Online appendix for "CEO talent, CEO compensation, and product market competition"

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Appendix A. Proofs of propositions in Sections 2 and 3

Proof of Proposition 1

Due to the complementarity between firm quality and CEO talent, the total surplus generated by a firm-CEO pair in each period t, which is the firm's gross profit $\Pi_t(x, y)$ given by (7), satisfies the *supermodularity* condition,

$$\frac{\partial^2 \Pi_t}{\partial x \partial y} > 0. \tag{A1}$$

This condition immediately implies that only positive assortative matching (PAM), that is, more talented CEOs are matched to higher quality firms, holds.

By PAM, we can restrict attention to matches where firm i is matched with CEO i. Then the total surplus generated by CEO-firm pair i is

$$\Pi_t(x[i], y[i]) = \frac{R_t((P_0/w_0)\rho x[i]y[i])^{\sigma-1}}{\sigma}, \tag{A2}$$

and this surplus must be apportioned to the CEO and the firm in a way that ensures the stability of the matching correspondence. Let $\pi_t[i]$ be the *equilibrium* net profit of the firm and $u_t[i]$ be the *equilibrium* compensation of the CEO in period t. The following relation holds in equilibrium:

$$\Pi_t(x[i], y[i]) = \pi_t[i] + u_t[i], \tag{A3}$$

so that we only need to derive the equilibrium payoff profile of either side, and then the other side's payoff immediately follows from this relation.

To begin with, we consider the participation constraints. The payoff to each party can never be less than its outside payoff. The outside payoffs of firms and CEOs are identical for all types and denoted by $\widetilde{\pi}_t$ and $\widetilde{u}_t$. The participation constraints are, therefore,

$$\pi_t[i] \geq \widetilde{\pi}_t; \; u_t[i] \geq \widetilde{u}_t. \tag{A4}$$

Next, we consider the incentive compatibility constraints which require that neither of the parties is strictly better off by matching with a new type of partner other than the *equilibrium* partner.

Let $m \in [0,1]$ denote firm i's choice of its CEO for the current period, and $u_t[m]$ denote the CEO's compensation. For other periods, the firm is matched with its equilibrium partner, CEO i. By (A2) and (A3), the firm's incentive constraint is

$$\pi_t[i] = \max_m \ \Pi_t(x[i], y[m]) - u_t[m] = \max_m \ \frac{R_t((P_0/w_0)\rho x[i]y[m])^{\sigma-1}}{\sigma} - u_t[m]. \tag{A5}$$

As in a usual screening problem, if the single crossing property (that is, the slope of the firm-side indifference curve (in absolute value) increases with firm type i) holds, then the set of incentive constraints above is equivalent to the following two sets of constraints: (i) monotonicity and (ii) local incentive compatibility constraints. From (A5), it is easy to check the single crossing property, that is, the marginal payoff of partner type m, relative to that of compensation payment u_t, rises with firm type i. Accordingly, the firm's global incentive constraint (A5) can be replaced by the monotonicity and local incentive compatibility constraints. Because the monotonicity constraint immediately holds due to PAM, the incentive compatibility constraint can be replaced by the local incentive compatibility constraint. We obtain the local constraint by differentiating (A5) with respect to m and setting m to i, which determinines the slope of the equilibrium CEO pay profile as follows:

$$u_t'[i] = R_t(P_0/w_0)^{\sigma-1}\rho^\sigma x[i]^{\sigma-1}y[i]^{\sigma-2}y'[i]. \tag{A6}$$

By (A2) and (A3), we also obtain the slope of the firm's equilibrium net profit profile,

$$\pi_t'[i] = R_t(P_0/w_0)^{\sigma-1}\rho^\sigma x[i]^{\sigma-2}y[i]^{\sigma-1}x'[i]. \tag{A7}$$

Integrating the above differential equations, we obtain the equilibrium equations for $\pi_t[i]$ and $u_t[i]$ as shown in (10) and (11), respectively. Q.E.D.

Proof of Proposition 2

As the entry cost f_e increases, the right-hand side of the free entry condition (19) increases. Since the left-hand side of (19) is an increasing function of the initial aggregate price index P_0, the equilibrium price index P_0^* increases with f_e. As the aggregate price index in any period $t > 0$ increases with the initial price index ($P_t = P_0\mu_t$), the equilibrium price index P_t^* in period t also increases with f_e. It then immediately follows from the market clearing condition (20) that the mass N of firms in the market declines with the entry cost f_e. By (10), (11), and (14), firm value and CEO pay increase with the initial aggregate price index, which implies a positive impact of the entry cost on payoff variables in each period. Q.E.D.

Proof of Proposition 3

First, define from (19)

$$f(\sigma, P_0) = \frac{R_0(P_0/w_0)^{\sigma-1}}{1-\beta\delta}\left[\frac{(\rho x[0]y[0])^{\sigma-1}}{\sigma} + \rho^\sigma \int_0^1 \left[\int_0^i x[j]^{\sigma-2}y[j]^{\sigma-1}x'[j]dj\right]di\right] - \frac{\tilde{u}_0}{1-\beta\delta}. \tag{A8}$$

If $P_0^*(\sigma)$ denotes the initial equilibrium price index when the product substitutability is σ, then

$$f(\sigma, P_0^*(\sigma)) = f_e. \tag{A9}$$

By taking the derivative of f with respect to σ, one can observe that $\partial f/\partial\sigma$ is greater than zero if P_0 exceeds a threshold $\bar{P}_0(\sigma)$ and is less than zero otherwise. By (A9) and the implicit function theorem, we can write

$$\frac{dP_0^*(\sigma)}{d\sigma} = -\frac{\partial f/\partial \sigma}{\partial f/\partial P_0}|_{P_0=P_0^*(\sigma)}. \tag{A10}$$

Since $\partial f/\partial P_0 > 0$, the sign of the left-hand side of (A10) is the negative of the sign of $\partial f/\partial \sigma$, which depends on whether $P_0^*(\sigma) > \bar{P}_0(\sigma)$ or $P_0^*(\sigma) < \bar{P}_0(\sigma)$. From the proof of Proposition 2, we note that $P_0^*(\sigma)$ increases with the entry cost f_e. Accordingly, there exists a threshold level of the entry cost, $\bar{f}_e(\sigma)$, such that $P_0^*(\sigma) > \bar{P}_0(\sigma)$ if $f_e > \bar{f}_e(\sigma)$ and $P_0^*(\sigma) < \bar{P}_0(\sigma)$ if $f_e < \bar{f}_e(\sigma)$. Consequently, $dP_0^*(\sigma)/d\sigma < 0$ in the former case, whereas $dP_0^*(\sigma)/d\sigma > 0$ in the latter case.

We now examine the effect of σ on CEO pay and firm value. We first differentiate equation (11) with respect to σ as follows:

$$\frac{\partial u_t[i]}{\partial \sigma} = \int_0^i \left(\frac{\partial h_t(j,\sigma)}{\partial \sigma}\right) dj = \int_0^i \left(h_t(j,\sigma)\frac{\partial \ln h_t(j,\sigma)}{\partial \sigma}\right) dj. \tag{A11}$$

In the above, $h_t(j,\sigma) = R_t(P_0^*(\sigma)/w_0)^{\sigma-1}\rho^\sigma x[j]^{\sigma-1}y[j]^{\sigma-2}y'[j]$ where $P_0^*(\sigma)$ is the equilibrium price index when the product substitutability is σ. Taking the derivative of $\ln h_t(j,\sigma)$, we obtain

$$\frac{\partial}{\partial \sigma}\ln h_t(j,\sigma) = \ln(P_0^*(\sigma)/w_0) + (\sigma-1)\frac{\partial}{\partial \sigma}\ln(P_0^*(\sigma)/w_0) + \ln\rho + \frac{1}{\sigma-1} + \ln(x[j]y[j]). \tag{A12}$$

It then follows that there exists a trigger level $\tilde{j}$ such that $\partial \ln h_t(j,\sigma)/\partial\sigma > 0$ for $j > \tilde{j}$ and $\partial \ln h_t(j,\sigma)/\partial\sigma < 0$ for $j < \tilde{j}$. Since $h_t(j,\sigma)$ is positive, the integrand in (A11) has the same sign as that of $\partial \ln h_t(j,\sigma)/\partial\sigma$. Accordingly, one can see that the right-hand side of (A11) is negative unless i is sufficiently high. Note that the threshold for i, denoted by $\hat{i}$, is different from $\tilde{j}$ at which $\partial \ln h_t(j,\sigma)/\partial\sigma = 0$. Therefore, CEO pay level increases (decreases) with σ when the rank of a firm is above (below) $\hat{i}$. In a similar manner, we can prove the argument for firm value becuase, by (10) and (14),

$$\frac{\partial \mathcal{V}_t[i]}{\partial \sigma} = \frac{1}{1-\beta\delta}\int_0^i \left(\frac{\partial k_t(j,\sigma)}{\partial \sigma}\right) dj = \frac{1}{1-\beta\delta}\int_0^i \left(k_t(j,\sigma)\frac{\partial \ln k_t(j,\sigma)}{\partial \sigma}\right) dj, \tag{A13}$$

where $k_t(j,\sigma) = R_t(P_0^*(\sigma)/w_0)^{\sigma-1}\rho^\sigma x[j]^{\sigma-2}y[j]^{\sigma-1}x'[j]$. Q.E.D.

Appendix B. Comparison with Gabaix and Landier (2008)

B.1. Aggregate and industry-level GL analyses

We begin by briefly summarizing GL's aggregate analysis. In the static model presented in their main paper, GL exogenously specify a firm's gross profit as $\Lambda[m] = cS[m]^{\gamma_{GL}}T[m]$, where $m \in [1, \overline{m}]$ is firm rank by size, and $\overline{m}$ is the number of firms in their aggregate sample. Firm size $S[m]$ and CEO talent $T[m]$ *decrease with* m following their convention. GL assume a Pareto firm size distribution with tail index, α_{GL}, and an extreme value CEO talent distribution with tail index, β_{GL}. Using the specific functional forms for the firm size and CEO talent distributions, they derive the equilibrium pay of the CEO of rank m, who is matched to the firm of rank m by PAM, as

$$w[m] = D[m_*]S[m_*]^{\beta_{GL}/\alpha_{GL}}S[m]^{\gamma_{GL}-\beta_{GL}/\alpha_{GL}}, \tag{A14}$$

where m_* denotes the rank of a reference firm, and $D[m_*]$ is a constant that depends on m_*.

