CEO Talent, CEO Compensation, and Product Market Competition*

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Abstract

We study how the distributions of CEO talent and compensation vary across industries, and how product market characteristics affect these distributions. We develop a market equilibrium model that incorporates the competitive assignment of CEOs to firms in a framework in which firms engage in imperfect product market—specifically, monopolistic—competition. We use the model to address the following principal research questions: (i) How important is managerial talent when the product market environment in which firms operate is considered? (ii) How do product market characteristics, such as the entry cost and the elasticity of substitution between differentiated products, affect CEO compensation? (iii) How does the distribution of CEO talent vary across industries? (iv) To what extent can product market characteristics explain the wide variation in the levels and distributions of CEO compensation across industries?

Using the distributions of CEO pay and firm value in each of twelve Fama-French industries, we calibrate the parameters of our structural model, and indirectly infer the unobserved distributions of CEO talent and firm quality that together determine firm output. We then conduct several counterfactual experiments using the calibrated models corresponding to each of the industries. We find that the distribution of CEO talent does, indeed, vary dramatically across industries. More importantly, contrary to the conclusions of earlier studies that abstract away from the effects of the product market (Terviö, 2008 and Gabaix and Landier, 2008), the impact of CEO talent on firm value appears to be quite significant. Our estimates of the effect of CEO talent on firm value for the industries in our sample are two orders of magnitude higher than those obtained by the aforementioned studies. Further, our estimates suggest that the compensation of CEOs is quantitatively in line with their contributions to firms. Broadly, our study shows that it is important to incorporate the product market environment in which firms operate when assessing the contributions of CEOs to firms.

JEL Classification: D43, D59, G30, J24, J31, L11, L13, M52
Key Words: CEO Talent, Firm-CEO Matching, CEO compensation, Monopolistic Competition

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1 Introduction

In 2005, the average (median) CEO in the energy and telecom industries earned \$10.22 (4.72) million and \$7.48 (3.86) million, respectively, whereas the average (median) CEO in the consumer durable goods industry earned only \$3.24 (2.68) million (based on data on S&P 1500 firms). The difference between the maximum and minimum CEO pay levels within an industry ranges from \$12.63 million in the consumer durable goods industry to \$92.20 million in the business equipment industry. Why do the levels and distributions of CEO pay vary so dramatically across industries? Are variations in industry characteristics largely responsible for the variations in the distributions of CEO pay or do inter-industry variations in the distributions of managerial ability/talent play an important role in explaining these findings? How important is managerial talent when industry characteristics and, more generally, the product market environment in which firms operate are considered? To what extent do product market characteristics affect the levels and distributions of CEO compensation and firm value across industries?

We address these questions by developing a market equilibrium model in which the competitive assignment of CEOs to firms and imperfect product market competition among firms interact to determine the distributions of firm value and managerial compensation. Managers of different talent levels are matched to firms of different qualities, and their match quality determines firm productivity. There exists a unique, stationary equilibrium of the model in which CEO-firm matches and the distributions of firm market value and managerial compensation are endogenously determined. We calibrate the structural model using the distributions of firm value and CEO pay in each of twelve Fama-French industries. In addition to the key structural parameters of the model, we also indirectly infer the unobserved distributions of CEO talent and firm quality in each of the industries. We then conduct counterfactual experiments using the calibrated models corresponding to each of the industries to explore the quantitative effects of managerial talent and product market characteristics.

First, we show that there is substantial variation not only in the distributions of firm quality and managerial talent across industries, but also in their relative contributions to firm value. The dispersions of these attributes are much larger in high-tech industries—including business equipment, health care, and telecom—relative to traditional manufacturing industries. Second, in contrast with the strikingly small estimate obtained by Gabaix and Landier (2008), we find that, when product market characteristics are taken into account, CEO talent has a much more significant impact on firm value. Our estimates of the impact of CEO talent are roughly two orders of magnitude higher than that of Gabaix and Landier (2008). Our results show that the incorporation of product market characteristics and intra-industry competition among firms plays a central role in generating the significantly different estimates. Third, again in contrast with the findings of Gabaix and Landier (2008) and Terviö (2008), our estimates of the impact of CEO talent on firm value are of the same order of magnitude as the ratio of CEO compensation to firm value. The compensation of CEOs is, therefore, quantitatively in line with their marginal products. Fourth, we analytically derive a number of novel implications for the effects of product market characteristics on the number of active firms in an industry as well as the distributions of managerial compensation and firm value.

We build a discrete time, infinite horizon model of an industry in which there is a continuum of heterogeneous firms engaging in imperfect product market—specifically, monopolistic—competition (Dixit and Stiglitz, 1977). We explicitly incorporate heterogeneity in manager and firm attributes as well as the endogenous matching of CEOs to firms. Managers are characterized by a variable referred to as *talent*, and firms are also characterized by a single variable, namely *firm quality.* Firms are established by entrepreneurs who make an initial sunk investment. Firm quality, which is a random variable drawn from a known distribution, is realized after entry. Consequently, firms are identical ex ante (i.e. prior to entry), but differentiated ex post. Each firm then hires a manager. Firm qualities and managerial talents are observable to market participants. Similar to Terviö (2008), the *match quality* is a multiplicative function of CEO talent and firm quality. The match quality determines the firm's productivity in each period. Firms are monopolistically competitive in that they take the aggregate price index—the weighted average of the prices charged by each firm—as given when they make their output and pricing decisions. A firm produces in each period unless it faces an exogenous shock that forces it to exit the market (Melitz, 2003).

We derive the unique, *stationary equilibrium with free entry* in which the matching of CEOs to firms as well as the distributions of firm value and CEO pay are endogenously determined. The equilibrium satisfies several conditions. First, the free entry condition implies that the value of an entering firm—which rationally anticipates the outcome of the matching process between firms and managers—equals the entry cost. Second, in the stationary equilibrium, exiting firms are exactly replaced by new entrants so that the mass of firms remains constant through time. Third, the market clearing condition is satisfied in equilibrium, that is, the aggregate revenue of firms equals the aggregate payoffs to entrepreneurs, managers and workers. The equilibrium of the model depends on product market characteristics—the entry cost, the elasticity of substitution between products, the market size, and the exit probability of firms—as well as the distributions of managerial talent and firm quality.

Our structural approach requires the identification of the distributions of firm quality and managerial talent (that are unobservable to the econometrician) as well as the estimation of unknown model parameters such as the exit probability and the elasticity of substitution between products that determine the product market structure. We treat a sample of firm-CEO observations that belong to an industry as a market equilibrium outcome. We chooses quantiles of the observed distributions of firm value and CEO pay as the moments to be matched to the corresponding model-predicted statistics. In addition, we use the observed distributions of firm value and CEO pay to identify the unobserved distributions of firm quality and CEO talent—the *factor distributions*—as in the analysis of Terviö (2003, 2008).

There is significant variation in the inferred distributions of firm quality and managerial talent across industries. Consistent with what casual empiricism might suggest, the dispersions of CEO talent and firm quality are much larger in high-tech industries, such as business equipment, health care, and telecom, relative to traditional manufacturing industries. Second, in line with anecdotal and empirical evidence (e.g., Daines, Nair, and Kornhauser, 2005; Pan, 2010; Falato, Li and Milbourn, 2010), we show that managerial talent is, indeed, an important factor in the production process as differences in managerial talent could make a significant difference to firm value. Following Gabaix and Landier (2008), we measure the impact of talent as the benefit the median firm could obtain from the replacement of the current CEO with the best one in the same industry. Our estimates for different industries in our sample, which are obtained by explicitly incorporating product market influences, are largely two orders of magnitude higher than the strikingly small estimate of Gabaix and Landier (2008), who abstract away from product market effects. For example, the median firm in the business equipment industry could obtain an about 2.9% increase in its market value if its CEO were replaced with the best CEO. It should also be noted that, while the ratio of extra compensation payments to be incurred if the firm had to provide the best CEO with his current level of compensation is larger than the CEO's impact on the firm's value, it is not orders of magnitude higher as in Gabaix and Landier (2008). For instance, for the median firm in the business equipment industry, the ratio of additional future compensation payments to firm value is 10.7%. For other industries too, the costs are about three or four times greater than the benefits. This finding suggests that the remunerations of CEOs are roughly in line with their relative contributions to firms. Moreover, we find that the impact of CEO talent varies dramatically across industries. The median firm in the business equipment and health care industries could increase its market value by about 2.9% and 2.5%, respectively, whereas the sizes of the impact in the chemical, consumer durable goods, and manufacturing industries are only 0.85%, 1.15% and 1.16%, respectively.

Finally, we analytically derive the effects of product market characteristics on firm value, CEO compensation, and the mass of active firms. A decline in the entry cost and/or the exit probability leads to more firms in the market and, therefore, tougher price competition, which in turn lowers firm value and CEO pay. While the effects of a marginal increase in product substitutability are ambiguous in general because they depend on the values of other product market parameters, our analysis of the *calibrated* model yields clear predictions. An increase in the product substitutability induces less firms to enter the market, which in turn lessens price competition. Since the marginal return to managerial talent decreases (on average) with the product substitutability, so does the average managerial compensation. Furthermore, the effects of product market characteristics vary quantitatively across industries. Taken together, our results suggest that industry-related factors, including those linked to the CEO labor market and those linked to the product market, are very critical determinants of the levels and distributions of CEO compensation.

Our work revisits the fundamental question of how important managerial talent is if competition for CEO talent in an efficient labor market exists, which is raised and explored by the seminal studies of Terviö (2003, 2008) and Gabaix and Landier (2008). Both studies conclude that differences in CEO talent are very small and have little influence on shareholder value that is largely driven by firm-specific factors. Recent empirical studies, however, find that managerial talent is an important determinant of firm performance (Bertrand and Schoar, 2003; Daines, Nair, and Kornhauser, 2005; Bennedsen, Perez-Gonzalez, and Wolfenzon, 2006; Graham, Li, and Qiu, 2010; Pan, 2010; Falato, Li and Milbourn, 2010; Leverty and Grace, 2010). These studies find both statistically and economically significant impact of CEO characteristics, which are especially narrowed down to CEO talent for some studies, on CEO pay and firm performance, controlling for firm characteristics.

To reconcile the results from the competitive assignment models with the empirical evidence, we conjecture that industry structures matter in determining the level of CEO pay and in identifying the importance of CEO talent. There are three channels through which industry structures could affect the assignment process of CEOs to firms and, thereby, the distribution of CEO pay. First, the fundamental economics of an industry, that is, the nature of the product market, varies across industries. Specifically, different product market structures could imply different marginal returns to CEO talent and, therefore, CEO pay. Second, different industries might be characterized by different degrees of firm heterogeneity, and the sources of firm heterogeneity could also be different across industries. Third, to the extent that markets for CEO talent are segmented by industry, industry-level talent distributions might differ, which suggests that the CEO talent distribution and the effects of CEO talent on firms should be estimated at the industry level rather than at the entire economy level.

Terviö (2008) and Gabaix and Landier (2008) abstract away from industry and product market effects in their models. They estimate their models using a full sample of the largest firms in different industries, that is, they aggregate firms across industries in their estimation exercises. By contrast, given the discussion above, we develop a single market equilibrium framework in which the competitive assignment of CEOs to firms is incorporated and then estimate the structural model "industry by industry." In the literature on CEO turnover, Parrino (1997) and Cremers and Grinstein (2010) report that a dominant portion of new CEOs are insiders of hiring firms or come from other firms in the same industry and that most of those from outside their industries still have some relevant industry experience such as business relationships. The latter study further documents cross-industry differences in CEO selection practices and their explanatory power when examining different CEO compensation practices, thereby providing the evidence of fragmented

CEO talent pools across industries. These studies in part support our premise that there are CEO labor markets composed of senior managers within or outside firms in the same industry who have industry-specific skills.

The plan for the paper is as follows. Section 2 reviews the related literature in more detail. In Section 3, we present the model. In Section 4, we characterize the equilibrium and analytically derive implications of the model for the qualitative effects of product market characteristics on firm value and CEO pay. In Section 5, we describe our data and estimation procedure. Section 6 presents the results of the model calibration, including the structural parameter estimates and the factor distributions implied by the data. Section 7 contains counterfactual exercises using the calibrated models. Section 8 summarizes and concludes.

