

Note that this value is equivalent to equation (AI.1) when $\theta_{t-1} = \theta(A_t)$ with the exception of the switching cost suffered by the firm. Furthermore, $\theta_{t-1} = \theta(A_t)$ implies that the CEO of the firm at the close of *t-1* is the optimal manager of the firm at time *t* given the assets of the firm at time *t*. Thus, the value of the firm when replacing the current CEO is:

$$\begin{aligned} V(\theta_{t-1}, A_t)^{replace} &= A_t\theta(A_t) - W\big(\theta(A_t)\big) + \beta \\ &\cdot E_t\big[(1-\delta)\cdot V(\theta(A_t), A_{t+1}) \\ &+ \delta \cdot [V(\theta(A_{t+1}), A_{t+1}) - c_{retire}\cdot A_{t+1}]\big] - A_t \cdot c_{replace} \end{aligned} \qquad \text{(AI.10)}$$

$$V(\theta_{t-1}, A_t)^{replace} = V(\theta(A_t), A_t) - A_t \cdot c_{replace} \qquad \text{(AI.11)}$$

Thus, by substituting equations (AI.8) and (AI.11) into the original maximization problem that the firm faces the following Bellman equation is achieved:

$$V(\theta', A_t)$$

$$\equiv \max_{d_t} \begin{cases} A_t\theta' - W(\theta') + \beta \cdot E_t\big[(1-\delta) \cdot V(\theta', A_{t+1}) + \delta \cdot [V(\theta(A_{t+1}), A_{t+1}) - c_r \\ V(\theta(A_t), A_t) - A_t \cdot c_{replace} \end{cases} \qquad \text{(AI.12)}$$

Appendix D

Equilibrium Distributions

Equilibrium Distributions of Firms and Managers in the Labor Market

i. Distribution of Competitive Firm Sizes

In equilibrium, the stationary distribution of firms competing in the labor market is a function of the optimal policy function of the firm. While asset productivity of a firm has been treated as a continuous random variable up to this point, the steady state distribution is more easily explained in a discrete context. Therefore, let a firm's productive assets, A, take on values from the discrete set $\{A_0, A_1, \dots, A_N\}$. Then, given the optimal policy function that solves the dynamic programming problem, $(\underline{A}, \overline{A})$, a firm will not replace its manager so long as its productive assets satisfy the following condition: $A \in [\underline{A}, \overline{A}]$.

The stationary distribution of firms entering the labor market requires the probability distribution of a firm's productive assets upon entering the labor pool, conditional on having assets A_i when the incumbent manager was hired. To do this, I must separate a firm's dynamics into two parts, 1) the changing of its assets due to productivity shocks and 2) the need to enter the labor market, either by choice or due to managerial retirement. Therefore, two Markov chains will be constructed, each with dimensions (N+1) *x* (N+1). The first of these, Π, represents the probability of moving from A' to A in a single period. This Markov chain also features an additional state, indexed by *N+1*, that serves as an absorbing state for firms who have already entered the labor market. Let $p_{i,j} \equiv P(A = A_j | A' = A_i)$, then:

$$\Pi = \begin{bmatrix} p_{0,0} & \cdots & p_{0,N} & 0 \\ \vdots & \ddots & \vdots & \vdots \\ p_{N,0} & \cdots & p_{N,N} & 0 \\ 0 & \cdots & 0 & 1 \end{bmatrix} \tag{AII.1}$$

The second Markov chain, Γ, represents the likelihood of a firm seeking out a new manager given their current level of assets, A_j. This probability is composed of two factors. First, every firm is at risk of their manager retiring at the end of the previous period. Secondly, if A_j is outside the switching threshold, $(\underline{A}, \overline{A})$, the firm will enter the labor market with certainty. The last column of this matrix represents the firm's likelihood of changing managers, while the diagonal values represent the firm's likelihood of retaining their current manager. All other elements have a value of zero, as a firm will either retain their current manager and stay in their current state or replace their manager thereby entering the absorbing state:

$$\Gamma = \begin{matrix} 0 \\ \vdots \\ \underline{A}-1 \\ \underline{A} \\ \vdots \\ \overline{A} \\ \overline{A}+1 \\ \vdots \\ n+1 \end{matrix} \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & \dots & \dots & 1-\delta & \dots & \dots & \vdots & \vdots & \delta \\ 0 & \dots & \dots & 0 & 1-\delta & 0 & \vdots & \vdots & \vdots \\ 0 & \dots & \dots & \dots & \dots & 1-\delta & \vdots & \vdots & \delta \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad \text{(AII.2)}$$

Therefore, the probability of a firm transitioning from A_i to A_j after *t* periods can then be found in the *ith* row and *jth* column of the following matrix:

$$(\Pi\Gamma)^{(t)} \equiv \prod_{i=1}^{t} (\Pi \cdot \Gamma) \quad \text{(AII.3)}$$