To calibrate the tail index α_{GL} of the Pareto firm size distribution, GL run the OLS regression below for each year:

$$\ln(\text{firm size}) = -\alpha_{GL} \ln(\text{firm rank by size} - 1/2) + \text{constant}, \tag{A15}$$

and then compute the time-series average of the regression coefficients over the sample period. To calibrate the remaining parameters $(\beta_{GL}, \gamma_{GL})$, GL evaluate (A14) by regressing log CEO pay on log reference firm size and log individual firm size. They calibrate the exponent parameter γ_{GL} of firm size in the profit function to one ($\gamma_{GL} = 1$) by confirming the null hypothesis that the sum of the two regression coefficients, β_{GL}/α_{GL} and $\gamma_{GL} - \beta_{GL}/\alpha_{GL}$, is equal to one.

In GL's framework, the percentage change in the value of the reference firm of rank m_* if its CEO were replaced with the CEO of rank m is given by

$$\frac{\Delta V[m]}{V[m_*]} = (\alpha_{GL}\gamma_{GL}/\beta_{GL} - 1)\left(1 - (m/m_*)^{\beta_{GL}}\right)\frac{w[m_*]}{S[m_*]}. \tag{A16}$$

GL choose the median firm in their sample as the reference firm and define CEO impact as the proportional change in the reference firm's value if its CEO were replaced with the best CEO. Hence, the CEO impact measure is simply obtained by setting the rank m to the rank of the best CEO ($m = 1$) in (A16). We note that the two elasticities—*the firm size-firm rank elasticity and the CEO pay-firm size elasticity*—obtained from the aforementioned regressions play key roles in determining the CEO impact measure in GL's analysis.

We now show how we infer the aggregate CEO talent profile from GL's analysis. By definition, we can rewrite the proportional change in the reference firm's value that results from replacing its CEO with the new CEO of rank m as

$$\frac{\Delta V[m]}{V[m_*]} \approx \frac{cS[m_*]T[m] - cS[m_*]T[m_*]}{cS[m_*]T[m_*]} = \frac{T[m] - T[m_*]}{T[m_*]}. \tag{A17}$$

In the above, we use the fact that (as noted in Section 4.3.4), CEO pay is small relative to a firm's gross profit so that firm value is proportional to gross profit. From the above, we obtain

$$\frac{\Delta V[m]}{V[m_*]} \approx \frac{T[m]}{T[m_*]} - 1 \Rightarrow \frac{T[m]}{T[m_*]} \approx 1 + \frac{\Delta V[m]}{V[m_*]}. \tag{A18}$$

Using (A16) and (A18), we obtain the talent ratio, $T[m]/T[m_*]$, for any firm rank $m \in [1, \overline{m}]$. By dividing $T[m]/T[m_*]$ by $T[\overline{m}]/T[m_*]$, we obtain the relative CEO talent profile over firm rank m, $T[m]/T[\overline{m}]$, where $T[\overline{m}]$ is the lowest CEO talent (by GL's notational convention). As we discussed in Section 4.3.4, the CEO talent profile in GL's model is comparable to the CEO factor profile in our model. The relative factor profile in GL's aggregate analysis is, therefore, given by

$$\frac{\tilde{y}[q]}{\tilde{y}[0]} = \frac{T[(\overline{m} - 1)(1 - q) + 1]}{T[\overline{m}]}, \text{ for } q \in \left\{0, \tfrac{1}{\overline{m}-1}, ..., \tfrac{\overline{m}-2}{\overline{m}-1}, 1\right\}, \tag{A19}$$

where we use the relation between the firm quantile q and the firm rank m, $m = (\overline{m} - 1)(1 - q) + 1$.

As disscussed in the main body, we implement GL's framework and analysis at the *industry level* by following the procedure described above. In the industry-level GL analysis, we allow the elasticity parameters, $(\alpha_{GL}, \beta_{GL})$, to vary across industries.[19] Hence, the industry-level GL analysis

[19] As noted above, GL calibrate the parameter γ_{GL} to one in their aggregate analysis. The parameter could, in

incorporates industry segmentation. To obtain the industry-level GL factor profiles, we repeat the procedure used to obtain the aggregate factor profile, but implement it at the industry level. In other words, when we compute (A16), we use the parameter values calibrated at the industry level using the industry-level elasticities, set the number of firms to the number of firms within each industry, and consider the relative ranks of firms within their respective industries.

B.2. The elasticities and CEO impact at the aggregate and industry levels: A simple example

GL's aggregate sample is a subset of the set of all firms, and is constituted using varying numbers of firms from different industries. We construct a simple example to show that, depending on the data, and how the aggregate sample is constructed from different industry samples, the CEO pay-firm size and firm size-firm rank elasticities in the aggregate sample could be above, below, or within the ranges of the corresponding industry-level elasticities. Hence, the CEO impact estimate from the aggregate sample could be greater than, less than, or approximately equal to the industry-level estimate. In other words, depending on the true data generating process (DGP), the misspecification bias in GL's aggregate CEO impact estimate could be positive, negative, or there could be no bias at all.

Consider two industries with the same firm size profile $S[m]$. The firm size-firm rank elasticity is then the same in these two industries. We consider the following CEO pay function for firms in industry $j = 1, 2$: $w_j[m] = a_j S[m]^{b_j}$ where a_j and b_j are positive constants that differ for the two industries. To clarify the point we make via our example, we assume that PAM holds perfectly at the industry level so that the relation between CEO pay and firm value is strictly monotonic. Note that b_j is the CEO pay-firm size elasticity in industry j. Also, for simplicity, we do not consider time-series variation in payoffs.

Specifically, we assume the same firm size profile for both industries with a firm size-firm rank elasticity of 2.5. We set the parameter values of the CEO pay functions as follows: ($a_1 = 0.135$, $b_1 = 0.3$) and ($a_2 = 0.007$, $b_2 = 0.7$). We then construct *different* aggregate samples of firms (that is, different sets of firm size and CEO pay values) by choosing *different* numbers of firms from the two industries. Using each aggregate sample, we run the regressions of log firm size on log firm rank, and log CEO pay on log firm size to obtain the aggregate firm size-firm rank and CEO pay-firm size elasticities, respectively.

Table H3 in Appendix H shows the results for three different aggregate samples. As the table shows, depending on the proportions of firms from the two industries in the aggregate sample, the elasticities in the aggregate sample could be below, above, or within the respective ranges of the industry-level elasticities. The resulting CEO impact estimates at the aggregate level are, therefore, below or above the industry-level estimates.

The simple example shows that the signs of the differences between the aggregate and industry-level elasticities crucially depend on the data, and how the aggregate sample is constructed from the industry samples. In this simple example, we assumed that PAM holds perfectly at the industry level, which is clearly not the case in the data. If we introduce noise in the relations between CEO pay and firm size as well as between firm size and firm rank at the industry level, then it further bolsters the basic argument that the misspecification bias in GL's aggregate impact estimate

principle, differ from one at the industry level. It turns out that for all industries except two industries (business equipment and healthcare), we cannot reject the null hypothesis that the parameter equals one at the industry level. For the two industries where it differs from one, the parameter has a minor effect on the impact estimates. In particular, the salient aspects of our discussion of the comparison among the aggregate GL analysis, the industry-level GL analysis, and our analysis are unaffected by whether γ_{GL} differs from one. Consequently, to simplify the discussion, we henceforth set the parameter to one for all industries. The results for the two industries where the parameter differs from one are available upon request.

depends on the data. In other words, there is no general theoretical result that can tell us what the bias will be without going to the data.

The fact that we cannot theoretically predict the misspecification bias in GL's model is actually not surprising within the broader context of the estimation of misspecified models. Consider a simple regression model with misspecification stemming from omitted variables. The biases in the regression coefficients are determined by the correlations between the regressors and the omitted variables. In the vast majority of cases, we do not know the true or theoretical correlations so that the only way to determine potential biases due to omitted variables is to include them and re-run the regression. The industry-level GL analysis that we discussed in Appendix B.1 follows a similar approach by correcting the misspecification in GL's aggregate analysis.

B.3. Statistical significance of negative misspecification bias in GL's aggregate analysis: Parametric bootstrapping

We perform a parametric bootstrapping analysis to examine the statistical robustness of the negative misspecification bias in GL's aggregate analysis. We use our model (the "true" model by our identifying assumption) to generate fictitious industry-level samples by injecting random shocks. We then combine the industry samples to form aggregate samples with the relative proportions of firms from each industry being the same as in GL's sample. For simplicity, we do not consider time-series variation.

We multiply the model-predicted values of firm size and CEO pay for each firm i by random shocks, $\exp(\epsilon_i^f)$ and $\exp(\epsilon_i^c)$, respectively, where $\epsilon_i^f \sim N(0, \sigma_f^2)$ and $\epsilon_i^c \sim N(0, \sigma_c^2)$. We choose σ_f^2 and σ_c^2 to match the variances of the residuals in the cross-sectional regressions of log firm size on log firm rank and log CEO pay on log firm rank, respectively. That is, we run these regressions using the industry-level data and then obtain the variances of the residuals for each year. We then take the averages of the variances over the sample period and use them as the variances of the shocks.

For each bootstrapped sample, we generate the stationary profiles of firm value and CEO pay given by (23) and (24) for each industry using the baseline parameter estimates in Table 5. We then make random draws of the shocks to firm value and to CEO pay across firms from the estimated log normal distributions above, and multiply the model-predicted values of each firm i's firm size and CEO pay by $\exp(\epsilon_i^f)$ and $\exp(\epsilon_i^c)$, respectively. We then group these industry-level observations together to form our simulated aggregate sample in the same relative proportions of firms from different industries as in GL's aggregate sample. We repeat the process to generate 5,000 such simulated industry and aggregate samples. We compute the correlations between the ranks of firms by size and their ranks by CEO pay, the firm size-firm rank and CEO pay-firm size elasticities, and the CEO impact measures at the aggregate and industry levels.

Panel A in Table H5 shows the means and standard deviations (in parentheses) of the moments from the 5,000 bootstrapped aggregate samples constructed by grouping the largest firms in different industries. Panel B shows the means and standard deviations (in parentheses) of the industry-level moments from the 5,000 bootstrapped industry samples. In the third line of the results for each industry, we report the t-statistics for the tests of the null hypothesis that the aggregate value of each moment is equal to its industry-level value.

First, consistent with our premise of PAM at the industry level, the correlation between firm size ranks and CEO pay ranks is lower at the aggregate level than at the industry level. The difference between the aggregate and industry-level correlations is statistically significant for every industry. Second, both the firm size-firm rank and CEO pay-firm size elasticities are lower at the aggregate level than at the industry level, but the difference is statistically significant only for the firm size-firm rank elasticity. Lastly, we compare the resulting CEO impact estimates at the aggregate and industry levels. The negative bias of the CEO impact estimate at the aggregate level relative to the industry-level value is, indeed, statistically significant for every industry. In summary, our bootstrapping analysis shows that the lower firm size-firm rank and CEO pay-firm size elasticities at the aggregate level lead to a negative misspecification bias in GL's aggregate estimate that is statistically robust.