2 Related Literature

As discussed earlier, our work contributes to the recent literature initiated by Terviö (2003) that studies CEO pay levels in a competitive assignment framework. In Terviö (2003, 2008) and Gabaix and Landier (2008), the underlying idea is that, in a competitive and frictionless labor market for CEO talent, CEOs with different talents are competitively matched to heterogeneous firms at different pay levels. Both studies mainly argue that while talent differences between CEOs are very small, significant differences in firm quality, which is complementary to CEO talent and thus affects the marginal return to talent, can explain large pay dispersions for such small talent differences. In this study, we argue that when product market/industry characteristics are taken into account, differences in CEO talent are much more significant and can justify a substantial portion of the difference in CEO pay levels.

Our research is related to the literature that addresses how the distributions of firm size and CEO compensation change in response to economic conditions. The literature includes the studies of Raith (2003), Falato and Kadyrzhanova (2007), Baranchuk, MacDonald, and Yang (2010), Subramanian, Plehn-Dujowich and Li (2011), and Wu (2011). These studies mainly look at the effects of product market characteristics on optimal managerial incentives by incorporating agency conflicts arising from moral hazard in a market equilibrium framework. As in our study, Wu (2011) employs a standard monopolistic competition framework with Dixit-Stiglitz preferences to address the role of the product market. However, he bases his analysis on the early job assignment model, which considers the allocation of heterogeneous managers across ex ante identical firms, so that ex post firm size and CEO pay differences across firms are solely attributed to the heterogeneity in managerial skills. By changing the degree of complementarity between firm and managerial attributes in a business cycle model, rather than stressing product market effects, Alder (2009) shows that managerial attributes actually play an important role in the determination of firm size and CEO pay.

Recently, several studies have empirically examined the association between managerial characteristics —especially, managerial talent—and CEO pay and firm performance. Falato, Li, and Milbourn (2010) study the effects of CEO talent on firm performance using a media-based measure of CEO talent, the age of the executive when he took his first CEO job, and the selectivity of his undergraduate college. They document that replacing the CEO of median talent with the most talented CEO in their sample would improve firm operating performance by between 1.3% and 2.3%, which is two orders of magnitude greater than the estimate of Gabaix and Landier (2008) but largely consistent with our estimates for the industries in our sample. Daines, Nair, and Kornhauser (2005) define CEO skill as the persistence of positive performance and the reversal of poor performance and find a positive link between CEO skill and pay especially when pay is performance based and when there are large shareholders. Also, the link between skill and pay appears to be stronger in industries where pay dispersion is large, which supports our conjecture that CEO talent may matter more for firms in some industries than those in other industries. Focusing on the U.S. property-liability insurance industry, Leverty and Grace (2010) use several firm efficiency variables obtained from the Data Envelopment Analysis (DEA) as proxies for managerial ability and find that managerial ability plays an important role in reducing the duration of regulatory scrutiny, the likelihood of failure, and the cost of failure. Finally, Pan (2010) estimates an executive-firm matching model incorporating three matching dimensions, one of which is the usual complementarity between firm size and managerial talent, and finds that higher matching quality is associated with better subsequent firm performance.

3 The Model

We develop a discrete-time, infinite horizon model of an industry with dates $t = 0, 1, 2, ...$ The industry consists of a continuum of heterogeneous operating firms, heterogeneous managers, and identical production workers. The firms engage in Dixit-Stiglitz monopolistic competition with a constant elasticity of product substitution. Production requires raw labor supplied by production workers and specialized human capital provided by managers.

There are three stages of the model as follows:

- Stage 1: (Entry) A group of (identical) entrepreneurs drawn from the pool of workers establish a firm at date t by making an initial sunk investment. Subsequent to entry, the firm's *quality* is realized. Firm quality is a random variable that is drawn from a known distribution and then remains constant through time. Firms are, therefore, identical ex ante, but differentiated ex post.

- Stage 2: (Manager-Firm Matching) The owners (entrepreneurs) of each firm hire a manager from a continuum of potential managers of various talent levels in a competitive executive labor market. Managerial talent is observable and is constant through time.

- Stage 3: (Production and Exit) In each period, each firm produces its good, generates profit, and pays its manager. It continues over an infinite time horizon unless it faces an exogenous negative shock that forces it to exit the market (Melitz, 2003).

Since each firm's quality is realized ex post after entry, there is *two-sided heterogeneity* in the assignment process between firms and managers. We focus on a stationary equilibrium with free entry in which exiting firms are exactly replaced by new entrants. Consequently, the equilibrium distributions of managerial talent and firm quality among active firms, and the equilibrium distributions of firm market value and CEO pay are stationary.

We solve the model by backward induction. We first analyze an active firm's (that is, a firm that successfully matches with a manager) profit maximization problem in each period. Next, we study the competitive assignment process between heterogeneous firms and managers. Finally, we examine firms' entry decisions into the market.

3.1 Preferences, Market Demand and Production

The representative consumer has preferences for consumption of a continuum of goods in each period that are described by the utility function

$$U = \left[\int_{\Omega} q(\omega)^{\rho} d\omega \right]^{\frac{1}{\rho}} ; 0 < \rho < 1, \tag{1}$$

where Ω is the set of available goods and ω is a finite measure on the Borel σ-algebra of Ω. If $p(\omega)$ is the price of good ω, the consumer's demand $q(\omega)$ for good ω solves the following utility maximization problem:

$$\begin{aligned} \max_{q(\omega)} \quad & U = \left[\int_{\Omega} q(\omega)^{\rho} d\omega \right]^{\frac{1}{\rho}} \\ \text{subject to} \quad & \int_{\Omega} p(\omega) q(\omega) d\omega = R. \end{aligned} \tag{2}$$

In the above, R represents the total expenditure of the representative consumer on goods produced by the industry. It is natural to interpret R as the *size* of the industry.

As shown by Dixit and Stiglitz (1977), the optimal consumption of each good is

$$q(\omega) = U \left[\frac{P}{p(\omega)} \right]^{1/(1-\rho)}, \tag{3}$$

where P is the *aggregate price index* that is given by

$$P = \left[\int_{\Omega} p(\omega)^{\frac{\rho}{\rho-1}} d\omega \right]^{\frac{\rho-1}{\rho}}. \tag{4}$$

Further,

$$R = PU. \tag{5}$$

The optimal consumption (3) of each good represents the market demand that the firm producing this particular good faces in the market. From (3), we see that

$$\frac{q(\omega)}{q(\omega')} = \left[\frac{p(\omega')}{p(\omega)} \right]^{1/(1-\rho)}, \tag{6}$$

which implies that any two products in the market are substitutes, and the elasticity of substitution between these products is

$$\sigma = \frac{1}{1-\rho} > 1. \tag{7}$$

This is also the constant price elasticity of demand for each good as seen in (3).

We now turn to the production decision of each firm for any period after it has matched with a manager. The assignment process of managers to firms is described in the next section. Production is driven by production labor supplied by production workers. The firm's quality and the manager's talent together determine the firm's productivity. We normalize the labor wage rate to 1, that is, the labor wage is the numeraire with respect to which all payoffs are measured.

More precisely, suppose that the firm has quality $x \in R_+$ and its manager has talent $y \in R_+$. As in Tervio (2008), there is complementarity between firm quality and managerial talent. Specifically, the match quality θ takes the multiplicative form

$$\theta(x, y) = xy. \tag{8}$$

The firm's productivity equals the match quality $\theta(x, y)$, that is, the inverse of the match quality is the firm's marginal cost of production measured in units of labor. As discussed by Tervio (2008), the key, substantive property of (8) is the *complementarity* of firm quality and managerial talent. There is actually little loss of generality in assuming the particular form (8). We could alternatively assume that $\theta(x, y) = f(x)g(y)$ for strictly increasing and nonnegative functions $f(.)$ and $g(.)$. In this case, we could simply "redefine" firm quality as $x' = f(x)$ and managerial talent as $y' = g(y)$.

At the beginning of each period, the firm chooses its price in order to maximize its net profit, that is, revenue net of variable production costs and managerial compensation. Suppose the manager's compensation is u (note that this is endogenously determined as the outcome of the matching process between firms and managers). The firm's net profit is

$$\pi(x, y, u) = \max_{p} \; pq(p) - \frac{q(p)}{\theta(x, y)} - u, \tag{9}$$

where the market demand curve, $q(p)$, is given by (3) (We omit the argument ω to simplify the notation). Since there is a continuum of firms, each firm takes the aggregate variables U and P as given when it chooses its price and output quantity. The second term on the right hand side of (9) represents total labor wages received by production workers who are employed by the firm. The profit maximization condition equates the marginal revenue with the marginal cost of production, thereby yielding the firm's optimal price,

$$p(x, y) = \frac{1}{\rho x y}. \tag{10}$$

Consequently, the firm produces the following level of its good,

$$q(x, y) = q(p(x, y)) = RP^{\sigma-1}(\rho x y)^{\sigma}, \tag{11}$$

and its resulting revenue is given by

$$r(x, y) = p(x, y)q(x, y) = R(P\rho x y)^{\sigma-1}. \tag{12}$$

The firm's gross profit (profit *inclusive of* managerial compensation) is

$$\Pi(x, y) = p(x, y)q(x, y) - \frac{q(x, y)}{\theta(x, y)} = \frac{R(P\rho x y)^{\sigma-1}}{\sigma}. \tag{13}$$

The firm's net profit—the gross profit less managerial compensation—is

$$\pi(x, y, u) = \Pi(x, y) - u = \frac{R(P\rho x y)^{\sigma-1}}{\sigma} - u. \tag{14}$$

3.2 Manager-Firm Matching

We now describe the assignment of managers of different abilities to firms of different qualities and the determination of managerial compensation. Managerial abilities and firm qualities are constant through time as in Gabaix and Landier (2008) and Tervio (2008). Since the distributions of CEO talent and firm quality are stationary, each firm continues to hire the same type of manager and pays the same remuneration. Hence, its productivity level remains constant over time, and so does its net profit. More specifically, if a firm of quality x hires a manager of talent y whose compensation is u, the firm will earn net profit $\pi(x, y, u)$, given by (14), in each period until it has to exit the market for some exogenous reasons. Denoting the probability of staying in the market for another period by β, the firm's market value—the present value of future earnings net of payoffs to the manager—is

$$\phi(x, y, u) = \sum_{t=0}^{\infty} \beta^t \pi(x, y, u) = \frac{\pi(x, y, u)}{1 - \beta} = \frac{1}{1 - \beta}\left[\frac{R(P\rho xy)^{\sigma-1}}{\sigma} - u\right]. \tag{15}$$

Following Legros and Newman (2007), we refer to the function $\phi(x, y, u)$ as the bargaining frontier for the firm, which implies its maximum payoff when it pays the manager u, and denote the quasi-inverse function of $\phi(x, y, u)$ by $\psi(x, y, v) : \phi(x, y, \psi(x, y, v)) = v$, where $\psi(x, y, v)$ is the bargaining frontier for the manager. Let $S(x, y)$ be the total surplus generated by this firm-manager pair, which is the first term of $\phi(x, y, u)$,

$$S(x, y) = \frac{R(P\rho xy)^{\sigma-1}}{(1 - \beta)\sigma}. \tag{16}$$

We easily see that $S(x, y)$ satisfies the *supermodularity* condition

$$\frac{\partial^2 S}{\partial x \partial y} > 0. \tag{17}$$

It follows from the results of Legros and Newman (2007) that the matching equilibrium is unique, and is characterized by positive assortative matching (PAM), that is, higher quality firms are matched to managers with higher talents.

We now derive the equilibrium payoffs to firms and managers. Let $X(\cdot)$ and $Y(\cdot)$ be the cumulative distribution functions of firm quality and managerial talent, respectively. As in Terviö (2008), we work with the quantiles of the distribution functions. Specifically, for each $i \in [0, 1]$, define

$$\begin{aligned} x[i] &= x \quad \text{if} \quad X(x) = i, \\ y[i] &= y \quad \text{if} \quad Y(y) = i. \end{aligned} \tag{18}$$

Consequently, $x'[i] > 0$ and $y'[i] > 0$ where $i \in [0,1]$, that is, higher i denotes a higher quality firm and a more talented manager. By PAM, we can restrict attention to matches where firm i is matched with manager i. In other words, we can use the index i to denote a matched manager-firm pair.