The probability that a firm enters the labor market with assets A_j conditional on having initial assets A_i is found in (AII.4), below. Intuitively, the ith row of $(\Pi\Gamma)^{(t)}$ represents the distribution of a firm's assets after *t* periods without entering the labor market, conditional on starting with assets A_i. Multiplying this value by Π and taking the element in the *i*th row and *j*th column yields the probability of transitioning to A_j in one additional period. This value is then multiplied by the probability of entering the labor market given assets A_j, which is equal to 1 if the A_j is beyond the replacement threshold or δ if A_j is within the optimal switching threshold but the current CEO retires. Summing over all the possible number of periods before entering the labor market gives the final probability:

$$P_{i,j} \equiv \begin{cases} \sum_{t=1}^{\infty} \left[(\Pi\Gamma)^{(t)} \cdot \Pi \right]_{i,j} \cdot \delta \ \text{ if } A_j \in [\underline{A}, \overline{A}] \\ \sum_{t=1}^{\infty} \left[(\Pi\Gamma)^{(t)} \cdot \Pi \right]_{i,j} \cdot 1 \ \text{ if } A_j \notin [\underline{A}, \overline{A}] \end{cases} \tag{AII.4}$$

Finally, given $P_{i,j}$ for all possible values of *i* and *j*, the stationary distribution of firms upon entering the labor market, represented by the column vector Π of dimension 1 *x* N, satisfies the following condition:

$$\Pi = \Pi \cdot \begin{bmatrix} P_{0,0} & \cdots & P_{N,0} \\ \vdots & \ddots & \vdots \\ P_{0,N} & \cdots & P_{N,N} \end{bmatrix} \tag{AII.5}$$

ii. Distribution of Labor Pool Talent

Given the distribution of firms entering the labor market, it is relatively straightforward to find the distribution of talent levels for managers in the labor market. This pool has two contributing sources, newly born CEOs in the economy and CEOs who have been released from their current firm. These two groups must be characterized separately and then aggregated into one distribution.

In the framework of the model, the distribution of newly born CEOs is assumed to be exogenous. Furthermore, in equilibrium the measure of these CEOs being born is equal to the percentage that retired in the same period, similar to an overlapping generation framework. Using the extreme value theorem the ability of a manager in the xth percentile is defined as:

$$\theta(x) = \theta_{max} - \frac{B}{\propto} \cdot x^{\propto} \tag{AII.6}$$

Alternatively, the distribution of managers participating in the labor pool after previously running a firm is closely related to the distribution of firm's entering the labor pool. I first discretize the distribution of managers. For each of the firms in the discrete set $\{A_0, A_1, \dots, A_N\}$, assign a manager according to (AII.7):

$$\theta_i = \theta(A_i) = F_{\theta}^{-1}(F_s(A_i)) \tag{AII.7}$$

Next, consider a firm with an initial assets A_i. The firm's choice to enter the labor market will be made due to managerial replacement or retirement. Therefore, I first factor out the probability of retirement. If the firm's assets upon entering the labor market are still within the switching threshold of the firm, the CEO retired with certainty. Alternatively, if the firm is outside the switching threshold, the probability that their CEO retired is equal to δ. Therefore, by leveraging (AII.4), the probability of a firm with initial assets A_i releasing their current manager of talent level θ_i back into the labor market is:

$$Prob(\theta_i \text{ re-entering} | A_i) = \left(1 - \sum_{j | A_j \in [\underline{A}, \overline{A}]} P_{i,j}\right) \cdot (1 - \delta) \tag{AII.8}$$

Finally, the distribution of CEOs that re-enter the labor market is proportional to (AII.8), which is conditional on having initial assets A_i, multiplied by the probability of having initial assets A_i. By referencing the stationary distribution of firm sizes in the labor market found in equation (AII.5), the distribution of talent re-entering the pool is proportional to:

$$f_\theta(\theta_i) = \Pi_i \cdot \left(1 - \sum_{j|A_j \in [\underline{A}, \overline{A}]} P_{i,j} \right) \cdot (1 - \delta) \tag{AII.9}$$

Therefore, aggregating (AII.6) and (AII.9) yields the overall talent distribution of managers found in the labor market.

Appendix E

General Equilibrium Solution

Solution to the General Equilibrium

i. General Equilibrium Solution

The general equilibrium solution is found by first assuming a distribution of firms and managers participating in the labor market as well as a wage schedule, and solving the dynamic programming problem faced by a firm given these distributions. Wages are then recalculated given the value function, and the dynamic programming problem is solved for again. After finding the fixed point of this problem, the optimal policy function generated by the solution is used to generate a new pair of distributions for firms and managers participating in the labor market. Given these new distributions, the solution to the maximization problem is calculated again. This process is repeated until the current policy function is identical to that of the previous iteration, at which point the general equilibrium has been found.