B.4. Comparison between our framework and the industry-level GL framework

In this Appendix, we compare our framework with GL's framework implemented at the industry level.

Dynamic industry-level GL framework

To facilate a direct comparison with our model, we describe the dynamic extension of the static model that GL present in their main paper.[20] GL consider a framework with *permanent CEO impact* in which a CEO's talent *in each period* affects the firm's earnings in all future periods *multiplicatively*. We proceed with the discussion below following their notation that we introduced in Appendix B.1.

A firm's gross profit in the first period $[0, 1]$ or period 0 is

$$\Lambda_0(S, T_0) = c_0 S T_0, \tag{A20}$$

where S is the firm size, T_0 is the talent of the initial CEO, and c_0 is a constant. Recall from footnote 19 that we set the exponent parameter of firm size in GL's profit function to one ($\gamma_{GL} = 1$). The current CEO affects the firm's earnings in all future periods even if she is replaced by another CEO at date 1. Specifically, if the firm's CEO at date 1 has talent T_1 (this CEO could be the same as the initial CEO in which case the CEO's talent is T_0), the firm's gross profit in period $[1, 2]$ or period 1 is

$$\Lambda_1(S, T_0, T_1) = \frac{c_1}{c_0}\Lambda_0(S, T_0)T_1 = c_1 S T_0 T_1, \tag{A21}$$

where c_1 is a random variable that represents an industry-wide shock to earnings in period 1. Note that, in period 1, the firm's earnings are multiplicatively affected by the previous and current CEOs' talents. More generally, if the firm has a history of CEOs whose talents are summarized by $(T_0, T_1, \ldots, T_t)$ until period t (in particular, the firm could have the same CEO over time as is the case in equilibrium), the firm's gross profit over the period $[t, t+1]$ is

$$\Lambda_t(S, T_0, T_1, \ldots, T_t) = \frac{c_t}{c_{t-1}}\Lambda_{t-1}(S, T_0, T_1, \ldots, T_{t-1})T_t = c_t S T_0 \times T_1 \times \ldots \times T_t. \tag{A22}$$

In the above, we assume that the industry-wide shock process c_t follows a stationary Markov process as in our framework: $E[c_s|c_t] = \beta^{s-t}c_t$ for any $s \geq t$.

In equilibrium, PAM holds, that is, a firm of rank $m \in [1, N]$ is matched to a CEO of rank $m \in [1, N]$ through time. Recall that, following GL's convention, firm size, $S[m]$, and CEO talent,

[20] GL briefly mention the dynamic extension of their model, which incorporates CEO-firm matching in each period as in our model, in footnote 6 of their paper.

$T[m]$, *decrease* with m. By (A22), the firm's gross profit in period $[t, t+1]$ is then

$$\Lambda_t[m] = \Lambda_t(S[m], T[m]) = c_t S[m] T[m]^{t+1}. \tag{A23}$$

Consequently, the firm's gross profit in period 0 is

$$\Lambda_0[m] = c_0 S[m] T[m], \tag{A24}$$

that is, the gross profit is proportional to the product of "firm size" and "CEO talent" as GL assume in the static model presented in the main body of their paper.

The equilibrium firm value (the expected present value of the firm's future earnings) at any date t is then given by

$$V_t[m] = E_t\left[\sum_{s=t}^{\infty} \delta^{s-t}\Lambda_s[m]\right] = \sum_{s=t}^{\infty} \delta^{s-t}\beta^{s-t} T[m]^{s-t}\Lambda_t[m] = \frac{\Lambda_t[m]}{1-\varphi T[m]} = \frac{c_t S[m] T[m]^{t+1}}{1-\varphi T[m]}, \tag{A25}$$

where $\varphi = \beta\delta$ is the industry's effective discount factor. In the above, we consider gross earnings inclusive of CEO pay in each period because CEO pay is typically small relative to earnings.

To derive the equilibrium CEO pay profile, we consider firm m's incentive compatibility (IC) condition to ensure PAM. Suppose that the firm makes the (off-equilibrium) choice of the CEO of rank l for the period $[t, t+1]$, *but leaving the equilibrium outcome in future periods* (where firm m is matched to its equilibrium partner CEO m) *unaltered.* Let $w_t[l]$ denote the equilibrium pay of CEO l over the period $[t, t+1]$. The equilibrium CEO pay profile satisfies the following IC condition associated with PAM,

$$\begin{aligned}
m &= \arg\max_{l\in[1,\overline{m}]} E_t\left[\sum_{s=t}^{\infty} \delta^{s-t}\Lambda_s(S[m], T[m])\frac{T[l]}{T[m]}\right] - w_t[l], \\
&= \arg\max_{l\in[1,\overline{m}]} E_t\left[\sum_{s=t}^{\infty} \delta^{s-t}\Lambda_s[m]\right]\frac{T[l]}{T[m]} - w_t[l] \\
&= \arg\max_{l\in[1,\overline{m}]} V_t[m]\frac{T[l]}{T[m]} - w_t[l].
\end{aligned} \tag{A26}$$

In the above maximization problem, CEO l affects the firm's earnings in *each future period* $[s, s+1]$ for $s \geq t$ by the proportion $T[l]$. Accordingly, the firm's value due to the off-equilibrium deviation over the current period (assuming that its equilibrium choices are maintained in future periods) is given by the expectation of the summation on the R.H.S. of the first equality above. The second and third equalities above follows from (A25). The first-order condition of the optimization problem is

$$w_t'[m] = V_t[m]\frac{T'[m]}{T[m]}. \tag{A27}$$

The above implies that, for a given CEO talent profile, $T[\cdot]$, the incremental pay of CEO m relative to her nearest (lower ranked) competitor—that is, the slope of the CEO pay profile—is proportional to the *firm's value*, $V_t[m]$.

Our framework

In our framework, a CEO affects her firm's earnings *period by period.* As in GL, we have PAM in each period so that a firm of rank $i \in [0,1]$ is matched to a CEO of rank $i \in [0,1]$ in each period. The firm's equilibrium gross profit in period $[t, t+1]$ is

$$\Pi_t[i] = \Pi_t(\tilde{x}[i], \tilde{y}[i]) = \tilde{c}_t \tilde{x}[i]\tilde{y}[i]. \tag{A28}$$

In the above, $\tilde{x}[\cdot] = x[\cdot]^{\sigma-1}$ is the firm size profile and $\tilde{y}[\cdot] = y[\cdot]^{\sigma-1}$ is the CEO factor profile as we discussed in Section 4.3.4. Note that, in contrast with GL's notational convention, the firm size and CEO factor increase with i. The firm profit in period 0 is, therefore,

$$\Pi_0[i] = \tilde{c}_0 \tilde{x}[i]\tilde{y}[i] \tag{A29}$$

Comparing (A24) and (A29), we note that firm profit in period 0 in both models is proportional to the product of a firm-specific term and a CEO-specific term. GL refer to the CEO-specific term in their profit function as "CEO talent." We use different notation for the firm profit (as well as firm value and CEO pay below) in our model relative to the industry-level GL model to clarify that the two models are different. As we discuss later, however, we take the models to the *same* industry-level data to infer the respective CEO factor profile and impact measure.

Firm i's equilibrium value (the expected present value of its future earnings inclusive of CEO pay) at any date t is

$$\mathcal{V}_t[i] = E_t\left[\sum_{s=t}^{\infty} \delta^{s-t}\Pi_s[i]\right] = \frac{\Pi_t[i]}{1-\varphi} = \frac{\tilde{c}_t \tilde{x}[i]\tilde{y}[i]}{1-\varphi}. \tag{A30}$$

As we showed in Sections 4.2 and 4.4, and as GL show in their paper, the equilibrium payoff variables and the CEO impact measure depend on the *ratios* of firm sizes and CEO talents across firms. Without loss of generality, therefore, we can set $T[0] = 1$ in GL's framework. Further, because the variation in CEO talent is very small relative to the variation in firm size, $T[m] \approx 1$. It then follows from (A23) and (A28) that the CEO-specific term in GL's firm profit expression is the "CEO talent," whereas it is the "CEO factor" in our framework. From (A25) and (A30), we see that the firm value expressions have similar multiplicative forms in the two frameworks as $T[m] \approx 1$. Consequently, the normalization implies the correspondence between firm profits/values in GL's and our frameworks that we alluded to (based on GL's static model) in Sections 4.3.4 and 4.4.2.

Let $u_t[j]$ denote the equilibrium pay of CEO j in period t. In our framework, firm i's incentive compatibility (IC) condition for the period $[t, t+1]$, is

$$i = \arg\max_{j\in[0,1]} \tilde{c}_t \tilde{x}[i]\tilde{y}[j] - u_t[j] + E_t\left[\sum_{s=t+1}^{\infty} (\delta^{s-t}\Pi_s(\tilde{x}[i], \tilde{y}[i]) - u_s[i])\right]. \tag{A31}$$

The first two terms on the R.H.S. above represents the firm's earnings net of CEO pay in the current period from its off-equilibrium choice of CEO j, while the last term on the R.H.S. represents the fact that the equilibrium outcome in future periods—that is, firm i is matched to CEO i—is unaltered. The first-order condition of the optimization problem in (A31) is

$$u'_t[i] = \tilde{c}_t \tilde{x}[i]\tilde{y}'[i] = \Pi_t[i]\frac{\tilde{y}'[i]}{\tilde{y}[i]}, \tag{A32}$$

where the second equality follows from (A28). In contrast with GL, (A32) implies that, in our model, the incremental pay of a CEO relative to her nearest competitor—the slope of the CEO pay profile—is proportional to the firm's earnings, $\Pi_t[i]$, *during the period.*

Comparison of impact measures

By (A27), the CEO talent profile in GL's model satisfies

$$\frac{T'[m]}{T[m]} = \frac{w_t'[m]}{V_t[m]}. \tag{A33}$$

As defined in the main body, the CEO impact estimate is determined by the best to median CEO factor (or, equivalently, CEO talent in GL) ratio among S&P 1500 firms in the industry. If n_* is the rank of the median S&P 1500 firm in the industry (recall that the S&P 1500 firms are the largest n firms among N firms operating in the industry), we obtain from (A33)

$$\text{Impact measure in GL's model} \approx \frac{T[1]}{T[n_*]} - 1 = \exp\left[\int_{n_*}^{1} \frac{w_t'[m]}{V_t[m]} dm\right] - 1.$$

To facilitate the comparison with the impact measure in our model, we redefine the impact measure in GL's model in terms of firm quantiles rather than firm ranks. Defining $i = \frac{N-m}{N-1}$, we can rewrite the above as

$$\text{Impact measure in GL's model} \approx \exp\left[\int_{i_*}^{1} \frac{w_t'[i]}{V_t[i]} di\right] - 1, \tag{A34}$$

where i_* is the quantile of the median S&P 1500 firm in the industry.