The total surplus, $S(x[i], y[i])$ in (16), must be apportioned to the manager and the firm in a way that ensures the stability of the matching correspondence. Let $u[i]$ be the equilibrium compensation of manager i for each period and $v[i]$ be the equilibrium payoff to firm i, that is, its market value. To begin with, we consider the participation constraints for both parties. The payoff to each party must be on its frontier given its partner's payoff, $\phi(x, y, \cdot)$ and $\psi(x, y, \cdot)$, respectively, and can never be less than their outside payoffs, v_0 and u_0, which are assumed to be identical for all types, that is,

$$v[i] = \phi(x[i], y[i], u[i]); \quad v[i] \geq v_0, \tag{19}$$

$$u[i] = \psi(x[i], y[i], v[i]); \quad u[i] \geq u_0. \tag{20}$$

Note that, by (15), (16), and (19), the relation between $v[i]$ and $u[i]$ is given by

$$S(x[i], y[i]) = v[i] + \frac{u[i]}{1-\beta} = \frac{R(P\rho x[i]y[i])^{\sigma-1}}{(1-\beta)\sigma}, \tag{21}$$

and that the outside payoffs, by definition, imply the payoffs of the lowest active firm-manager pair in the market:

$$S(x[0], y[0]) = v_0 + \frac{u_0}{(1-\beta)} = \frac{R(P\rho x[0]y[0])^{\sigma-1}}{(1-\beta)\sigma}. \tag{22}$$

The next set of constraints to be considered are the incentive compatibility constraints. Each party chooses its best matching partner. If $m(i)$ denote firm i's choice of its manager and $n(i)$ denotes manager i's choice of his firm, then the incentive constraints are

$$v[i] = \max_{m(i)} \ \phi(x[i], y[m(i)], u[m(i)]), \tag{23}$$

$$u[i] = \max_{n(i)} \ \psi(x[n(i)], y[i], v[n(i)]). \tag{24}$$

As in a usual screening problem, a "single crossing" property holds in the framework analyzed here so that the set of incentive constraints above is equivalent to the following two sets of constraints: (i) Monotonicity and (ii) Local incentive compatibility (Bolton and Dewatripont, 2005). We describe the procedure for the firm's constraint (23) because it is analogous to the procedure for the manager's constraint (24). Firm i faces a set of choices that can be described as $\big(m, u[m]\big)$ and needs to choose the best one. From (15) and (23), it is easy to check the single crossing property that the indifference curve for a higher type has a greater slope, that is, the marginal payoff of partner type m relative to that of payment u rises with firm type i:

$$\frac{\partial}{\partial i}\left[-\frac{\partial v/\partial m}{\partial v/\partial u}\right] > 0. \tag{25}$$

As a consequence, the set of incentive constraints can be replaced by the monotonicity condition,

$$\frac{dm(i)}{di} \geq 0, \tag{26}$$

and the local incentive condition,

$$\frac{d\phi(x[i], y[m(i)], u[m(i)])}{dm}\bigg|_{m(i)=i} = 0. \tag{27}$$

Since the monotonicity condition holds due to PAM, the firm's global incentive compatibility is equivalent to the local incentive condition above. The same argument applies to the incentive compatibility for the manager. From the local incentive conditions, we derive the following differential equations in $u[i]$ and $v[i]$:

$$u'(i) = -\frac{\phi_2}{\phi_3}y'[i] = RP^{\sigma-1}\rho^{\sigma}x[i]^{\sigma-1}y[i]^{\sigma-2}y'[i], \tag{28}$$

$$v'(i) = -\frac{\psi_1}{\psi_3}x'[i] = \frac{RP^{\sigma-1}\rho^{\sigma}x[i]^{\sigma-2}y[i]^{\sigma-1}x'[i]}{1-\beta}, \tag{29}$$

where the second equation can also be obtained from (21). Integrating the above, we obtain

$$u(i) \quad = \quad u_0 + \int_0^i RP^{\sigma-1}\rho^{\sigma}x[j]^{\sigma-1}y[j]^{\sigma-2}y'[j]dj, \tag{30}$$

$$v(i) \quad = \quad v_0 + \int_0^i \frac{RP^{\sigma-1}\rho^\sigma x[j]^{\sigma-2} y[j]^{\sigma-1} x'[j]}{1-\beta} dj. \tag{31}$$

3.3 Market Entry

Given the distributions of managerial talent and firm quality, we have derived the distributions of firm value and managerial compensation for active firms in the market. These distributions are rationally anticipated by prospective entrants (a group of entrepreneurs) into the market. Entry into the market requires a fixed sunk investment of $f_e > 0$. Since the quality x of a newly established firm is determined only *after* it enters the market, the quality of the firm is an unknown random variable with cdf X at the "market entry" stage. By (18), it can be shown that its rank, compared with incumbent firms, is also a random variable. Free entry ensures that the expected firm value equals the entry cost, that is,

$$E[v[i]] = \int_0^1 v[i]di = f_e, \tag{32}$$

where $v[i]$ is given by (31).

4 Equilibrium

A stationary equilibrium is characterized by a mass N^* of active firms, a distribution $x[i]$ of firm quality, a distribution $y[i]$ of managerial talent, an aggregate price index P^*, and payoff profiles—managerial compensation $u[i]$ and firm value $v[i]$—such that the following conditions hold:

1. *Firm Profit Maximization*: In any period, each active firm i produces $q(i)$ units of its good at price $p(i)$ per unit to maximize its net profit as described in (9), where

$$p(i) = \frac{1}{\rho x[i] y[i]}; \quad q(i) = RP^{*\sigma-1}(\rho x[i]y[i])^\sigma. \tag{33}$$

2. *Manager-Firm Matching and Payoffs* : A manager ranked i is assigned to the equally ranked firm i. The equilibrium payoff profiles satisfy

$$v[i] \quad = \quad \frac{1}{1-\beta}\left[\frac{R(P^*\rho x[i]y[i])^{\sigma-1}}{\sigma} - u[i]\right], \tag{34}$$

$$u[i] \;=\; u_0 + \int_0^i \left(R P^{*\sigma-1} \rho^\sigma x[j]^{\sigma-1} y[j]^{\sigma-2} y'[j] \right) dj. \tag{35}$$

3. *Free Entry of Firms and Aggregate Price Index*: The free entry condition determines the aggregate price index P^* as follows

$$RP^{*\sigma-1}\left[\frac{(\rho x[0]y[0])^{\sigma-1}}{\sigma} + \rho^\sigma \int_0^1 \Big[\int_0^i x[j]^{\sigma-2} y[j]^{\sigma-1} x'[j] dj\Big] di\right] = u_0 + (1-\beta) f_e. \tag{36}$$

4. *Market Clearing and Mass of Firms*: In any period, the aggregate revenue of active firms must equal the aggregate expenditure R by the representative consumer, that is,

$$R = \int_0^1 r(x[i], y[i]) N^* di \quad \Rightarrow N^* = \Big[\int_0^1 (P^* \rho x[i] y[i])^{\sigma-1} di\Big]^{-1}, \tag{37}$$

which is derived from the revenue function given by (12) and determines the equilibrium mass N^* of producing firms.

It immediately follows from the above that there exists a unique, stationary equilibrium in which the aggregate price index P^* and the mass N^* of active firms are determined by (36) and (37), respectively. Further, they remain constant over time so that the distributions of firm value and managerial compensation are also invariant over time.

Using the above equilibrium characterization, we analytically explore the effects of product market characteristics—the entry cost, the likelihood of exit, the market size, and the elasticity of substitution—on the mass of active firms, firm value and CEO compensation. We begin by deriving the effects of the product market characteristics on the aggregate price index because the other equilibrium variables depend on it.

Proposition 1 (Product Market Characteristics and Aggregate Price Index)

- *The aggregate price index P^* increases with the entry cost f_e and the likelihood of exit $1-\beta$, while it decreases with the market size R.*

- *There exist threshold levels $\bar{f}_e(\sigma)$ and $1-\bar{\beta}(\sigma)$ of the entry cost and the exit probability, respectively, such that the aggregate price index increases with a marginal increase in the* *elasticity of substitution σ if the entry cost f_e or the likelihood of exit $1-\beta$ is below their respective thresholds, and decreases if they are above.*

Before discussing the intuition for the above proposition, we derive the effects of product market characteristics on the mass of firms.

Proposition 2 (Product Market Characteristics and the Mass of Firms)

- *The mass of active firms declines with the entry cost f_e and the likelihood of exit $1-\beta$, but increases with the market size R.*

- *The mass of active firms may decrease or increase with a marginal increase in the elasticity of substitution σ.*

The intuitions for Propositions 1 and 2 are as follows. An increase in either the entry cost f_e or the exit probability $1-\beta$ deters potential firms from entering the market because the expected payoff from entry declines. Accordingly, there are fewer firms operating in the market. Few active firms reduces competition so that the aggregate price index increases. An increase in the market size R attracts more entrants due to the expectation of a higher profitability. The larger mass of active firms intensifies competition so that the aggregate price index declines. Contrary to the entry cost, the exit probability and the market size, the effects of the elasticity of substitution σ are more complex. For a *fixed* aggregate price index, one can show that the left-hand side of (36) increases with a marginal increase in σ when the price index is above a threshold $\overline{P}(\sigma)$ and decreases otherwise. This observation in turn implies that, to satisfy the free entry condition, the aggregate price index must decrease with a marginal increase in σ in the former case, but increase in the latter case. Since the aggregate price index increases with the entry cost f_e and the exit probability $1-\beta$, there exist threshold levels of the entry cost and the exit probability, respectively, such that the aggregate price index is greater than $\overline{P}(\sigma)$ if the entry cost or the exit probability exceeds their respective thresholds, and is less than $\overline{P}(\sigma)$ otherwise. Consequently, the variation of the aggregate price index with the product elasticity depends on the entry cost and the exit probability. By (37), the differential effects of the product elasticity on the equilibrium aggregate price cause the former to have an ambiguous effect on the mass of active firms.

Proposition 3 (Product Market Characteristics, Firm Value, and CEO Pay)

- *Managerial compensation increases with the entry cost* f_e *and the likelihood of exit* $1 - \beta$, *but is not affected by the market size* R.

- *Firm value increases with the entry cost* f_e, *but does not change with the market size* R. *However, the effect of the exit probability* $1 - \beta$ *is ambiguous.*

- *There exists a trigger* $\bar{\imath}$ *such that managerial compensation increases with a marginal increase in the elasticity of substitution* σ *if* $i > \bar{\imath}$, *but decreases if* $i < \bar{\imath}$.

An increase in the market size R decreases the aggregate price index. While the former has a positive effect on firm value and CEO pay, the latter has a negative effect. To ensure that the free entry condition (36) is satisfied, these effects exactly cancel out so that an individual firm's market value and its manager's compensation do not change in response to the increase in the market size. An increase in the entry cost or the exit probability increases the aggregate price index so that CEO pay increases. The effect of the exit probability on firm value is, however, ambiguous. This is because the increase in the aggregate price index with the exit probability has a positive effect on firm value, whereas an increase in the exit probability also has a direct, negative effect on the present value of firm profits by (34).

The effects of product substitutability on CEO pay depend on the rank of the firm in the industry. A more elastic product market has differential effects on firms with larger firms benefiting relatively more (in terms of greater gross earnings) than smaller firms. Consequently, CEO pay increases with product substitutability if the rank is above a trigger, and decreases if it is below. Because firm value depends on the firm's *net earnings* (gross earnings less CEO pay), the effects of product substitutability on firm value are ambiguous, in general.

As we see in the next section, some of the ambiguous effects of product market characteristics on firm value and CEO pay can be pinned down when we calibrate the model to data.

5 Empirical Analysis

To quantitatively investigate the extent to which managerial talent and product market characteristics affect firm size and managerial compensation, we calibrate the model to U.S. data. Because the model is one of competing firms in the same industry, we calibrate the model "industry by industry." We then compare the calibrated models across industries.