I rely on numerical techniques to solve the dynamic programming problem and the associated firm size and talent distributions. Firms are assumed to take on discrete levels of productive asset whose logged values are evenly spaced over a grid of 1,200 points. The assets at the upper and lower endpoints are chosen to match the assets of the largest and 500th firm, respectively, in our sample as of 1993. While these assets remain fixed from iteration to iteration, the associated probability mass function does not, and must be solved for. However, in order to solve the dynamic programming problem, a size distribution must first be assumed. Therefore, consistent with the findings of Gabaix and Landier (2008), the initial distribution is assumed to be governed by Zipf's law.[2] All atomistic firms that lie on a

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[2] While the distribution of size is assumed to follow Zipf's law, the general equilibrium solution is not dependent on these starting values. However, while any distribution could be assumed, the speed of

discrete grid point are assumed to have managers of equal talent levels. Therefore, given parameter values governing the distribution of manager ability, talent levels can be computed (AII.6) using the probability mass associated with each point. Finally, given these firm sizes and talent levels, an initial guess for the wages earned by each manager is generated according to (3).

Given parameter values, manager and firm distributions, and wages, (6) is solved for by value function iteration. The iterative process continues until the difference in values from one iteration to the next converges to a sufficiently small amount.[3] However, the resulting values are implicitly a function of the initial series of wages specified, which do not necessarily satisfy (7). Competitive wages are such that a firm's value upon entering the labor market would be unchanged if it was matched with a manager one ranking better than its optimal match, thus making the firm indifferent between the two managers. To find this equilibrium, the firm values from the previous step are used to update the wage levels and firm values are re-computed. This process is repeated until the difference in wages from one iteration to the next is sufficiently small. At this point, the equilibrium wages have been found given a distribution of firms and managers participating in the labor market. This also yields a decision rule that each firm will follow when deicing to retain or replace its manager.

This optimally policy function can then be used in equations (AII.5) to update the probability mass function of the firms participating in the labor market. Finally, the distribution of managers in the pool can be updated by aggregating the resulting probability

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convergence does depend on the initial probability mass function. As I do not have a prior on the general form of the final distribution, Zipf's law seems as suitable as any for a starting guess.

[3] The value function is iterated over until the sum of the absolute changes from one iteration to the next is less than 0.01.

mass function of CEOs re-entering the pool from equation (AII.9) with the newly born individuals entering the pool for the first time.

After repeating this cycle until every firm's decision remains unchanged from one solution of the optimization problem to the next, the optimal policy function in a competitive equilibrium has been generated, given an initial parameter set.

Appendix F

Simulated Method of Moments

Simulated Moment Generation

Given a set of model parameters, the general equilibrium is first computed from which the optimal policy function is derived. Next 500 firms are created, each one given an initial size according to Zipf's law and optimally matched with a CEO drawn from the distribution governed by the model parameters.[4] After creation, 150 years are allowed to pass so a steady state can be established. In each year, every firm's level of productive assets experiences a shock drawn from a uniform distribution with mean one and support dictated by the model parameters. Additionally, each firm's manager faces a chance of retirement with probability δ. If either a firm's CEO retires or the productivity shock it received moves it beyond the switching threshold, it enters the labor pool to seek a replacement. The pool of CEOs available to choose from is comprised from two sources. First, all the managers released by their respective firms re-enter the labor market. The second source consists of a group of newly born managers, whose total number equals the number of CEOs that retired in the previous period, is drawn from the distribution governed by the model's parameters. Each firm competing in the pool is assigned a new manager according to their relative ranking amongst all other competing firms, and wages are set accordingly. Each firm then generates revenues based on amount of assets at the start of the period and the current manager in place, and pays out all revenue net wages to the shareholders as a dividend.

After 150 years have passed, the entire time-series of profits for the current CEO spells are collected. The economy is then permitted to continue for another 18 years. Thus

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[4] In addition to Zipf's law, which dictates the spacing between firms, the size of one firm must be specified to pin down the distribution. Therefore, the size of the 500th firm is set to roughly correspond to the size of the 500th firm in the sample in 1993.

the final panel consists of 500 firms over a 19 year span, consistent with the data collected from Compustat and Execucomp.

Once the full panel has been simulated, moments are calculated from the generated data in exactly the same way as they were computed on the actual data. The economy is then reset, and is simulated again until 64 sets of moments have been generated. At this point, the objective function from (8) is computed. I seek to find the parameter set corresponding to the global minimum of the objective function, which may also have many local minima. Therefore, standard convex optimization routines should be avoided. Ideally, the global minimum would be found using a grid search over the state space of feasible parameter values; however the computationally intensive nature of the problem makes this impractical. For these reasons, a simulated annealing routine is used to estimate the model, where the initial temperature is estimated from a set of 50 random parameter values. To avoid any unnecessary instability in the optimization process, for each set of parameters considered the same random seed is used when initializing the economy for the first time.

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