Similarly, by (A32), the CEO factor profile in our model satisfies

$$\frac{\tilde{y}'[i]}{\tilde{y}[i]} = \frac{u_t'[i]}{\Pi_t[i]} = \frac{u_t'[i]}{(1-\varphi)\mathcal{V}_t[i]}, \tag{A35}$$

where the second equality above follows from (A30). From (A35), we obtain

$$\text{Impact measure in our model} \approx \frac{\tilde{y}[1]}{\tilde{y}[i_*]} - 1 = \exp\left[\int_{i_*}^{1} \frac{u_t'[i]}{(1-\varphi)\mathcal{V}_t[i]} di\right] - 1. \tag{A36}$$

We infer the CEO factor profile and impact measure in each model (that is, the industry-level GL model and our model) using the *same industry-level CEO pay and firm size data.* It then follows that $w_t \approx u_t$ and $V_t \approx \mathcal{V}_t$ in (A33) and (A35). These relations are approximate because the industry-level GL analysis and our analysis employ different econometric approaches to take our respective models to the data. As we discussed in footnote 16, our econometric approach matches additional moments that provide a closer match to the data. Because the term $\frac{1}{1-\varphi} > 1$ in (A35), the inferred CEO factor profile in GL's model is flatter than the corresponding factor profile in our model.

Because $w_t' \ll V_t$ and $u_t' \ll \mathcal{V}_t$, it follows from (A34) and (A36) that

$$\text{Impact measure in GL's model} \approx \int_{i_*}^{1} \frac{w_t'[i]}{V_t[i]} di,$$

$$\text{Impact measure in our model} \approx \int_{i_*}^{1} \frac{u_t'[i]}{(1-\varphi)\mathcal{V}_t[i]} di.$$

As $w_t' \approx u_t'$ and $V_t \approx \mathcal{V}_t$, the above implies the relation (31) between the industry-level GL impact estimates and our estimates.

As we mentioned in Section 4.4.2, the preceding discussion implies that the industry-level GL estimates would approximately coincide with ours if we were to modify their model so that CEOs influence firms "period by period" as in our model. This modification corresponds to the "temporary impact" version of GL's model that they discuss briefly in their paper. In footnote 42 of their paper, GL report that replacing the median CEO with the best CEO in the "temporary impact" version of their *aggregate model* would increase gross earnings in each period by 0.284%, but firm value by 0.016%. This is because they assume that the median CEO is replaced by the best CEO *for only one period* in the counterfactual experiment, instead of *permanently through time* as in their main analysis, and our analysis. Because firm value is the expected present value of earnings, it would increase by 0.284% if the median CEO were permanently replaced by the best CEO in GL's aggregate model. The difference between our estimates and the estimate of 0.284% is due to the misspecification bias in GL's aggregate model from not incorporating industry segmentation.

If we were to implement GL's "temporary impact" model *at the industry level,* and measure CEO impact using the counterfactual experiment where the median CEO is permanently replaced by the best CEO, we would obtain impact estimates similar to our estimates. To faciliate a meaningful comparison across different models, we believe that it is important to use the same counterfactual experiment to measure CEO impact as we do in the various robustness analyses that we carry out in the paper. Further, note that the equilibrium outcome is "PAM through time" in both versions of GL's model, our model, and its various extensions. Because the equilibrium outcome is unaffected by the modeling of CEO influence, it makes sense that the counterfactual experiment should also not be dictated by the nature of CEO influence in the various models.

Appendix C. Extended models with moral hazard

In this appendix, we extend the basic model presented in Section 2 to incorporate moral hazard.

C.1. Basic moral hazard model

We alter the basic model to allow for firms to experience idiosyncratic productivity shocks in each period after matching occurs. The distributions of the shocks depend on the CEOs' costly effort choices. A firm's realized productivity in each period is, therefore, affected by firm quality, CEO talent and effort. Suppose that a firm with quality x matches with a CEO with ability y in period t. Its match quality is then given by $\eta = xy$. The firm offers the CEO an incentive contract to influence her effort choice. The CEO then exerts effort, $e_{\eta,t} \in [0,1]$, that stochastically affects the firm's productivity. Specifically, the firm's productivity (defined as in the basic model) is additionally affected by a multiplicative idiosyncratic shock ϕ_t that takes two possible values: $h \geq 1$ and $l < 1$ with probabilities $e_{\eta,t}$ and $1 - e_{\eta,t}$, respectively. The market size R_t scales with the demand shock G_t, and we can show that the firm's revenues and gross earnings scale with the same aggregate shock G_t and the firm-level idiosyncratic shock ϕ_t.

Without loss of generality, we can assume that the CEO's contractual compensation in period t is contingent on the realized idiosyncratic productivity shock, that is, $c_{\eta,t}(\phi_t)$. The CEO's expected utility is given by

$$E_t^e\left[c_{\eta,t}(\phi_t)\right] - \kappa_t(e_{\eta,t}) = e_{\eta,t}c_{\eta,t}(h) + (1-e_{\eta,t})c_{\eta,t}(l) - \kappa_t(e_{\eta,t}), \tag{A37}$$

where $E_t^e[\cdot]$ denotes the expectation with respect to the idiosyncratic shock distribution induced by her effort choice $e_{\eta,t}$. In the above, $\kappa_t(\cdot)$ is an effort cost function that is strictly increasing, convex, and thrice continuously differentiable, with $\kappa_t(0) = 0$ and $\kappa_t'''(\cdot) \geq 0$. The effort cost function scales with the aggregate shock G_t that affects the market size—that is, $\kappa_t(\cdot) = G_t\kappa(\cdot)$—representing the notion that, *ceteris paribus*, an increase in the scale of the firm determined by the shock G_t increases the effort cost. We choose the following form, $\kappa_t(e) = G_t\kappa e^2/(1-e)$, that satisfies the Inada conditions at 0 and 1 ($\kappa_t'(0) = 0$; $\kappa_t'(1) = \infty$) to ensure an interior solution for the CEO's effort.

Let $\Upsilon_{\eta,t}$ denote the CEO's *guaranteed* wage in period t that is endogenously determined in the equilibrium of the CEO-firm matching market. The firm offers the CEO an incentive contract $(c_{\eta,t}(\cdot),\ e_{\eta,t})$ to maximize its expected net profit (gross profit net of the CEO's compensation payment). The incentive compatibility (IC) and individual rationality (IR) constraints are

$$e_{\eta,t} = \arg\max_{\tilde{e}}\ E_t^{\tilde{e}}\left[c_{\eta,t}(\phi_t)\right] - \kappa_t(\tilde{e}); \tag{A38}$$

$$c_{\eta,t}(h) \geq \Upsilon_{\eta,t};\ c_{\eta,t}(l) \geq \Upsilon_{\eta,t}. \tag{A39}$$

The constraints, (A39), which imply the downward rigidity of CEO pay—that is, the CEO receives at least the guaranteed wage, $\Upsilon_{\eta,t}$—are akin to "limited liability" constraints. These constraints ensure that the CEO receives nonzero incentive compensation even with linear risk preferences.

Proposition A1 (Optimal incentive contracts)
The CEO of a firm whose match quality is η exerts time-invariant effort, $e_{\eta,t} = e_\eta$, that solves

$$\frac{R\left((P_0/w_0)\rho\eta\right)^{\sigma-1}}{\sigma}\left(h^{\sigma-1} - l^{\sigma-1}\right) = \kappa'\left(e_\eta\right) + e_\eta\kappa''\left(e_\eta\right). \tag{A40}$$

The CEO's compensation payments in the low and high productivity states are

$$c_{\eta,t}(l) = \Upsilon_{\eta,t};\quad c_{\eta,t}(h) = \Upsilon_{\eta,t} + \kappa_t'\left(e_\eta\right). \tag{A41}$$

The CEO's pay-performance sensitivity (PPS) is also time-invariant and given by

$$PPS_{\eta,t} = \frac{c_{\eta,t}(h) - c_{\eta,t}(l)}{\pi_{\eta,t}(h) - \pi_{\eta,t}(l)} = \frac{\kappa'(e_\eta)}{e_\eta\kappa''(e_\eta)}. \tag{A42}$$

We denote the CEO's (ex ante) incentive pay by $z_{\eta,t} \equiv e_\eta\left[c_{\eta,t}(h) - c_{\eta,t}(l)\right] = e_\eta\kappa_t'(e_\eta)$ so that her expected total compensation is given by $u_{\eta,t} = \Upsilon_{\eta,t} + z_{\eta,t}$. The equilibrium in the CEO-firm matching market rationally anticipates the optimal incentive contracts for CEOs after matching occurs.

As in the basic model, the matching problem under moral hazard is one of transferable utility as the firm's expected net profit $\Psi_{\eta,t}(\Upsilon_{\eta,t})$ is separable in the CEO's guaranteed wage $\Upsilon_{\eta,t}$. In this scenario, a sufficient condition for the matching equilibrium to feature PAM is that the firm's expected net profit $\Psi_{\eta,t}(\Upsilon_t)$ be supermodular with respect to firm quality x and CEO ability y, that is,

$$\frac{\partial^2\Psi_{\eta(x,y),t}(\Upsilon_{\eta,t})}{\partial x\partial y} > 0. \tag{A43}$$

If $\sigma > 2$ (as we assumed in the main body), the above condition holds from the properties of the effort cost function $\kappa_t(e)$. As in the proof of Proposition 1, we now determine the equilibrium payoff functions $\Upsilon_t[i]$ and $\Psi_t[i]$ that satify the firm's and CEO's participation constraints and incentive compatibility constraints. Suppose $m \in [0,1]$ is firm i's choice of its CEO for the current period (whereas it is matched with its equilibrium partner, CEO i, for future periods) , and $\Upsilon[m]$ is the wage that CEO m is guaranteed to receive. The firm-side incentive constraint, which considers an off-equilibrium deviation that only affects the firm's earnings in the current period, and not in future periods, is given by

$$\begin{aligned}\Psi_t[i] \quad = \quad \max_m \; e[m]\left[\frac{R_t\left((P_0/w_0)\rho h x[i]y[m]\right)^{\sigma-1}}{\sigma} - \kappa_t'\left(e[m]\right)\right] \\ +(1-e[m])\left[\frac{R_t\left((P_0/w_0)\rho l x[i]y[m]\right)^{\sigma-1}}{\sigma}\right] - \Upsilon_t[m].\end{aligned} \tag{A44}$$

The global incentive compatibility constraint above can be replaced by its local incentive constraint obtained by differentiating (A44) with respect to m and setting m to i, which yields the slope of the equilibrium guaranteed wage of CEO i as follows:

$$\Upsilon_t'[i] = R_t(P_0/w_0)^{\sigma-1}\rho^\sigma x[i]^{\sigma-1}y[i]^{\sigma-2}y'[i]\left(e[i]h^{\sigma-1} + (1-e[i])l^{\sigma-1}\right). \tag{A45}$$

Integrating the above differential equation, we obtain the equilibrium equation for $\Upsilon_t[i]$ as shown in the proposition below.