5.1 Data

Our sample includes S&P 1500 firms from the ExecuComp database. We obtain firm-specific variables from the Compustat annual database, and the Fama-French "twelve industry" classification as well as industry portfolio returns from Kenneth French's website. We collect firm-CEO observations over the period 1992-2009 except for those in which sales or book value of equity are nonpositive. We partition the entire sample into different industry sectors. Among the twelve sectors, we exclude financial firms (SIC = 6000-6999) because the model is strictly applicable to conventional firms producing goods and services and selling them to consumers instead of financial intermediaries. In addition, because our model is one of unregulated firms, we do not include regulated firms (SIC = 481 and 4900-4949) based on Loughran and Ritter (1997). Further, we do not consider firms in miscellaneous industries that are classified as "Other" in the Fama-French classification. Accordingly, the final sample consists of 2,049 publicly traded U.S. companies and 20,635 firm-year observations, which are grouped into nine different industry sectors labeled as Consumer Nondurables, Consumer Durables, Manufacturing, Energy, Chemicals, Business Equipment, Telecom, Shops, and Health Care.[1]

We now describe the variables used in the analysis. We compute total firm value (debt plus equity) as the market value of equity plus the book value of total assets minus the book value of equity.[2] Our measure of CEO compensation is "total compensation," which includes salary,

[1] List of industry sectors: (1) Consumer Nondurables — Food, Tobacco, Textiles, Apparel, Leather, Toys (2) Consumer Durables — Cars, TV's, Furniture, Household Appliances (3) Manufacturing — Machinery, Trucks, Planes, Off Furnishing, Paper, Commercial Printing (4) Energy — Oil, Gas, and Coal Extraction and Products (5) Chemicals — Chemicals and Allied Products (6) Business Equipment — Computers, Software, and Electronic Equipment (7) Telecom — Telephone and Television Transmission (except for Telephone communications, SIC:481) (8) Shops — Wholesale, Retail, and Some Services (Laundries, Repair Shops) (9) Health Care — Medical Equipment and Drugs

[2] Terviö (2003, 2008) uses market capitalization that is common shares outstanding multiplied by the share price (Compustat item $MKVALT$) as firm market value.

bonus, other annual, restricted stock grants, stock options (using the Black-Scholes formula), and long-term incentives. For the purpose of comparison, we also carry out tests using only CEO "cash compensation" (the sum of salary and annual bonus). In our analysis, we indirectly infer the product substitutability of each industry by calibrating the model to match moments of the distributions of CEO compensation and firm value in the data. To validate and evaluate our indirect estimates of the industry product substitutabilities, we also compute the *price-cost margin* for each industry. The "negative" price-cost margin is often used as an empirical proxy for product substitutability (see Nevo, 2001). We compute the price-cost margin as industry sales divided by industry operating costs. In particular, a firm's operating costs include costs of goods sold, selling, general and administrative expenses, and depreciation, depletion, and amortization. We measure all variables in 2005 U.S. dollars using the GDP deflator provided by the Bureau of Economic Analysis.

Since the model's implications are cross-sectional, we take the averages of the variables for each firm over the time period during which it was operating. Importantly, rather than using the actual CEO pay variables, we employ a Lowess (locally weighted regression scatter plot smoothing) curve to capture a smoothed pattern between CEO pay and firm value from the actual noisy relation. As Terviö (2008) points out, it facilitates the calibration of the assignment model that involves a monotone matching correspondence. For each industry, we rank firms by firm value and then perform a Lowess smoothing (bandwidth, 0.7) of the relation between CEO compensation levels and firm ranks. Hereafter, the observed distribution of CEO compensation refers to the smoothed levels.

Table 1 provides the cross-industry summary statistics for the variables in our analysis. There is wide variation across industries. First, the business equipment industry contains the largest number of firms. Given that this measure counts the number of firms that appeared in the sample even for a short time period, it could be because many new dot-com companies went public especially around the dot-com bubble period even though many of them failed shortly. Second, the mean value of CEO total compensation is much higher in the energy, business equipment, and telecom industries, relative to the manufacturing industry. Third, differences in CEO pay levels across industries do not necessarily correspond to firm size differences across industries. For instance, the total market value of the average firm in the business equipment industry is \$5.65 billion and that in the consumer durable goods industry is \$12.10 billion, whereas the average CEO earned \$4.88 million in the former industry but earned only \$3.33 million in the latter industry. These preliminary findings suggest that CEO pay does not increase with firm size *across industries,* and that product market/industry characteristics are key determinants of CEO pay and firm size. Our subsequent analysis, in which we calibrate our model to "industry by industry" data on the distributions of CEO compensation and firm value, provides further support for these preliminary findings.

5.2 Calibration

We estimate the structural parameters of the model by matching moments of the distributions of CEO pay and firm value in a given industry. The calibration strategy is as follows:

1. By (34) and (35), the distributions of firm value and CEO pay depend on the distributions of firm quality, $x[i]$, and CEO talent, $y[i]$, that are *unobserved* by the econometrician. We hereafter refer to the latter distributions as *factor distributions*. For a given candidate vector of model parameter values—that is, the "deep" structural parameters of the model—we indirectly infer the factor distributions from the *observed* distributions of firm value and CEO pay in the industry using (28) and (29).

2. In the second step, we employ the indirectly inferred factor distributions obtained from step 1 to generate the model-predicted distributions of CEO pay and firm value using (34) and (35).

3. In the third step, we compare some statistics from the model-predicted distributions of CEO pay and firm value with the corresponding observed statistics.

4. We repeat steps 1-3 until we obtain the baseline set of model parameters as those that minimize the distance (in a suitable metric) between the observed moments and the predicted moments.

We now describe the calibration procedure in more detail. The set of parameters to be calibrated is

$$\Delta = \{\beta, R, \sigma, u_0\}. \tag{38}$$

Each of the above parameters is determined as follows. As Melitz (2003) notes, β can be viewed either as the likelihood that each operating firm will stay in the market for another period or as the time discount rate for the industry. The industry discount rate is usually calculated using the industry cost of equity, r, assuming annual compounding:

$$\beta = 1/(1 + r). \tag{39}$$

To estimate the cost of equity or the required (expected) rate of return r, we employ the Capital Asset Pricing Model (CAPM) (see Kaplan, 1995; Fama and French, 1997). We use industry portfolio returns and excess returns on the market portfolio which are provided on Kenneth French's website. Both sets of returns are value-weighted, monthly returns. We first compute the industry beta (using the data dated before the sample period: 1926-1991) by running a regression of the monthly industry excess returns on the monthly excess returns of the market index. We then obtain the expected monthly industry returns using the CAPM relation for the sample period from 1992 to 2009. We annualize these monthly returns and take the averages over the sample period.

Because R is the aggregate revenue of all operating firms in the market, we set it equal to industry sales, that is, the sum of net sales for firms operating in the industry.

We determine the remaining two parameters—the elasticity of product substitution σ and the wage of the lowest ability manager, u_0—by matching several moments from the model-predicted distributions of firm value and managerial compensation with the corresponding observed moments. More specifically, we match mean values, minimum and maximum values, and deciles of the distributions of firm value and CEO pay. Let Obs_i and $Pred_i$ be the observed and predicted values of each selected statistic; then the baseline values of σ and u_0 solve

$$(\sigma, u_0) = \arg\min_{\tilde{\sigma}, \tilde{u_0}} \ \Sigma_i \Big(\frac{Pred_i(\tilde{\sigma}, \tilde{u_0}) - Obs_i}{Obs_i} \Big)^2. \tag{40}$$

As indicated above, the baseline values of σ and u_0 minimize the sum of the squared percentage deviations of the predicted statistics from the observed ones.

We now describe how we generate the model-predicted distributions of firm value and CEO pay for a candidate parameter vector Δ, that is, steps 1 and 2 of our calibration strategy described earlier. We first identify the unobserved factor distributions following Terviö (2003, 2008). Recall that the slopes of the payoff functions must follow (28) and (29), which guarantees matching stability. Dividing these slopes by the equation for the total surplus (21), respectively, yields the following equations for the rates of increase of the factors.

$$\frac{x'[i]}{x[i]} = \frac{v'(i)}{(\sigma-1)[v(i)+u(i)/(1-\beta)]}, \tag{41}$$

$$\frac{y'[i]}{y[i]} = \frac{u'(i)}{(1-\beta)(\sigma-1)[v(i)+u(i)/(1-\beta)]}. \tag{42}$$

We can then obtain the profiles of the unobserved factors relative to the lowest type by integrating these equations, respectively.

$$\frac{x[i]}{x[0]} = \exp\left\{\int_0^i \frac{x'[j]}{x[j]}dj\right\} = \exp\left\{\frac{1}{\sigma-1}\int_0^i \frac{v'(j)}{v(j)+u(j)/(1-\beta)}dj\right\}, \tag{43}$$

$$\frac{y[i]}{y[0]} = \exp\left\{\int_0^i \frac{y'[j]}{y[j]}dj\right\} = \exp\left\{\frac{1}{(1-\beta)(\sigma-1)}\int_0^i \frac{u'(j)}{v(j)+u(j)/(1-\beta)}dj\right\}. \tag{44}$$

We calculate the relative factor values by numerically integrating the right-hand sides of equations (43) and (44). As in Terviö (2003, 2008), the constants $x[0]$ and $y[0]$ cannot be identified and are not required for our calibration, that is, we only need the relative factor distributions, $x[i]/x[0]$ and $y[i]/y[0]$.

Next, we use the indirectly inferred relative factor distributions to generate the model-predicted distributions of firm value and CEO pay from (34) and (35). Note that the equilibrium aggregate price index P^* enters both (34) and (35). We determine the equilibrium aggregate price index as follows. Treating the observed number of firms in the industry as the equilibrium mass N^* of firms in the model, the equilibrium condition (37) can be rewritten as

$$P^* = \frac{1}{\rho}\left[\int_0^1 (x[i]y[i])^{\sigma-1}N^* di\right]^{\frac{1}{1-\sigma}}. \tag{45}$$

Since $x[0]$ and $y[0]$ are undetermined, we can only compute the *relative* aggregate price index, P_0, which is defined as

$$P_0 = P^* \rho x[0] y[0] = \left[\int_0^1 \left(\frac{x[i]}{x[0]} \frac{y[i]}{y[0]} \right)^{\sigma - 1} N^* di \right]^{\frac{1}{1-\sigma}}. \tag{46}$$

Third, we generate the predicted distributions of firm value and CEO pay by plugging the given parameter values, the inferred relative factor values $x[i]/x[0]$ and $y[i]/y[0]$, and the relative aggregate price index P_0 into (34) and (35).

We compare the selected statistics from the predicted distributions with their observed counterparts. We minimize the sum of squared percentage differences between the model-predicted and observed values of the statistics as described in (40) to obtain the baseline values of σ and u_0.

5.3 Calibration Results

Through the calibration procedure illustrated in the previous section, we obtain the baseline parameter values and the factor distributions for *each* of the nine industries in our sample. Table 2 reports the estimates of the parameters in the first four columns. The first two parameters β and R are obtained directly from the data as described earlier. The other two parameter values—σ and u_0—are obtained by matching moments of the predicted distributions of firm value and CEO compensation to their observed values. There are significant differences in the calibrated values of the product substitutability σ across industries. The product substitutability is lower in the business equipment, health care, and telecom industries, whereas it is higher in the industries of consumer durable goods and shops. This result is intuitive given that, in high-technology-intensity sectors, product innovation plays a critical role and products tend to display a high degree of product differentiation (Ioannidis and Schreyer, 1997; Anderton, 1999). Moreover, because σ can also be interpreted as the price elasticity for each good, the finding of Tellis (1988) also supports our result. By reviewing econometric studies that estimate price elasticities of different brands and markets, he documents that price elasticity for pharmaceutical products is lower than all other product categories and the difference is particularly significant and large for detergents and durable goods in comparison with pharmaceutical products.[3]

[3]The very high value of σ for the consumer durable goods industry is, in fact, consistent with a general consensus in the literature on industrial organization that in any durable good industry, competition will be more intense than

Previous empirical literature uses the negative price-cost margin of the industry as a proxy for product substitutability (e.g. Nevo, 2001; Karuna, 2007). The underlying motivation for this proxy is that the *higher* is the extent of product substitutability in an industry, the greater is the price elasticity of demand, and the *lower* is the price-cost margin. To further validate our estimates of the parameter σ, we compare the ranking of industries with respect to our estimates of σ with the corresponding ranking obtained by using the industry negative price-cost margin estimates.