Proposition A2 (Matching equilibrium under moral hazard)
If $\sigma > 2$, there is positive assortative matching (PAM) between CEOs and firms in each period t. The equilibrium guaranteed wage of CEO i that is matched to firm i, and its equilibrium market value are given by

$$\Upsilon_t[i] = \widetilde{u}_t + \int_0^i R_t(P_0/w_0)^{\sigma-1}\rho^\sigma x[j]^{\sigma-1}y[j]^{\sigma-2}y'[j]\left(e[j]h^{\sigma-1} + (1-e[j])l^{\sigma-1}\right)dj, \tag{A46}$$

$$\mathcal{V}_t[i] = \frac{1}{1-\beta\delta}\left(\frac{R_t\left((P_0/w_0)\rho x[i]y[i]\right)^{\sigma-1}}{\sigma}\left(e[i]h^{\sigma-1} + (1-e[i])l^{\sigma-1}\right) - e[i]\kappa_t'(e[i]) - \Upsilon_t[i]\right), \tag{A47}$$

where $e[i]$ is the optimal contractual effort exerted by CEO i.

All firms continue to match with a CEO of the same ability and provide the same incentive contract in each period because their qualities and, therefore, their ranks remain the same over time. As in the basic model, the free entry condition uniquely determines the initial aggregate price index, P_0^*.

By (A46), the equilibrium guaranteed wage increases with firm rank i. CEO effort also increases with firm rank i by (A40) and the properties of the CEO effort function, $\kappa_t(e)$. It then follows from (A41) that the expected incentive compensation, $e[i]\kappa_t'(e[i])$, and, therefore, the expected total compensation also increase with firm rank i. By (A42), CEO PPS decreases with firm rank i, provided that

$$\frac{e\kappa''(e)}{\kappa'(e)} \text{ is monotonically increasing in effort } e, \tag{A48}$$

which holds if the function $\kappa(e)$ has a power or exponential form that we assume in this extended model. We can also show that the expected net profit and, therefore, firm value increase with firm rank i. The following proposition summarizes the properties of firm value and CEO pay.

Proposition A3 (Firm rank, firm value, and CEO compensation)
CEO effort and expected total compensation, and firm market value in any period t increase monotonically with firm rank i. PPS declines monotonically with firm rank i.

The additional parameters relative to the baseline model include the two possible values (h, l) of firms' idiosyncratic productivity shocks and the coefficient parameter (κ) in the CEO effort cost function. Because the equilibrium variables only depend upon the spread between high and low productivities , $h^{\sigma-1} - l^{\sigma-1}$, we set $h = 1$ with no loss of generality. To identify these parameters, we include additional moments pertaining to the decreasing profile of CEO PPS. Specifically, we choose the ratios of the mean values of PPS in firm quintiles to the mean value of PPS in the bottom quintile, and the ratio of the intra-industry PPS dispersion to the firm value dispersion.

The additional parameters to be estimated, (κ, l), both increase the convexity of the profile of PPS, but decrease the ratio of the intra-industry PPS dispersion to the firm value dispersion. The additional moments of PPS thus help to identify these two parameters from the other parameters. Further, among other moments, the four quintile ratios of firm value—the ratios of average firm values in successive quintiles—help to identify these two parameters separately because the convexity of the firm size profile increases with κ, but decreases with l. The distinction mainly comes from the differential effects of the two parameters on the profile of the expected firm productivity, $e[i]h^{\sigma-1} + (1 - e[i])l^{\sigma-1}$, that has a multiplicative effect on firm size as shown in (A47). The expected firm productivity becomes more convex in firm rank as κ increases because the convexity of the CEO effort profile $e[i]$ increases with κ. In contrast, the expected productivity bcomes close to the constant $h^{\sigma-1}$ and, therefore, less convex as l increases.

C.2. Extended moral hazard model with CEO risk aversion

In this section, we extend the basic model in Section 2 to incorporate moral hazard and CEO risk aversion. As in the above model, a firm experiences an ex post (after matching) idiosyncratic shock that, together with its CEO's effort, affects the realization of its profit. We adopt a "CARA-normal" specification where the shock is normally distributed and the CEO has constant absolute risk aversion (CARA) preferences.

We consider a firm whose match quality is $\eta = xy$. In each period, the firm's profit after matching is affected by the manager's effort $e_{\eta,t}$ and the firm-level idiosyncratic shock $\phi_{\eta,t}$ as follows:

$$\widetilde{\Pi}_{\eta,t}(e_{\eta,t}, \phi_{\eta,t}) = \Pi_{\eta,t}[1 + e_{\eta,t}] + \left(\frac{\Pi_{\eta,t}}{G_t}\right)\sqrt{G_t}\phi_{\eta,t}, \tag{A49}$$

where $\Pi_{\eta,t} = \frac{R_t((P_0/w_0)\rho\eta)^{\sigma-1}}{\sigma}$ and $\phi_{\eta,t}$ is normally distributed with mean 0 and variance s^2.

The CEO's risk preference is represented by a negative exponential utility function with γ as the coefficient of absolute risk aversion that is assumed to be the same for all CEOs in the sector. The effort cost function, $\kappa_{\eta,t}(e)$, is a strictly increasing and convex function of the effort level e. This also scales with the firm's size captured by its gross profit $\Pi_{\eta,t}$, representing the notion that, ceteris paribus, an increase in the scale of the firm increases the effort cost. Specifically, we consider $\kappa_{\eta,t}(e) = \frac{1}{2}\kappa e^2\Pi_{\eta,t}$. We can, without loss of generality, restrict consideration to contracts in which the CEO's compensation has the following affine form,

$$c_{\eta,t} = a_{\eta,t} + b_{\eta,t}\widetilde{\Pi}_{\eta,t}. \tag{A50}$$

Given the above incentive contract characterized by $(a_{\eta,t}, b_{\eta,t})$, the CEO's problem is to find an effort level such that her expected utility is maximized:

$$\max_{e}\ E_t^{\phi}\left[-\exp\left\{-\gamma\left(c_{\eta,t}-\kappa_{\eta,t}(e)\right)\right\}\right] = -\exp\left[-\gamma CE_{\eta,t}(e)\right]. \tag{A51}$$

where $CE_{\eta,t}$ is the CEO's certainty equivalent payoff given by

$$\begin{aligned} CE_{\eta,t}(e) &= a_{\eta,t}+b_{\eta,t}E_t^{\phi}\left[\widetilde{\Pi}_{\eta,t}\right]-\kappa_{\eta,t}(e)-\frac{1}{2}\gamma b_{\eta,t}^2 V_t^{\phi}\left[\widetilde{\Pi}_{\eta,t}\right] \\ &= a_{\eta,t}+b_{\eta,t}\Pi_{\eta,t}\left(1+e\right)-\kappa_{\eta,t}(e)-\frac{1}{2}\gamma b_{\eta,t}^2\left(\Pi_{\eta,t}^2/G_t\right)s^2. \end{aligned} \tag{A52}$$

From the above, the CEO's optimal effort choice, given her pay-performance sensitivity (PPS), $b_{\eta,t}$, specified in the incentive contract, solves the first-order condition $b_{\eta,t}\Pi_{\eta,t}-\kappa_{\eta,t}'(e)=0$, so that $e(b_{\eta,t})=b_{\eta,t}/\kappa$. The CEO's individual rationality (IR) constraint is that her expected utility is at least as great as her utility if she received the guaranteed wage $\Upsilon_{\eta,t}$ that is endogenously determined as an outcome of the matching process:

$$-\exp\left[-\gamma CE_{\eta,t}(e)\right]\geq-\exp\left[-\gamma\Upsilon_{\eta,t}\right].$$

From the above, we obtain the contractual parameter $a_{\eta,t}$ as a function of the PPS, $b_{\eta,t}$:

$$a_{\eta,t}=\Upsilon_{\eta,t}-b_{\eta,t}\Pi_{\eta,t}(1+e(b_{\eta,t}))+\kappa_{\eta,t}(e(b_{\eta,t}))+\frac{1}{2}\gamma b_{\eta,t}^2\left(\Pi_{\eta,t}^2/G_t\right)s^2.$$

The firm's optimal contracting problem is then to choose $b_{\eta,t}$ to maximize its expected net profit, that is, its expected gross profit less the CEO's compensation payment:

$$\begin{aligned} & b_{\eta,t}=\arg\max_{b}\ \Psi_{\eta,t}=E_t^{\phi}\left[\widetilde{\Pi}_{\eta,t}-c_{\eta,t}\right]=E_t^{\phi}\left[(1-b)\widetilde{\Pi}_{\eta,t}-a_{\eta,t}\right] \\ \Rightarrow\ & b_{\eta,t}=\arg\max_{b}\ \Pi_{\eta,t}(1+e(b))-\kappa_{\eta,t}(e(b))-\frac{1}{2}\gamma b^2\left(\Pi_{\eta,t}^2/G_t\right)s^2-\Upsilon_{\eta,t}. \end{aligned}$$

By the first-order condition, the CEO's optimal incentive compensationin period t is characterized by the following PPS and cash compensation parameters,

$$b_{\eta,t} = b_\eta=\frac{1}{1+\kappa\gamma s^2(\Pi_{\eta,t}/G_t)}, \tag{A53}$$

$$a_{\eta,t} = \Upsilon_{\eta,t}-b_{\eta,t}\Pi_{\eta,t}(1+e(b_{\eta,t}))+\overbrace{\kappa_{\eta,t}(e(b_{\eta,t}))}^{\text{effort cost}}+\overbrace{\frac{1}{2}\gamma b_{\eta,t}^2\left(\Pi_{\eta,t}^2/G_t\right)s^2}^{\text{risk premium}}, \tag{A54}$$

from which we see that the CEO's PPS and effort are time-invariant. The CEO's expected total compensation is then given by $u_{\eta,t}=a_{\eta,t}+b_{\eta,t}E_t^{\phi}[\widetilde{\Pi}_{\eta,t}]=\Upsilon_{\eta,t}+z_{\eta,t}$, where the second term is given by $z_{\eta,t}\equiv\frac{1}{2\kappa}b_{\eta,t}\Pi_{\eta,t}$, which represents her expected (ex ante) incentive pay that includes both the effort cost and risk premium $(\zeta_{\eta,t})$. From the optimal contract above, the firm's maximum expected net profit when the CEO receives a guaranteed wage of $\Upsilon_{\eta,t}$ is given by

$$\Psi_{\eta,t}(\Upsilon_{\eta,t})=E_t^{\phi}\left[\widetilde{\Pi}_{\eta,t}-c_{\eta,t}\right]=\Pi_{\eta,t}(1+e(b_\eta))-\kappa_{\eta,t}(e(b_\eta))-\frac{1}{2}\gamma b_\eta^2\left(\Pi_{\eta,t}^2/G_t\right)s^2-\Upsilon_{\eta,t}. \tag{A55}$$

We now derive the matching equilibrium in the CEO-firm matching market, which endogenously determines the CEO's reservation payoff $\Upsilon_{\eta,t}$. The supermodularity condition for the matching equilibrium to be positive assortative holds if $\kappa \geq 1/3$, which we henceforth assume and later verify that it holds in the data. We can then restrict attention to matches where firm i is matched with CEO i. As in the proof of Proposition 1, we employ the equilibrium conditions for stable matching to determine the equilibrium payoff functions $\Upsilon_t[i]$ and $\Psi_t[i]$. In particular, we obtain

$$\Upsilon_t'[i] = R_t(P_0/w_0)^{\sigma-1}\rho^{\sigma}x[i]^{\sigma-1}y[i]^{\sigma-2}y'[i]\left(1+\frac{1}{\kappa}b[i]^2\right). \tag{A56}$$

where $b[i] = b(x[i], y[i]) = \frac{1}{1+\kappa\gamma s^2\Pi_0[i]}$ with $\Pi_t[i] = \frac{R_t((P_0/w_0)\rho x[i]y[i])^{\sigma-1}}{\sigma}$. Integrating the above differential equation, we can obtain the equilibrium guaranteed wage of CEO i in period t.

All firms continue to match with a CEO of the same ability and provide the same incentive contract in each period because their qualities and, therefore, their ranks remain the same over time. Consequently, firm i's market value is

$$\mathcal{V}_t[i] \quad = \quad \frac{1}{1-\beta\delta}\Psi_t[i] = \frac{1}{1-\beta\delta}\left(\Pi_t[i]\left(1+\frac{b[i]}{2\kappa}\right) - \Upsilon_t[i]\right). \tag{A57}$$

We can show that CEO PPS declines monotonically with firm rank i, but expected CEO pay and firm value increase as long as the elasticity of the firm quality profile is greater than that of the CEO talent profile ($x'[i]/x[i] > y'[i]/y[i]$) that we verify in the data.

Appendix D. Long-term effects of CEOs

In this appendix, we extend the basic model in the main body by allowing CEOs to have long-term effects on firms' earnings. By (7), the effect of a CEO's talent y on the firm's earnings for the current period are determined by the CEO factor, $y^{\sigma-1}$. Consider an infinitely lived firm that has a history of CEOs whose talents are summarized by $(y_t, y_{t-1}, y_{t-2}, \ldots)$. As in the basic model, the firm's earnings are proportional to the product of a firm-specific term and a CEO-specific term. Following Terviö (2008), the CEO-specific term at date t, $\widehat{y}_t$, is a weighted average of the past and current CEOs' factors,

$$\widehat{y}_t = Y(y_t, y_{t-1}, y_{t-2}, \ldots) = \sum_{\tau=0}^{\infty}\varsigma_\tau y_{t-\tau}^{\sigma-1}. \tag{A58}$$

A CEO's influence fades at a constant rate $\lambda > 0$, that is, $\varsigma_{\tau+1} = \frac{\varsigma_\tau}{1+\lambda}$. Using the fact that $Y(y, y, y, \ldots) = y^{\sigma-1}$, we can easily derive the weights as $\varsigma_\tau = \frac{\lambda}{(1+\lambda)^{\tau+1}}$.

From the above, we note two key differences from GL's framework described in Appendix B.4. First, the CEO factor in each period affects the firm's earnings in future periods in an *additive*, rather than *multiplicative*, manner. Second, the effect of the CEO factor on future earnings declines over time.

As in the proof of Proposition 1, the *supermodularity* condition immediately implies PAM in each period. That is, in equilibrium, firm i with quality $x[i]$ is matched to CEO i with talent $y[i]$ in every period. The firm's gross profit in period t is thus given by (7) with $x = x[i]$ and $y = y[i]$.

We now turn to the derivation of the equilibrium payoffs. By (9), (13), and (14), the firm's market value (the expected present value of the firm's future net profits) is given by

$$\mathcal{V}_t(x[i], y[i]) \quad = \quad E_t\left[\sum_{s=t}^{\infty}\delta^{s-t}(\Pi_s(x[i], y[i]) - u_s)\right] = \sum_{s=t}^{\infty}(\beta\delta)^{s-t}\left(\Pi_t(x[i], y[i]) - u_t[i]\right)$$

$$= \frac{1}{1-\beta\delta}\left[\frac{R_t((P_0/w_0)\rho)^{\sigma-1}x[i]^{\sigma-1}y[i]^{\sigma-1}}{\sigma} - u_t[i]\right]. \tag{A59}$$

Suppose that firm i hires CEO $m \in [0,1]$ only for the current period t. The CEO's compensation payment is set to $u_t[m]$. For other periods, the firm is matched with its equilibrium partner, that is, CEO i. By (A58) and (A59), the firm's incentive compatibility constraint for its CEO choice variable m is as follows:

$$\begin{aligned}
&\mathcal{V}_t(x[i], y[i]) \\
= \;& \max_m \sum_{s=t}^{\infty} (\beta\delta)^{s-t}\left[\frac{R_t((P_0/w_0)\rho)^{\sigma-1}x[i]^{\sigma-1}\left(\varsigma_{s-t}y[m]^{\sigma-1} + (1-\varsigma_{s-t})y[i]^{\sigma-1}\right)}{\sigma} - u_t[i]\right] \\
&+(u_t[i] - u_t[m]) \\
= \;& \max_m \frac{R_t((P_0/w_0)\rho)^{\sigma-1}}{\sigma}\left[\frac{\lambda}{(\lambda+1-\beta\delta)}x[i]^{\sigma-1}(y[m]^{\sigma-1} - y[i]^{\sigma-1}) + \frac{x[i]^{\sigma-1}y[i]^{\sigma-1}}{(1-\beta\delta)}\right] - \frac{u_t[i]}{(1-\beta\delta)} \\
&+(u_t[i] - u_t[m]).
\end{aligned} \tag{A60}$$

In the above, note that the impact weights of CEO m decrease over time and that the last term $(u_t[i] - u_t[m])$ represents the pay difference between CEO i and CEO m in the current period.

From (A60), we note that, as λ increases, the (off-equilibrium) replacement of CEO i with CEO m has a greater effect on firm value. As $\lambda \to \infty$, we approach our basic model. In other words, for $\lambda < \infty$, the CEO factor in each period affects current period earnings by a smaller proportion relative to our basic model. This is because earnings in each period are affected not just by the current period's CEO factor, but also by the CEO factors in previous periods. Consequently, for a given dispersion in CEO factors across firms, the dispersion in marginal CEO contributions *increases* with λ.

As in the proof of Proposition 1, we obtain the slope of the equilibrium CEO pay profile by differentiating (A60) with respect to m and setting m to i as follows:

$$u_t'[i] = R_t(P_0/w_0)^{\sigma-1}\rho^{\sigma}\left(\frac{\lambda}{(\lambda+1-\beta\delta)}x[i]^{\sigma-1}y[i]^{\sigma-2}y'[i]\right). \tag{A61}$$

As noted above, the dispersion in marginal CEO contributions for a given dispersion in CEO factors increases with λ. Consequently, we would expect the CEO pay profile to become steeper as λ increases. From (A61), we observe that, for a given slope of the CEO talent profile, $y'[\cdot]$, the slope of the CEO pay profile, indeed, increases with λ.

From (A59) and (A61), the equilibrium payoff profiles in the extended model with $\lambda > 0$ are

$$u_t[i] = \widetilde{u}_t + \int_0^i R_t(P_0^*/w_0)^{\sigma-1}\rho^{\sigma}\frac{\lambda}{(\lambda+1-\beta\delta)}x[j]^{\sigma-1}y[j]^{\sigma-2}y'[j]dj, \tag{A62}$$

$$\mathcal{V}_t[i] = \frac{1}{1-\beta\delta}\left[\frac{R_t((P_0^*/w_0)\rho)^{\sigma-1}x[i]^{\sigma-1}y[i]^{\sigma-1}}{\sigma} - u_t[i]\right], \tag{A63}$$

where we set the price index to its equilibrium value P_0^*. Note that the above equations are the same as those in the basic model in the limit as $\lambda \to \infty$, that is, when CEOs have an effect only on contemporaneous earnings.

We set the additional parameter λ to 0.1 and 0.5 as in Terviö (2008), and estimate the other parameters using the above equilibrium payoff profiles along the same lines as in the main analysis of the basic model. We then repeat our quantitative analysis of CEO impact to examine the robustness of our main implications.

Appendix E. Transferability of CEO ability within and across industries

E.1. Imperfect intra-industry transferability of CEO ability

In this subsection, we extend the basic model to allow for imperfect transferability of CEO ability across firms within the industry. The surplus generated by a CEO-firm match is the same as in the basic model and satisfies the supermodularity property, (A1), which implies PAM in equilibrium. As we now describe, however, imperfect transferability of CEO ability affects the division of the surplus between the firm and CEO (that is, firm value and CEO pay).