We calculate the industry price cost margin as industry sales divided by industry operating costs. We show the estimates of the measure in the last column of the table shows the estimates of the measure. Note that the numbers should only be interpreted in an *ordinal* sense, that is, the ranking of the industries according to the measure is more meaningful for our purposes than the actual numbers themselves. Note that the *higher* the product substitutability of an industry, the *lower* is the price-cost margin. We observe that the health care and telecom industries have relatively high price-cost margins, whereas shops and consumer durable goods industries have low values. Except for the business equipment industry, the ranking of industries by our estimated values of σ are consistent with the ranking by the negative price-cost margin. Because our estimates of σ are *indirectly inferred* from data on the distributions of firm value and CEO pay, the close correspondence between the two rankings provides additional support for the model.

In addition to the model parameter values, we indirectly infer the unobserved factor distributions in our calibration exercise. The two middle columns of Table 2 report the highest values of firm quality and managerial talent relative to their lowest ones. For any industry, it is obvious that differences in firm quality between the highest and lowest ranking firms are greater than those in managerial talent, which implies that the relative impact of firm quality on the resulting payoffs is higher than that of managerial talent as concluded by Gabaix and Landier (2008) and Terviö (2003, 2008). However, more importantly, *intra-industry dispersions* of the factors vary significantly across industries. Compared to other industries, the business equipment, health care, and telecom industries have higher relative values of firm quality and managerial talent.

In Figure 1, we report the entire factor distributions for the business equipment, health care, telecom, and manufacturing industries. The first two industries have much more widely dispersed

in a non-durable good industry (e.g., Coase, 1972).

firm and managerial characteristics across firms. In particular, the distributions of firm quality tend to be highly skewed to the right (convex), whereas those of managerial talent tend to be monotonically increasing (concave). The telecom industry shows a similar pattern (albeit higher) of firm heterogeneity to that of the manufacturing industry, whereas its talent distribution is closer to the first two industries even though there is little dispersion at the top of the distribution. Finally, firms and managers are very homogeneous in the manufacturing industry, which is also true for the other industries not reported in the graph.

Although our main focus is on the implications of managerial talent, we first discuss how to interpret the exogenous firm quality given that there are significant inter-industry variations in the inferred distributions of firm quality. The three industries with higher firm heterogeneity (business equipment, health care, and telecom industries) are usually referred to as high-tech industries (Loughran and Ritter, 2004). Moreover, in the first two industries, there are a small mass of firms that are much more significantly differentiated from other firms in the same industry. Terviö (2008) broadly interprets the dimension of firm heterogeneity that is complementary to CEO talent as the natural scale of a firm, that is, all exogenous determinants of the scope (niches) of a firm's operations that are linked to technology and consumer preferences. The strategy literature also attributes intra-industry firm heterogeneity to the establishment of unique product market positions (e.g., Caves and Porter, 1977). Such an interpretation is enhanced by our finding that variations in the firm-side dimension appear to be much greater in high-tech industries that are characterized by a greater variety of business ideas and technological innovations (Andersson et al., 2009).

We now discuss the implications of the inferred distributions of managerial talent. In Figure 1, compared to the manufacturing and other unreported industries, we observe greater intra-industry differences in CEO talent in high-tech industries. This finding, which is obtained by conducting the same procedure for each industry without any a priori assumption, suggests differences in CEO talent pools across industries. Although our analysis cannot compare the absolute levels of managerial talent between industries because the lowest levels are undetermined, a higher degree of CEO talent dispersion within an industry implies higher competition for CEO talent among firms. In other words, firms put greater emphasis on CEO human capital in those industries with greater heterogeneity in managerial talent. It is intuitive in the sense that the success of high-tech firms, which need to continuously develop new products and manage technological innovation in a highly competitive environment with very low barriers to entry and very high risk, is very closely tied to the talents of the workforce (Andersson et al., 2009). Further, "managerial rents" models in the management literature argue that managerial human capital is more emphasized in industries in the early stages of the product-life cycle (e.g., early biotechnology companies), relative to that in more mature industries, and in industries with characteristics that allow greater managerial discretion than industries with less latitude for managerial discretion (Castanias and Helfat, 2001). Given that industries producing a differentiable product or service and high-growth industries tend to provide more managerial discretion (Hambrick and Abrahamson, 1995), our finding of larger talent dispersions in high-tech industries is in line with these arguments.

One may argue that this finding might mainly be induced by the prevalence of equity-based compensation of CEOs in high-tech industries. To examine that possibility, we perform the same analysis using CEO cash compensation, containing only salary and annual bonus. Figure 3 shows that greater differences in CEO talent are still observed in high-tech industries, relative to other traditional industries, even though the relative talent levels are overall lower than those are in Figure 1. As another robustness check, we also test an extension in which the impact of management team (top senior executives) is taken into account. As a caveat on firm-CEO matching models, it is often pointed out that, upon CEO turnover, the top management team usually tends to be replaced together. An easier way to deal with this extension would be to assume that the quality of the management team is simply characterized by a one-dimensional variable and keep the current framework as it is except that the observed CEO compensation distribution should be replaced by the distribution of the average compensation of non-CEO executives. In Figure 4, one can observe similar patterns of firm quality and managerial talent distributions.

5.4 Counterfactual Experiments

We now conduct counterfactual experiments using the respective calibrated models that consist of the estimated baseline parameter values and the implied distributions of firm quality and CEO talent. First, we examine the quantitative impact of CEO talent in each industry. Second, we examine how product market characteristics affect firm value and CEO pay.

5.4.1 Impact of CEO Talent

We consider the experiment of Gabaix and Landier (2008) that examines the impact of CEO talent at the median-sized firm among the largest 500 firms. Suppose that the reference firm indexed by $i = 1/2$ could replace its manager by the best CEO indexed by $i = 1$ in the same industry. We assume that the aggregate market structure, such as the aggregate price index P^* and the equilibrium mass N^* of firms, remains unchanged with this event associated with only one firm. To begin with, using (21), we calculate the rate of increase in the total surplus S at this reference firm as

$$\frac{\Delta S}{S[1/2]} = \frac{S(x[1/2], y[1]) - S(x[1/2], y[1/2])}{S(x[1/2], y[1/2])} = \left(\frac{y[1]/y[0]}{y[1/2]/y[0]}\right)^{\sigma-1} - 1. \tag{47}$$

Next, we estimate how much the firm's market value v would change due to this event by using (15). In fact, this measure captures the gross benefit from hiring the best CEO, that is, the present value of additional future gross earnings relative to the current market value as shown below:

$$\frac{\Delta v}{v[1/2]} = \frac{\phi(x[1/2], y[1], u[1/2]) - \phi(x[1/2], y[1/2], u[1/2])}{\phi(x[1/2], y[1/2], u[1/2])} = \frac{\frac{R(P^*\rho x[1/2])^{\sigma-1}}{(1-\beta)\sigma}(y[1]^{\sigma-1} - y[1/2]^{\sigma-1})}{v[1/2]}. \tag{48}$$

For the purpose of comparison, we also consider the cost to be incurred if the firm was required to pay the best CEO his current compensation at the largest firm. We compute this as the ratio of the present value of future additional compensation payments relative to the current market value, that is,

$$\frac{\Delta u/(1-\beta)}{v[1/2]} = \frac{(u[1] - u[1/2])/(1-\beta)}{v[1/2]}. \tag{49}$$

Table 3 shows the results of this counterfactual experiment. Note that, since CEO compensation is relatively small compared to the firm's gross profit, changes in surplus and those in firm value are very similar. The percentage changes in firm value in the second column should be compared to the result of Gabaix and Landier (2008), whose sample is the largest 500 firms among S&P 1500 firms in different industries. In their estimation, replacing the median CEO by the number one CEO at no extra compensation payment increases firm value by only 0.016%. Our estimates, by contrast, are almost two orders of magnitude greater than their estimate in most sectors.

More importantly, there is considerable variation across industries. The impact of better CEOs is, indeed, much more quantitatively significant in the business equipment and health care industries (about 2.9% and 2.5%, respectively), whereas the size of the impact in the chemical industry (0.85%) is the lowest. In particular, notice that industries with lower impact of managerial talent are the chemical, consumer durable goods, and manufacturing industries which are often viewed as old economy industries in contrast with new economy or high-tech industries. Since there is no much difference in talent between the highest and the median ranking CEOs in the telecom industry as shown in Figure 1, this industry shows a somewhat low impact of managerial talent, which might be different if the replacement of the lowest ranking CEO with the best one was considered.

Further, these ratios of the benefit from hiring the best CEO should be compared with the ratios of additional compensation payments relative to firm market value that we report in the last column. Higher costs than benefits is a natural result of the competitive assignment process because otherwise the matching of the median firm-manager pair would not be sustained. As one can expect, the size of the additional cost is higher in the business equipment and health care industries (10.72% and 8.69%, respectively) in which the marginal returns to managerial talent are higher than in other industries. However, it is worth emphasizing that, for any industry, the size of the cost is roughly of the same order of magnitude as the size of the benefit. More precisely, the cost is about three or four times greater than the benefit. This result also contrasts sharply with the findings of Gabaix and Landier (2008). They document that the talent difference resulting in a mere 0.016% increase in firm market value implies 530% difference in CEO pay, which might be mainly attributed to the huge difference in firm size between the highest and median ranking firms, possibly, from different industries. For the purpose of comparison, we compute the cost measure from their calibration results,[4] and obtain the estimate of 1.77% if the discount rate is 0.9 (based on the estimated values of β in our analysis). This cost measure is two orders of magnitude higher than their estimate of the rate of increase in firm market value, 0.016%. Overall, our results show that when different industries are characterized by different structures of CEO talent and product markets, the impact of managerial talent is not negligible at all, and the compensation of CEOs is

[4] According to their notation, it is measured as the present value of additional future compensation payments, $w(1) - w(n_*)$, divided by $S(n_*)$, where n_* is 250.

quantitatively in line with their contributions to firms.

In addition to the effects of the hypothetical employment only at a reference firm, we now estimate the effects of counterfactual distributions, which is similar to the approach used by Terviö (2008). More specifically, we look at three cases in which all managers hypothetically have the same level of talent $y[I]$ with $I = 0, 1/2$, and 1, respectively, while the existing distribution of firm quality is kept in place. Since there is no heterogeneity on the side of managers, the current levels of compensation (35) from the competitive assignment process cannot be applied. Following Terviö (2008), we assume that all the managers would earn the same level of compensation that manager I receives in the original equilibrium with managerial heterogeneity, $u[I]$. All the product market characteristics are assumed to be the same, and we set the fixed entry cost f_e to the value of $E[v[i]]$ in the current equilibrium, following the free entry condition (32). We derive a new equilibrium under this structure, that is, a new set of the relative aggregate price index, P_0^I, and the mass of firms, N^I, using (36) and (37):

$$\frac{R}{\sigma}\left(P_0^I\right)^{\sigma-1}\int_0^1\left(\frac{x[i]}{x[0]}\frac{y[I]}{y[0]}\right)^{\sigma-1}di = u[I] + (1-\beta)f_e, \tag{50}$$

$$N^I = \frac{R/\sigma}{u[I] + (1-\beta)f_e}, \tag{51}$$

$$S([x[i], y[I]) = \frac{R}{(1-\beta)\sigma}\left(P_0^I\frac{x[i]}{x[0]}\frac{y[I]}{y[0]}\right)^{\sigma-1}, \tag{52}$$

and then compare the results of each counterfactual with the original equilibrium outcome.

Table 4 displays the percentage differences in consumer welfare, the mass of firms, and the mean value of the surplus. Note that consumer welfare is measured by the equilibrium utility level of the representative consumer, $U^* = R/P^*$, by (5), which is inversely related to the aggregate price index.