Consider firm i that is matched to CEO i in period t. Suppose that the firm makes the (off-equilibrium) choice of the CEO with rank $j \neq i$. The ability of the CEO with rank j is not fully transferred to the new firm (firm i). It is reasonable to assume that the proportion of the new CEO's ability that is transferable to the firm declines with the difference between the current and new CEOs' rankings. Specifically, the surplus generated by the new CEO-firm match is $\Pi_t(x[i], e^{-\tau|i-j|}y[j])$, where $\Pi_t(x[i], y[i]) = \left[\frac{R_t((P_0/w_0)\rho x[i]y[i])^{\sigma-1}}{\sigma}\right]$ as in the basic model, and the parameter $\tau > 0$ represents the degree of imperfect transferability of CEO ability. We recover the basic model as $\tau \to 0$. As in the proof of Proposition 1, it is enough to consider the following local downward incentive constraint:

$$u_t'[i] = \lim_{\varepsilon \to 0} \frac{\Pi_t(x[i], y[i]) - \Pi_t(x[i], e^{-\tau\varepsilon}y[i-\varepsilon])}{\varepsilon} = (\partial \Pi_t/\partial y)y'[i] + \tau(\sigma-1)\Pi_t(x[i], y[i]). \quad \text{(A64)}$$

Integrating the above, we obtain the equilibrium profiles of CEO pay and firm value as below:

$$u_t[i] = \widetilde{u}_t + \int_0^i R_t(P_0/w_0)^{\sigma-1}\rho^\sigma \left(x[j]^{\sigma-1}y[j]^{\sigma-2}y'[j] + \tau x[j]^{\sigma-1}y[j]^{\sigma-1}\right) dj, \quad \text{(A65)}$$

$$\mathcal{V}_t[i] = \frac{1}{1-\beta\delta}\left[\frac{R_t((P_0/w_0)\rho x[i]y[i])^{\sigma-1}}{\sigma} - u_t[i].\right]. \quad \text{(A66)}$$

We estimate the above model along the lines of the estimation of the basic model, but with the altered expressions for CEO pay and firm value that now depend on the parameter τ (the degree of imperfect transferability of ability). We discuss the identification of the additional parameter τ as the identification of the other parameters proceeds along the lines of the discussion in Section 4.2.1. Table H14 in Appendix H shows the signs of the sensitivities of the moments with respect to the parameters. By (A65), the slope of the CEO pay profile increases with τ so that the CEO pay quintile ratios (moments M_4-M_7) increase. By differentiating (A66) with respect to i and combining it with $u_t'[i]$, the slope of the firm value profile is given by

$$\mathcal{V}_t'[i] = \frac{1}{1-\beta\delta}\left[R_t(P_0/w_0)^{\sigma-1}\rho^\sigma \left(x[i]^{\sigma-2}y[i]^{\sigma-1}x'[i] - \tau x[i]^{\sigma-1}y[i]^{\sigma-1}\right)\right]. \quad \text{(A67)}$$

There are two effects of τ on the slope of the firm value profile. For a given price index, it decreases the slope of the firm value profile. However, due to the free entry condition, the aggregate price index also increases with τ that has the effect of increasing the slope of the firm value profile. The signs of the sensitivities of the firm value quintile ratios (moments M_8-M_{11}) in the table show that the second effect dominates. In contrast with the quintile ratios, which also increase with other parameters such as σ and α, the ratio of the CEO pay dispersion to the firm value dispersion increases *only* with τ, which helps to identify the imperfect transferability parameter separately from the other parameters. As in the estimation of the basic model, we also check that the Jacobian sensitivity matrix has full rank at the estimated parameter values and is well-conditioned so the necessary and sufficient conditions for local identification and numerical stability are satisfied.

E.2. Imperfect inter-industry transferability of CEO ability

In this subsection, we extend the model to incorporate transferability of CEO talent across industries. We consider a CEO working in industry sector k. The CEO's ability y ranked within the industry is the sum of the general component y_1 that is perfectly transferable across all industries and industry-specific component y_2 that is perfectly transferable only within the particular industry k :

$$y = \overbrace{y_1}^{\text{general ability}} + \overbrace{y_2}^{\text{industry-specific ability}}, \tag{A68}$$

where the two components of CEO ability are drawn from their respective distributions with probability density functions (p.d.f.) $f_1(y_1)$ and $f_2(y_2)$. For simplicity, we assume that the general and industry-specific components are independent (it is difficult, if not impossible, to identify a correlation between the two talent components given the data for our analysis) and follow extreme value distributions

$$f_j(y_j) = \frac{B_j}{\nu_j}(\overline{y}_j - y_j)^{\frac{1}{\nu_j}-1}, \tag{A69}$$

for $\underline{y}_j \leq y_j \leq \overline{y}_j$ and $j = 1, 2$. Note that the cumulative distribution function (c.d.f.) of y_j is

$$F_j(y_j) = 1 - B_j(\overline{y}_j - y_j)^{\frac{1}{\nu_j}}, \tag{A70}$$

and the parameters specifying the distribution need to satisfy

$$F_j(\underline{y}_j) = 0 \;\Rightarrow\; B_j = \left[\frac{1}{\overline{y}_j - \underline{y}_j}\right]^{\frac{1}{\nu_j}}. \tag{A71}$$

The CEO ability, y, is then drawn from a distribution with p.d.f. $f_Y(y)$ that is the convolution of $f_1(y_1)$ and $f_2(y_2)$:

$$f_Y(y) = \int_{\underline{y}_2}^{\overline{y}_2} f_1(y - y_2) f_2(y_2) dy_2. \tag{A72}$$

We further note that the integrand is zero unless $\underline{y}_1 \leq y - y_2 \leq \overline{y}_1$ (that is, $y - \overline{y}_1 \leq y_2 \leq y - \underline{y}_1$). Hence, we have

$$f_Y(y) = \begin{cases} \int_{\underline{y}_2}^{y-\underline{y}_1} f_1(y-y_2) f_2(y_2) dy_2 & \text{if } y < r_1 \text{ and } y < r_2, \\ \int_{\underline{y}_2}^{\overline{y}_2} f_1(y-y_2) f_2(y_2) dy_2 & \text{if } y < r_1 \text{ and } y \geq r_2, \\ \int_{y-\overline{y}_1}^{y-\underline{y}_1} f_1(y-y_2) f_2(y_2) dy_2 & \text{if } y \geq r_1 \text{ and } y < r_2, \\ \int_{y-\overline{y}_1}^{\overline{y}_2} f_1(y-y_2) f_2(y_2) dy_2 & \text{if } y \geq r_1 \text{ and } y \geq r_2, \end{cases} \tag{A73}$$

where $r_1 = \overline{y}_1 + \underline{y}_2$ and $r_2 = \underline{y}_1 + \overline{y}_2$. The c.d.f. of CEO ability is then given by

$$F_Y(y) = \int_{\underline{y}}^{y} f_Y(\tilde{y})d\tilde{y}, \tag{A74}$$

where $\underline{y} = \underline{y}_1 + \underline{y}_2$.

Suppose that there are K industries. The parameter set we estimate is $\Theta \equiv \{\theta_g, (\theta_k;\, k = 1, ..., K)\}$, where θ_g is the set of parameters determining the distribution of the general talent component, and θ_k is the set of industry-specific parameters including those determining the distribution of the industry-specific talent component for industry k. Because the parameters determining the general talent component apply across industries, while the industry-specific parameters correspond to each industry, our strategy is to estimate these parameters by *jointly matching* the moments that we employed in our estimation of the basic model across industries. It is convenient to proceed in two stages as follows.

For a given set of parameters of the general talent component distribution, $\tilde{\theta}_g$, we estimate the industry-specific parameter set $\theta_k\left(\tilde{\theta}_g\right)$ for industry $k \in \{1, ..., K\}$ by minimizing the weighted distance between the model-predicted and actual moments for industry k, that is, we solve

$$\theta_k(\tilde{\theta}_g) = \arg\min_{\tilde{\theta}_k}\ \Delta_k^2(\tilde{\theta}_k; \tilde{\theta}_g) \equiv g_k(\tilde{\theta}_k; \tilde{\theta}_g)' W_k g_k(\tilde{\theta}_k; \tilde{\theta}_g), \tag{A75}$$

where $g_k(\tilde{\theta}_k; \tilde{\theta}_g) = \left(\widehat{M}_k - \widehat{m}(\tilde{\theta}_k; \tilde{\theta}_g)\right)$. $\widehat{M}_k$ is the time-series average of the vector of data moments for industry k, $\widehat{m}(\tilde{\theta}_k; \tilde{\theta}_g)$ is the vector of the model-predicted moments given the general talent and industry-specific parameter vectors, and W_k is the inverse of the variance-covariance matrix of the data moments for industry k that is adjusted for autocorrelation using the Bartlett weights. In (A75), we explicitly indicate the dependence of the estimated industry-specific parameter set on the given set of general talent parameters for clarity. We compute the model-predicted moments, $\widehat{m}(\tilde{\theta}_k; \tilde{\theta}_g)$, for industry k using the procedure outlined in Section 4.2.2.

In the second stage, we solve the following optimization program for θ_g:

$$\theta_g = \arg\min_{\tilde{\theta}_g}\ \Delta(\tilde{\theta}_g)' \Delta(\tilde{\theta}_g) \tag{A76}$$

where $\Delta(\tilde{\theta}_g)$ is a vector whose k^{th} element is the square root of the minimized objective function in (A75), that is, $\Delta_k(\tilde{\theta}_g) = \Delta_k(\theta_k(\tilde{\theta}_g); \tilde{\theta}_g)$.

Our estimation strategy described above is, in fact, equivalent to solving the following optimization program:

$$\Theta = \arg\min_{\tilde{\Theta}}\ \mathbf{g}(\tilde{\Theta})' \mathbf{W} \mathbf{g}(\tilde{\Theta}), \tag{A77}$$

where $\mathbf{g}(\boldsymbol{\Theta}) = [g_1(\theta_1; \theta_g);\, \ldots\, ; g_K(\theta_K; \theta_g)]$ and $\mathbf{W}$ is a block diagonal matrix with diagonal submatrices W_k. The variance-covariance matrix of the estimated coefficients is

$$\text{var}(\Theta) = \frac{1}{T}(\Omega' \mathbf{W} \Omega)^{-1} \Omega' \mathbf{W} S \mathbf{W} \Omega (\Omega' \mathbf{W} \Omega)^{-1}, \tag{A78}$$

where $\Omega = \partial \mathbf{g}(\Theta)/\partial\Theta$, and S is estimated by the variance-covariance matrix of the data moments over k industries that is adjusted for autocorrelation using the Bartlett weights.

For a given pair of general talent parameters, the industry-specific parameters are determined by the first stage of our estimation procedure that is analogous to the estimation of the basic model. Consequently, as shown in Table H21, the identification of the industry-specific parameters proceeds along the lines of the discussion in Section 4.2.1. Table H22 shows how the moments across industries vary with each of the two general talent parameters ($\bar{y}_1$ and ν_1). The identification of the general talent parameters hinges on *inter-industry variation* in the moments. Note that the maximum level of the general ability $\bar{y}_1$ affects the moments across industries in different directions, whereas the tail index of the general ability profile ν_1 affects the industry-specific moments in the same direction. By (A72) and (A73), these parameters determine the shape of the CEO talent profile for each industry through the convolution with the industry-specific talent distribution.