First, consumer welfare in each counterfactual is worse than in the original economy. The integral on the left-hand side of (50) represents the industry-wide productivity and has a greater value if I is bigger. $u[I]$ on the right-hand side is also larger if I is bigger. When the hypothetical talent level of all managers is the lowest one, $y[0]$, the former effect is larger than the latter effect, resulting in a higher aggregate price and thus negatively affecting consumer welfare. Interestingly, even when all managers are of the highest type with $y[1]$, that is, the industry-wide productivity in this counterfactual is higher than in the original equilibrium, consumer welfare is still worse than the original equilibrium because of the high value of $u[1]$. Note that the mass of firms would decrease in this counterfactual. In other words, the high managerial compensation might attract less firms in the market and dampen market competition, thereby causing a deterioration in consumer welfare. In particular, industries with higher levels of CEO compensation show greater consumer welfare losses.

5.4.2 Impact of Product Market Characteristics

We now examine the effects of different product market characteristics on the equilibrium outcome. In the monopolistically competitive product market, there are several dimensions influencing the market structure: the elasticity of product substitution σ, the exit probability $1-\beta$, the entry cost f_e, and the market size R. We explore how each of these dimensions alters the equilibrium outcome, including consumer welfare (due to a change in the aggregate price index), the mass of firms, and the levels and distributions of CEO pay and firm market value, by varying that specific parameter over its plausible range.

Effects of Product Substitutability Table 5 shows the effects of the elasticity of product substitution across industries. To begin with, it is observed that, for any industry, the aggregate price index increases and the mass of firms declines as product substitutability increases. According to Proposition 1, this observation implies that the entry cost and the exit probability are below their respective thresholds. In this case, at the current equilibrium aggregate price, a marginal increase in product substitutability implies more intense price competition and therefore lowers firms' gross and net profits, which, in turn, adjusts the aggregate price upward to a new level for the free entry condition (36) to be met again. While the percentage change in the mass of firms seems to be similar across industries, the change in the aggregate price index varies significantly across industries. In particular, the aggregate price index is more sensitive to the elasticity of product substitution especially in the business equipment and health care industries, for which the baseline value of the parameter is relatively lower as shown in Table 2. Hence, the observation implies that these industries are not only heterogeneous in terms of product substitutability but also more vulnerable to some exogenous factors that would affect the degree of product substitutability. In contrast, the consumer durable goods industry has the least sensitivity of the aggregate price index. In fact, its least change in the consumer durable goods industry is also observed when any of other product market characteristics changes. This result might be explained by the argument of the price rigidity in this industry (Domowitz, Hubbard, and Petersen, 1986, 1988; Leith and Malley, 2007).

Next, we examine the effects of product substitutability for the equilibrium distributions of CEO pay and firm market value. CEO pay levels, measured by their mean values, decline with this dimension of market competition. In particular, CEO pay levels in the health care and business equipment industries are affected most by a change in this parameter. Roughly speaking, the average CEOs in these industries would face an about 8% pay cut in response to a 5% increase in product substitutability in the market.

In addition to the mean values of CEO pay, we further examine the shifts in CEO pay distributions in response to a 10% increase and a 10% decrease in product substitutability for the business equipment and telecom industries. Figure 2 displays the shifts in CEO pay distribution for these industries. As noted in the comparison of the mean values of CEO pay, the shifts in CEO pay distributions in the former industry are more noticeable than those in the latter industry. More importantly, the figure confirms the analytical result presented in Proposition 3 that an increase in the elasticity of product substitution affects managerial compensation differently across firms. That is, there is a certain rank such that managers below the rank get paid less than currently, whereas managers above that rank get paid more. While the trigger rank in the former industry is almost the highest one, it is lower ($\bar{\imath} = 0.9$) in the latter industry. This result implies that a change in product substitutability may induce a larger CEO pay dispersion within an industry.

Finally, while firms would face a more price-elastic demand in the market in response to an increase in product substitutability, they could also reduce CEO pay levels. It is shown in Table 5 that, due to these contrasting effects, product substitutability has a less significant quantitative effect on firm market value than it does on CEO pay.

Effects of the Exit Probability and Entry Cost The exit probability $1-\beta$ and the entry cost f_e affect the equilibrium outcome mainly through the aggregate price index determined by the free entry condition (36). As either of them increases, the free entry condition implies that the aggregate price index also must increase. The other equilibrium condition (37) implies that this market change lowers the mass of firms in the market. The intuition is that an increase in the exit probability or the entry cost induces fewer firms to enter the market and, therefore, reduces price competition, resulting in a higher aggregate price index. Consequently, the marginal returns to talent, the integrand in (35), increase so that managers would get paid more.

Table 6 displays the effects of the industry discount rate β instead of the exit probability $1-\beta$, and the effects of the fixed entry cost f_e are reported in Table 7. Notice that we consider smaller percentage changes in β because of its upper limit, $0 < \beta < 1$. The exit probability has a much more significant quantitative impact on the equilibrium outcome than any other parameters do. Since the parameter can be viewed as being negatively associated with industry risk that active firms face in the market, this observation suggests the important role of risk in determining the market equilibrium outcome. In particular, the telecom industry is overall most sensitive to this factor. Specifically, a 5% increase in risk leads to a 65.3% increase in the mean value of CEO pay in the telecom industry. Moreover, one can observe that the changes in firm value are relatively smaller than those in CEO pay and that their signs vary across industries, which in fact confirms the ambiguous effect of the discount rate on firm market value in Proposition 3. In contrast with the influence of the exit probability, that of the entry cost seems to be uniform across industries. Nonetheless, the price rigidity of the consumer durable goods industry still holds in response to a change in the exit probability and the entry cost.

Effects of the Market Size Table 8 confirms the effects of the market size R discussed in Section 4. At the current aggregate price, as the market size increases, the market demand each firm faces increases, and so does its profitability, which attracts more firms to the market. A greater mass of firms in the market induces more intense price competition, thereby driving the aggregate price index down. As discussed in Proposition 3, we also empirically observe that a firm's market value and managerial compensation are not affected by the market size R (therefore, unreported).

6 Conclusion and Future Work

We study how the distributions of CEO talent and compensation vary across industries, and how product market characteristics affect these distributions. We develop a market equilibrium model that incorporates the competitive assignment of CEOs to firms in a framework in which firms engage in imperfect product market—specifically, monopolistic—competition. The model enables the simultaneous analysis of the effects of managerial talent and product market characteristics on the determination of firm value and CEO pay distributions. We characterize the unique, stationary equilibrium of the model and then calibrate the model to a sample of firm-CEO observations in each of the nine industry sectors based on the twelve Fama-French industry classification. Using the respective calibrated models for different industries, we perform several counterfactual experiments to investigate the quantitative effects of managerial talent and those of product market characteristics.

There are several main results obtained from the analysis of the paper. First, we find that there is much variation in the distributions of firm quality and managerial talent across industries. As compared with other industries, high-tech industries are characterized by higher heterogeneity both in firm quality and in managerial talent. Second, contrary to the conclusions of Terviö (2008) and Gabaix and Landier (2008), the impact of CEO talent on shareholder value is, indeed, significant, and it is roughly of the same order of magnitude as CEO pay. The explicit incorporation of the product market environment in which firms operate plays a key role in generating these findings. Third, the contribution of CEO talent varies significantly across industries. As one may expect from the inferred talent distributions, managerial talent is more important to firm value in high-tech industries so that more intense competition for CEO talent in those industries leads to higher pay dispersions. Fourth, we analytically derive the effects of different product market characteristics on firm value and CEO pay. In particular, either the entry cost or the exit probability shifts the entire CEO pay distribution upward or downward, whereas the elasticity of product substitution may affect large and small firms differently, which leads to higher pay differences between CEOs in the same industry. Overall, our study shows that industry structures associated with CEO labor markets and product markets help explain the variations in the levels and distributions of CEO pay across industries.

In this paper, we abstract away from asymmetric information, risk and incentive provisions as in Gabaix and Landier (2008) and Tervio (2008). However, since a large body of research on CEO compensation is based upon agency problems, a natural next step would be to introduce asymmetric information stemming from moral hazard. Such an analysis could explore the importance of risk and moral hazard in the endogenous matching of CEOs to firms and the determination of CEO compensation levels and incentives. We could estimate agency costs arising from moral hazard across industries and obtain qualitative as well as quantitative implications for the effects of product market characteristics on managerial incentives and the inefficiencies arising from agency problems.

Appendix: Proofs

Proof of Proposition 1

As the entry cost f_e or the likelihood of exit $1-\beta$ increases, the right-hand side of (36) increases. Since the left-hand side of (36) is an increasing function of the aggregate price index, it follows that the equilibrium aggregate price must increase with f_e or $1-\beta$ to satisfy the equilibrium condition (36). The market size R has an opposite effect because R is on the left-hand side of (36).

The result above is used to show the second result about the effect of a marginal increase in σ. Here, we only prove the result with the threshold of the entry cost, $\bar{f}_e(\sigma)$ because the result with the threshold of the exit probability, $1-\bar{\beta}(\sigma)$ can be similarly shown. First, define from (36)

$$f(\sigma, P) = \frac{RP^{\sigma-1}}{1-\beta}\left[\frac{(\rho x[0]y[0])^{\sigma-1}}{\sigma} + \rho^{\sigma}\int_0^1\left[\int_0^i x[j]^{\sigma-2}y[j]^{\sigma-1}x'[j]dj\right]di\right] - \frac{u_0}{1-\beta}. \tag{53}$$

If $P^*(\sigma)$ denotes the equilibrium aggregate price index when the elasticity of substitution is σ,

$$f(\sigma, P^*(\sigma)) = f_e. \tag{54}$$

By taking the derivative of f with respect to σ, one can observe that $\frac{\partial f}{\partial \sigma}$ is greater than zero if P exceeds a threshold $\bar{P}(\sigma)$ and is less than zero otherwise. In addition, note that $\frac{\partial f}{\partial P} > 0$. By (54) and the implicit function theorem, we can write

$$\frac{dP^*(\sigma)}{d\sigma} = -\frac{\partial f/\partial \sigma}{\partial f/\partial P}\mid_{P=P^*(\sigma)}. \tag{55}$$

In the proof of the first result of this proposition, the aggregate price index $P^*(\sigma)$ has been shown to increase with the entry cost f_e. It then follows that there exists a threshold level $\bar{f}_e(\sigma)$ of the entry cost such that $P^*(\sigma) > \bar{P}(\sigma)$ if $f_e > \bar{f}_e(\sigma)$ and $P^*(\sigma) < \bar{P}(\sigma)$ if $f_e < \bar{f}_e(\sigma)$, which determines the sign of $\partial f/\partial \sigma$. Taken together, $\frac{dP^*(\sigma)}{d\sigma} < 0$ if $f_e > \bar{f}_e(\sigma)$ and $\frac{dP^*(\sigma)}{d\sigma} > 0$ if $f_e < \bar{f}_e(\sigma)$. Q.E.D.

Proof of Proposition 2

In the proof of Proposition 1, we have showed that the equilibrium aggregate price increases with the entry cost f_e or the exit probability $1-\beta$, whereas it decreases with R. By the observation and (37), we immediately have the first result of this proposition. On the other hand, the impact of a marginal increase in σ cannot be unambiguously determined because the mass of firms, given by (37), depends on the factor distributions as well as other product market characteristics. Hence, we empirically explore the effect of σ after calibrating the model to data. Q.E.D.

Proof of Proposition 3

Equation (36) can be rewritten as an equation for $RP^{*\sigma-1}$. Plugging that equation into (35) shows that CEO compensation increases with the the entry cost f_e and the likelihood of exit $1-\beta$, whereas it does not change with the market size R. To prove the effects on firm market value, we plug the equation for $RP^{*\sigma-1}$ and (35) into (34) and perform a partial integration, which provides the following equation:

$$v[i] = Qf_e + \frac{(Q-1)u_0}{1-\beta}, \tag{56}$$

where $Q = \frac{\frac{(\rho x[0]y[0])^{\sigma-1}}{\sigma} + \rho^\sigma \int_0^i x[j]^{\sigma-2} y[j]^{\sigma-1} x'[j] dj}{\frac{(\rho x[0]y[0])^{\sigma-1}}{\sigma} + \rho^\sigma \int_0^1 \int_0^i x[j]^{\sigma-2} y[j]^{\sigma-1} x'[j] dj di} > 0$. In the above, one can see that firm market value increases with the entry cost f_e, but is not affected by the market size R. It is also shown that firm market value increases with the exit probability $1-\beta$ if $Q < 1$, but decreases if $Q > 1$. However, since the value of Q depends on the factor distributions, the effect of the exit probability should be empirically tested after the factor distributions are implied by data.

Finally, we show the effect of product substitutability on CEO pay. We first differentiate equation (35) with respect to σ as follows:

$$\frac{\partial u[i]}{\partial \sigma} = \int_0^i \left(\frac{\partial h(j,\sigma)}{\partial \sigma} \right) dj = \int_0^i \left(h(j,\sigma) \frac{\partial \ln h(j,\sigma)}{\partial \sigma} \right) dj, \tag{57}$$

where $h(j,\sigma) = RP^*(\sigma)^{\sigma-1} \rho^\sigma x[j]^{\sigma-1} y[j]^{\sigma-2} y'[j]$ and $P^*(\sigma)$ is the equilibrium aggregate price index when the elasticity of substitution is σ. Taking the derivative of $\ln h(j,\sigma)$, we obtain

$$\frac{\partial}{\partial \sigma} \ln h(j,\sigma) = \ln P^*(\sigma) + (\sigma-1) \frac{\partial}{\partial \sigma} \ln P^*(\sigma) + \ln \rho + \frac{1}{\sigma-1} + \ln(x[j]y[j]). \tag{58}$$

It then follows that there exists a trigger level $\bar{j}$ of firm rank such that $\frac{\partial \ln h(j,\sigma)}{\partial \sigma} > 0$ for $j > \bar{j}$ and $\frac{\partial \ln h(j,\sigma)}{\partial \sigma} < 0$ for $j < \bar{j}$. Since $h(j,\sigma)$ is positive, the integrand in (57) has the same sign as that of $\frac{\partial \ln h(j,\sigma)}{\partial \sigma}$. Accordingly, it is evident that the right-hand side of (57) is negative unless i is sufficiently high. Note that the threshold for i, to be denoted by $\bar{\imath}$, is different from $\bar{j}$ at which $\frac{\partial \ln h(j,\sigma)}{\partial \sigma} = 0$. Therefore, CEO pay level increases (decreases) with σ when the rank of a firm is above (below) $\bar{\imath}$. Q.E.D.

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Table 1: Cross-Industry Summary Statistics

We extract firm-specific variables and CEO compensation variables for 1992-2009 from the Compustat Fundamentals Annual database and ExecuComp database, respectively. CEO Total Compensation is ExecuComp item $TDC1$, which represents the total compensation comprised of salary, bonus, other annual, total value of restricted stock granted, total value of stock-options granted (using Black-Scholes), long-term incentive payouts, and all other total, whereas CEO Cash Compensation (ExecuComp item $TOTAL\_CURR$) is comprised of only salary and bonus. Total Firm Value (market value of common equity plus book value of debt) is computed as common stock price (item $PRCC_F$) times shares outstanding at the end of fiscal year (item $CSHO$) plus total assets (item AT) minus book value of equity, which is computed as common equity (item CEQ) plus balance sheet deferred taxes (item $TXDB$). Total Assets is item AT, and Net Sales is item $SALE$. Operating Costs contains costs of goods sold (item $COGS$), selling, general and administrative expenses (item $XGAS$), and depreciation, depletion, and amortization (item DP). All nominal variables are converted to 2005 U.S. dollars (in millions) using the GDP deflator provided by the BEA. We take the averages of all of the above variables for each firm over the time period during which it was operating to construct a cross-sectional sample, and then group them into Fama-French's 12 industries (except for finance, regulated, and other miscellaneous groups). CEO total compensation variables below are not the actual variables, but smoothed ones obtained by performing a Lowess (bandwidth, 0.7) on the relation between the actual compensation levels and the ranks of the firms in terms of total firm value. In this table, We report the means and standard deviations (in parentheses) of the variables by industry.

Industry Sector	Number of Firms	CEO Total Compensation	CEO Cash Compensation	Total Firm Value	Total Assets	Net Sales	Operating Costs
All	2,049	4.158	1.093	6,656.87	3,568.24	3,523.28	3,184.76
		(3.183)	(0.575)	(20,878.71)	(12,479.35)	(11,341.15)	(10,410.12)
Consumer Nondurables	179	4.519	1.391	7,733.62	3,826.24	3,797.87	3,270.09
		(3.277)	(0.610)	(19,706.46)	(8,719.88)	(7,107.49)	(5,864.65)
Consumer Durables	79	3.332	1.276	12,101.22	10,560.74	7,955.60	7,463.66
		(2.413)	(0.741)	(48,959.69)	(46,190.00)	(28,532.65)	(26,869.93)
Manufacturing	344	3.247	1.101	4,800.97	3,093.20	3,011.03	2,724.85
		(2.120)	(0.505)	(9,333.92)	(5,633.12)	(5,439.08)	(4,961.03)
Energy	129	4.901	1.484	11,112.22	7,308.58	7,307.09	6,571.67
		(3.215)	(0.896)	(32,476.72)	(17,860.30)	(23,211.10)	(20,722.15)
Chemicals	81	3.803	1.289	7,811.80	4,139.14	3,871.18	3,400.54
		(2.330)	(0.562)	(19,369.27)	(8,998.54)	(7,518.10)	(6,447.83)
Business Equipment	570	4.878	0.854	5,650.21	2,190.35	1,825.21	1,627.05
		(4.197)	(0.425)	(19,557.22)	(6,704.69)	(5,951.96)	(5,276.70)
Telecom	47	9.427	2.051	19,090.18	13,465.62	4,712.52	4,042.46
		(8.435)	(1.666)	(22,914.43)	(18,590.19)	(7,080.78)	(6,028.28)
Shops	351	3.355	1.100	4,858.26	2,667.92	5,423.12	5,146.80
		(2.195)	(0.454)	(14,937.68)	(6,774.00)	(14,390.24)	(13,699.57)
Health Care	269	3.674	0.917	6,538.02	2,350.04	1,686.00	1,361.08
		(2.758)	(0.466)	(19,934.36)	(6,439.36)	(4,300.51)	(3,291.66)

Table 2: Parameter Estimates, Relative Factor Values, and Price-Cost Margin

Industry Sector	β	R	σ	u_0	x[1]/x[0]	y[1]/y[0]	Price-Cost Margin
Consumer Nondurables	0.9209	679,818.9	7.6894	0.9473	2.5822	1.0105	1.1614
Consumer Durables	0.8934	628,492.7	15.5667	0.6806	1.5280	1.0028	1.0659
Manufacturing	0.8952	1,035,794	11.8989	1.4094	1.8379	1.0033	1.1050
Energy	0.9155	942,614.6	10.3864	2.1119	1.9014	1.0017	1.1119
Chemicals	0.9071	313,565.5	7.7124	0.6533	2.3079	1.0059	1.1384
Business Equipment	0.8933	1,040,368	3.5215	0.8246	22.5727	1.0282	1.1218
Telecom	0.9324	221,488.3	4.9714	0.9281	4.1659	1.0200	1.1658
Shops	0.9099	1,903,514	14.6211	0.8163	1.6698	1.0039	1.0537
Health Care	0.9151	453,534.7	3.6899	0.8390	13.7848	1.0244	1.2387

Table 3: Impact of CEO Talent at the Median-Sized Firm

Industry Sector	$\frac{\Delta S}{S[1/2]}(\%)$	$\frac{\Delta v}{v[1/2]}(\%)$	$\frac{\Delta u/(1-\beta)}{v[1/2]}(\%)$
Consumer Nondurables	1.723	1.762	6.945
Consumer Durables	1.134	1.151	4.017
Manufacturing	1.134	1.163	3.944
Energy	1.229	1.246	3.147
Chemicals	0.841	0.852	2.157
Business Equipment	2.841	2.909	10.719
Telecom	1.179	1.195	3.985
Shops	1.575	1.608	5.353
Health Care	2.465	2.532	8.693

Table 4: Effects of Hypothetical Talent Distributions

	I=0	I=1/2	I=1	I=0	I=1/2	I=1	I=0	I=1/2	I=1
Industry Sector	$\frac{\Delta U^I}{U}$ (%)			$\frac{\Delta N^I}{N}$ (%)			$\frac{\Delta E[S]^I}{E[S]}$ (%)		
Consumer Nondurables	-0.866	-0.154	-0.200	0.728	0.240	-1.765	-0.720	-0.239	1.815
Consumer Durables	-0.228	-0.046	-0.058	0.507	0.142	-1.149	-0.505	-0.142	1.227
Manufacturing	-0.251	-0.059	-0.082	0.504	0.155	-1.223	-0.500	-0.154	1.243
Energy	-0.096	-0.080	-0.076	0.396	0.174	-1.004	-0.380	-0.173	1.040
Chemicals	-0.440	-0.060	-0.103	0.623	0.094	-1.024	-0.598	-0.094	1.078
Business Equipment	-2.224	-0.743	-0.661	0.784	0.354	-2.216	-0.769	-0.348	2.297
Telecom	-1.662	-0.119	-0.286	0.777	0.265	-1.561	-0.771	-0.264	1.581
Shops	-0.305	-0.068	-0.087	0.693	0.193	-1.616	-0.682	-0.190	1.668
Health Care	-2.009	-0.663	-0.432	0.627	0.241	-1.558	-0.611	-0.234	1.609

Table 5: Effects of Product Substitutability σ

(Change in σ)	-10%	-5%	5%	10%	-10%	-5%	5%	10%	-10%	-5%	5%	10%	-10%	-5%	5%	10%
Industry Sector	$\frac{\Delta U}{U}$ (%)				$\frac{\Delta N}{N}$ (%)				$\frac{\Delta E[u]}{E[u]}$ (%)				$\frac{\Delta E[v]}{E[v]}$ (%)			
Consumer Nondurables	10.63	4.77	-4.01	-7.37	11.30	5.08	-4.52	-9.04	10.73	5.45	-5.03	-9.99	0.09	0.17	0.29	0.42
Consumer Durables	3.69	1.68	-1.44	-2.66	11.69	5.19	-5.19	-9.09	10.12	5.23	-5.20	-10.49	-0.18	0.04	0.33	0.43
Manufacturing	7.01	3.20	-2.75	-5.09	11.01	5.22	-4.93	-9.28	4.28	2.23	-2.21	-4.52	-0.01	0.04	0.21	0.27
Energy	6.91	3.15	-2.66	-4.93	11.02	4.72	-5.51	-10.24	1.05	0.77	-1.18	-2.73	-0.36	-0.13	0.36	0.64
Chemicals	9.60	4.33	-3.64	-6.70	11.39	6.33	-5.06	-8.86	6.05	3.19	-3.30	-6.84	-0.28	-0.06	0.48	0.80
Business Equipment	47.11	19.15	-13.68	-23.77	11.39	5.34	-4.98	-9.43	15.13	7.78	-7.89	-15.66	-0.40	-0.18	0.32	0.57
Telecom	16.07	7.09	-5.84	-10.61	10.64	6.38	-4.26	-8.51	6.54	3.26	-2.41	-4.74	0.45	0.33	0.08	-0.03
Shops	5.43	2.49	-2.14	-3.98	11.21	5.46	-4.89	-9.48	8.23	4.22	-4.31	-8.67	-0.23	-0.09	0.23	0.41
Health Care	35.95	14.95	-11.06	-19.45	11.41	5.32	-4.94	-9.51	17.27	8.70	-8.40	-16.38	-0.44	-0.18	0.35	0.65

Table 6: Effects of Discount Rate β

(Change in β)	-5%	-2.5%	2.5%	5%	-5%	-2.5%	2.5%	5%	-5%	-2.5%	2.5%	5%	-5%	-2.5%	2.5%	5%
Industry Sector	$\frac{\Delta U}{U}(\%)$				$\frac{\Delta N}{N}(\%)$				$\frac{\Delta E[u]}{E[u]}(\%)$				$\frac{\Delta E[v]}{E[v]}(\%)$			
Consumer Nondurables	-6.71	-3.81	5.27	13.94	-37.29	-22.60	41.24	140.11	47.45	23.70	-23.12	-46.24	0.91	0.57	-0.09	-0.42
Consumer Durables	-2.38	-1.29	1.62	3.81	-29.87	-18.18	25.97	72.73	34.00	16.85	-16.74	-33.64	0.97	0.66	-0.16	-0.80
Manufacturing	-3.21	-1.76	2.20	5.19	-30.14	-17.68	26.67	73.33	20.25	10.14	-10.02	-20.10	0.20	0.16	0.16	0.16
Energy	-4.47	-2.50	3.45	8.71	-36.22	-22.05	37.01	118.11	30.77	15.43	-15.63	-31.12	0.97	0.54	-0.30	-0.81
Chemicals	-5.80	-3.23	4.28	10.56	-32.91	-20.25	32.91	97.47	41.59	20.75	-20.53	-40.92	1.06	0.77	-0.25	-0.76
Business Equipment	-13.05	-7.35	9.87	24.20	-29.89	-17.62	26.69	72.60	35.28	17.71	-17.60	-35.08	0.67	0.39	-0.22	-0.52
Telecom	-12.37	-7.17	11.12	34.00	-40.43	-25.53	53.19	221.28	65.31	32.33	-30.96	-61.54	0.16	0.10	0.35	0.53
Shops	-2.95	-1.63	2.16	5.30	-33.91	-20.40	33.91	102.30	38.40	19.17	-19.26	-38.41	0.44	0.25	-0.11	-0.31
Health Care	-15.13	-8.62	12.55	33.78	-35.74	-21.67	37.64	119.01	43.38	21.43	-21.20	-42.21	1.16	0.63	-0.50	-1.10

Table 7: Effects of Entry Cost f_e

(Change in f_e)	-10%	-5%	5%	10%	-10%	-5%	5%	10%	-10%	-5%	5%	10%	-10%	-5%	5%	10%
Industry Sector	$\frac{\Delta U}{U}(\%)$				$\frac{\Delta N}{N}(\%)$				$\frac{\Delta E[u]}{E[u]}(\%)$				$\frac{\Delta E[v]}{E[v]}(\%)$			
Consumer Nondurables	1.56	0.74	-0.76	-1.47	11.30	5.08	-4.52	-9.04	-7.83	-3.84	4.19	8.29	-9.86	-4.82	5.29	10.44
Consumer Durables	0.72	0.34	-0.34	-0.65	10.39	5.19	-5.19	-9.09	-7.96	-3.92	4.06	8.01	-9.93	-4.86	5.30	10.4
Manufacturing	0.95	0.46	-0.45	-0.87	10.72	4.93	-4.93	-9.28	-4.67	-2.31	2.41	4.76	-9.87	-4.88	5.12	10.12
Energy	1.14	0.55	-0.52	-1.01	11.02	4.72	-5.51	-9.45	-5.79	-2.87	2.88	5.72	-10.05	-4.97	5.20	10.27
Chemicals	1.58	0.76	-0.74	-1.43	11.39	5.06	-5.06	-8.86	-8.41	-4.17	4.32	8.50	-9.94	-4.85	5.32	10.45
Business Equipment	4.30	2.07	-1.94	-3.76	11.21	5.16	-4.98	-9.25	-8.40	-4.20	4.23	8.46	-10.06	-5.00	5.14	10.22
Telecom	2.61	1.24	-1.27	-2.40	10.64	6.38	-4.26	-8.51	-8.66	-4.25	4.85	9.56	-9.77	-4.77	5.19	10.18
Shops	0.78	0.38	-0.36	-0.70	11.21	5.17	-4.89	-9.20	-7.63	-3.81	3.82	7.62	-10.01	-4.97	5.10	10.15
Health Care	4.05	1.94	-1.84	-3.55	11.41	5.32	-4.94	-9.13	-7.88	-3.92	4.00	7.97	-10.11	-5.02	5.20	10.33

Table 8: Effects of Market Size R

(Change in R)	-10%	-5%	5%	10%	-10%	-5%	5%	10%
Industry Sector	$\frac{\Delta U}{U}(\%)$				$\frac{\Delta N}{N}(\%)$			
Consumer Nondurables	-1.62	-0.80	0.71	1.41	-10.17	-5.08	5.08	10.17
Consumer Durables	-0.72	-0.35	0.33	0.65	-10.39	-5.19	5.19	10.39
Manufacturing	-0.97	-0.48	0.44	0.87	-10.14	-5.22	4.64	9.86
Energy	-1.11	-0.55	0.53	1.03	-10.24	-5.51	4.72	9.45
Chemicals	-1.58	-0.78	0.72	1.43	-10.13	-5.06	5.06	10.13
Business Equipment	-4.15	-2.04	1.97	3.89	-10.14	-5.16	4.98	9.96
Telecom	-2.65	-1.33	1.17	2.36	-8.51	-4.26	6.38	10.64
Shops	-0.77	-0.38	0.36	0.70	-10.06	-5.17	4.89	10.06
Health Care	-3.92	-1.94	1.85	3.66	-10.27	-4.94	5.32	10.27

Figure 1: Inferred Distributions of Firm Quality and Managerial Talent

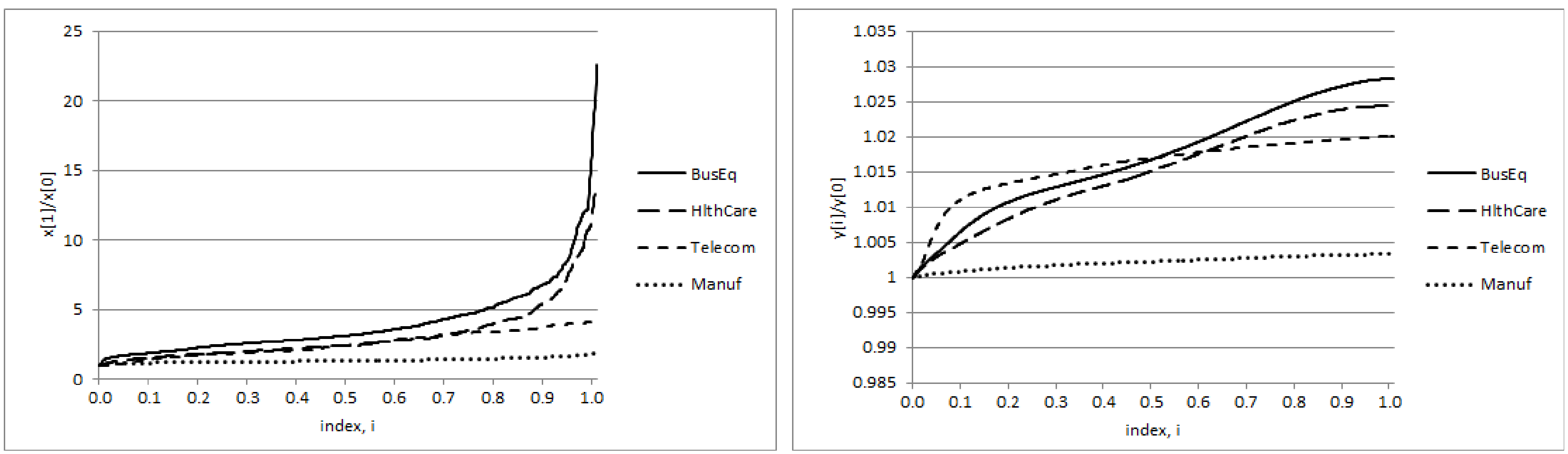

Figure 2: Shifts in CEO Pay Distributions due to Changes in σ (Business Equipment and Telecom)

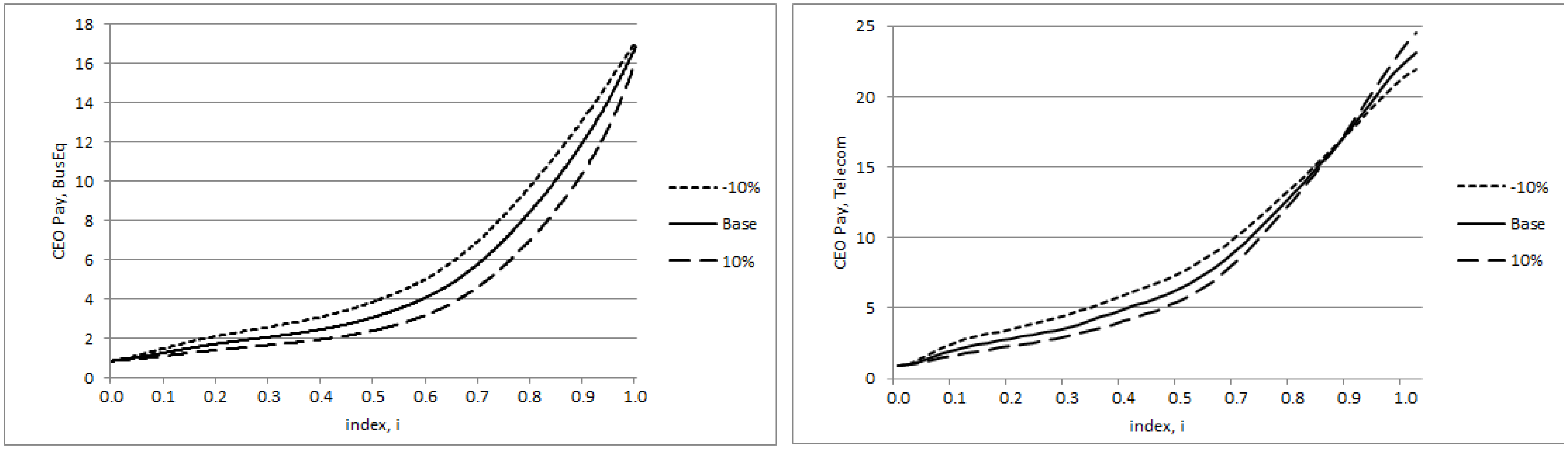

Figure 3: Inferred Distributions of Firm Quality and Managerial Talent (CEO Cash Compensation)

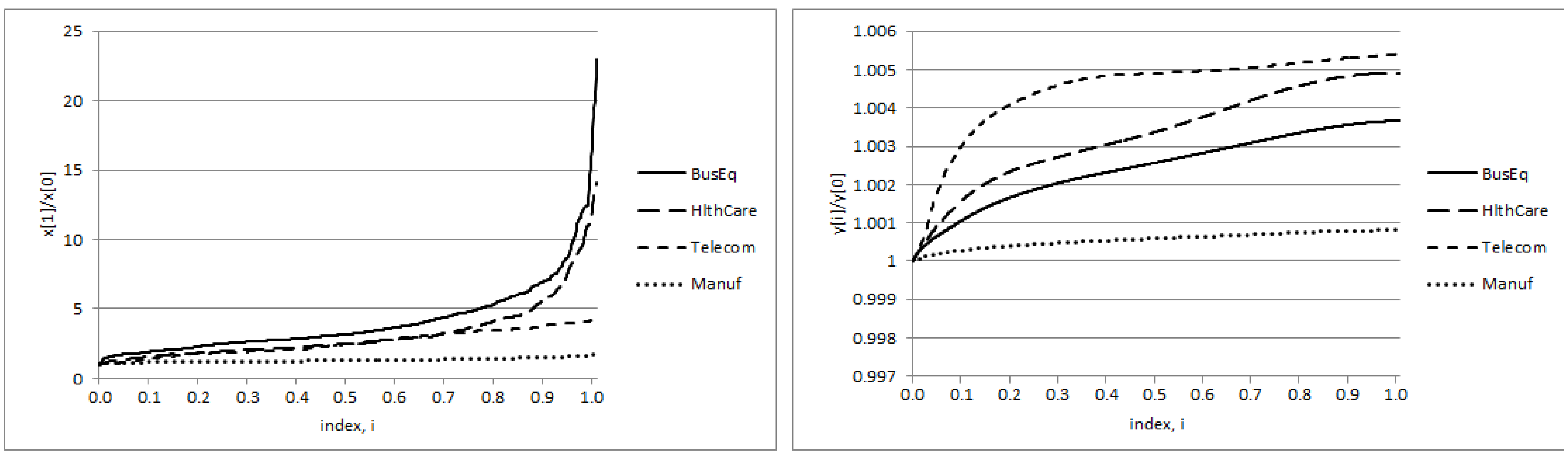

Figure 4: Inferred Distributions of Firm Quality and Managerial Talent (Non-CEO Total Compensation)