The effects of $\bar{y}_1$, keeping the maximum level of industry-specific ability $\bar{y}_2$ fixed, show substantial inter-industry variation, especially for the CEO pay and firm value quintile ratios. Unlike other moments, the regression intercept (M_1) moves with $\bar{y}_1$ in the same direction across industries, but in the opposite direction to the movement with the maximum level of industry-specific ability, $\bar{y}_2$ (see Table H21). Consequently, the regression intercept helps to identify these two parameters $(\bar{y}_1, \bar{y}_2)$ separately. The tail index, ν_1, which decreases the convexity of the general ability profile, decreases the convexity of the CEO talent profile unambiguously, thereby decreasing the quintile ratios of CEO pay ($M_4 - M_7$). Further, unlike the tail index of the industry-specific talent profile ν_2 (see Table H21), the tail index of the general ability profile, ν_1, has much less pronounced effects on the convexity of the firm value profile, which helps to separately identify these two tail indices.

Again, as in the previous models, we verify the necessary and sufficient conditions for local identification and numerical stability by confirming that the Jacobian matrix has full rank and is well-conditioned.

Appendix F. Parametric and non-parametric bootstrapping

We now examine the robustness of our implications to potential specification errors that would arise if our model is not the true data generating process (DGP). To address these issues, we adopt two approaches; parametric and non-parametric bootstrapping.

F.1. Parametric bootstrapping

We use our model to generate fictitious data panels by injecting random noise in each period and estimate the model treating the resulting data as if it were actual data. Suppose that, after matching occurs, there is an idiosyncratic shock to match quality that affects CEO pay multiplicatively. We assume that the shock to firm-CEO pair i in period t is specified by $\exp(\epsilon_{it})$ where $\epsilon_{it} \sim N(0, \sigma_t^2)$ so that the shock is log-normally distributed. We estimate σ_t^2 to match the variance of the error terms in the cross-sectional regression of log CEO pay on log firm value for each year. Next, we generate the stationary profiles of firm value and CEO pay in (23) and (24) using the baseline parameter estimates in Table 5. We then make random draws of the match quality shock across firms from the estimated log normal distribution and multiply the model-predicted value of each CEO's pay by $\exp(\epsilon_{it})$. By repeating the process for $T = 18$ periods, we generate a simulated data panel. We employ the same estimation approach described in Section 4.2.2 on the simulated data panel, thereby yielding a new set of parameter estimates. We generate 5,000 such simulated panels and compute the means and standard deviations of the 5,000 sets of parameter estimates that are the point estimates and standard errors of the parameters from the bootstrapping approach.

F.2. Non-parametric bootstrapping

To address the possibility that our parametric bootstrapping model could itself be misspecified, we also employ non-parametric bootstrapping. Instead of simulating fictitious data panels from the model, we resample from the original data to generate boostrapped samples. Specifically, our empirical data can be viewed as a matrix with each row being a (time series) vector of firm-CEO observations. As there is typically persistence in time-series data for a particular firm, we simulate panel datasets by bootstrapping rows of this matrix with replacement. In other words, the entire time series of observations for a particular firm will appear in a bootstrapped dataset. For each resampled data panel, we apply the same estimation approach as in Section 4.2.2. We repeat this procedure 5,000 times to generate 5,000 sets of parameter estimates. We then compute their means and standard deviations to obtain the point estimates and standard errors of the model parameters.

Appendix G. CEO-firm matching and the product market

We generalize the basic model by allowing for the possibility that the mass of *potential* CEOs exceeds the mass of *actual* CEOs who successfully match with firms operating in the product market. After characterizing the equilibrium, we quantitatively analyze the extended model.

G.1. The model

There is a mass M of potential CEOs who have managerial skills. CEO talent y is drawn from the c.d.f. $G(y)$ over $[y_{min}, y_{max}]$, which represents the *ex ante* talent distribution. In what follows, we show that, under certain reasonable conditions, there exists a unique cutoff level of talent such that only CEOs with abilities above the cutoff level match with firms. In particular, as we show later, the cutoff level is endogenously determined by the product market equilibrium conditions, which endogenously links the two channels—CEO labor markets and product markets.

Let $\bar{y}$ be the cutoff talent level. We then define a c.d.f. that represents the talent distribution only for CEOs with abilities above the cutoff level as follows:

$$F_Y(y|\bar{y}) = Pr[Y \leq y | Y \geq \bar{y}] = \frac{G(y) - G(\bar{y})}{1 - G(\bar{y})} \quad \text{for } y \geq \bar{y}, \tag{A79}$$

which has support $[0, 1]$. Since only these CEOs succeed in matching with firms, the above distribution function can be interpreted as the *ex post* talent distribution of the sector. We index these actual CEOs on the unit interval using $F_Y(y|\bar{y})$:

$$y[i|\bar{y}] = y \quad s.t. \quad F_Y(y|\bar{y}) = i, \quad \text{for } y \geq \bar{y}. \tag{A80}$$

The product market environment and one-to-one matching process between firms and mangers with talent above the cutoff level $\bar{y}$ are identical to those developed in the basic model. Accordingly, the payoff profiles are given by (17) and (18) except that $y[\cdot]$ and $y'[\cdot]$ in these equations need to be replaced by $y[\cdot|\bar{y}]$ and $y'[\cdot|\bar{y}]$, respectively. Note that the CEO with the cutoff talent level receives the reservation payoff $\tilde{u}_t$ from her outside opportunity.

We now describe how the equilibrium market variables are determined. First, the mass N of firms operating in the market must equal that of CEOs whose abilities are greater than $\bar{y}$,

$$N(\bar{y}) = M(1 - G(\bar{y})). \tag{A81}$$

Second, the product market clearing condition (20) can be rewritten as an equation for the initial aggregate price index $P_0(\bar{y})$:

$$(P_0(\bar{y})/w_0) = \left[N(\bar{y})\int_0^1 (\rho x[i]y[i|\bar{y}])^{\sigma-1}\,di\right]^{\frac{1}{1-\sigma}}, \tag{A82}$$

where $N(\bar{y})$ is given by (A81). Lastly, the free entry condition,

$$E_0\left[\mathcal{V}_0[i|\bar{y}]\right] = f_e, \tag{A83}$$

endogenously determines the cutoff talent level $\bar{y}$ along with (A81) and (A82), but its uniqueness is not guaranteed in general as the left-hand side of (A83) varies non-monotonically with $\bar{y}$.

G.2. Equilibrium

To ensure the uniqueness of an equilibrium, we impose the following reasonable assumptions on the ex ante talent distribution $G(y)$ and product market characteristics. First, the hazard rate of the ex ante talent distribution function $G(y)$, $h(y) \equiv \frac{g(y)}{1-G(y)}$, is nondecreasing in y. Second, the product substitutability satisfies $(\sigma-1) \leq g(y_{min})y_{min}$. Third, the fixed entry cost f_e is sufficiently large such that

$$E_0\left[\mathcal{V}_0[i|\bar{y} = y_{min}]\right] \leq f_e. \tag{A84}$$

The first two conditions guarantee that the expected firm value at time zero, $E_0\left[\mathcal{V}_0[i|\bar{y}]\right]$, monotonically increases with the cutoff talent level $\bar{y}$. In addition, the last condition ensures that there exists a cutoff level $y_{min} \leq \bar{y} \leq y_{max}$ at which the free entry condition (A83) is satisfied. Note that the extended model is reduced to the basic model when (A84) is satisfied with equality.

Proposition A4 (Existence and uniqueness of equilibrium)
Under the assumptions above, there exists a unique equilibrium in which the cutoff talent level $\bar{y}^*$ is uniquely determined by

$$R_0(P_0(\bar{y}^*)/w_0)^{\sigma-1}\left[\frac{(\rho x[0]\bar{y}^*)^{\sigma-1}}{\sigma} + \rho^\sigma\int_0^1\Big[\int_0^i x[j]^{\sigma-2}y[j|\bar{y}^*]^{\sigma-1}x'[j]dj\Big]di\right] = \tilde{u}_0 + (1-\beta\delta)f_e, \tag{A85}$$

where $(P_0(\bar{y}^*)/w)$ and $y[i|\bar{y}^*]$ are given by (A82) and (A80), respectively.

The equilibrium mass N of firms and the initial aggregate price index P_0^* are also uniquely determined by plugging $\bar{y}^*$ into (A81) and (A82), respectively. The equilibrium payoff profiles of the matched pairs are then obtained by plugging the equilibrium aggregate price index P_0^* and cutoff talent level $\bar{y}^*$ into (17) and (18).

G.3. Quantitative analysis

In our quantitative analysis, we investigate how the ex post CEO talent profiles are endogenously determined by product market characteristics. We start with the estimated baseline equilibrium in Section 4.3. In (22), $y[0]$ is, more exactly, the lowest talent level among actual CEOs, so that the ex post talent dispersion in the baseline equilibrium is obtained by

$$y_{max}/\bar{y}^* = c_2/(c_2-1), \tag{A86}$$

where c_2 is set to the estimate reported in Table 5. We then back out the constant term $MB(y_{max})^{1/\nu}$ from (A81) and (22), $MB(y_{max})^{1/\nu} = N/(1 - \bar{y}^*/y_{max})^{1/\nu}$, where N is set to the average number of firms in the industry over the sample period.

We now consider a change in a product market parameter—for example, the product substitutability changes from σ to σ'—kepping other parameter values as well as the firm quality profile (21) fixed. We determine the new cutoff talent level, $\bar{y}(\sigma')$, in equilibrium where the free entry condition (A85) is satisfied under the new level of product substitutability. More specifically, by (22) and (A86), the ex post relative talent values are given by

$$y[i|\bar{y}(\sigma')]/\bar{y}(\sigma') = y_{max}/\bar{y}(\sigma') - (y_{max}/\bar{y}(\sigma') - 1)(1-i)^{\nu}, \tag{A87}$$

and the new relative aggregate price index (A82) is given by

$$\begin{aligned}&\big((P_0(\bar{y}(\sigma'))/w_0)\rho x[0]\bar{y}(\sigma')\big)\\ = \;&\left[MB(y_{max})^{1/\nu}(1-\bar{y}(\sigma')/y_{max})^{1/\nu}\int_0^1 \big((x[i]/x[0])(y[i|\bar{y}(\sigma')]/\bar{y}(\sigma'))\big)^{\sigma'-1}\,di\right]^{\frac{1}{1-\sigma'}}.\end{aligned} \tag{A88}$$

By (A87) and (A88), the free entry condition (A85) uniquely determines the new ex post talent dispersion, $y_{max}/\bar{y}(\sigma')$.

Appendix H. Results of additional robustness tests

Table H1

Out-of-sample period test.

This table compares the actual and model-predicted moments for the out-of-sample period 2011-2013 that we do not include in our baseline parameter estimation. The actual moments are the time-series averages of the moments computed using the data over the period 2011-2013. We obtain the model-predicted moments using the baseline parameter estimates in Table 5. The third line of the results for each industry reports the t-statistics for the tests of the null hypothesis that the actual and model-predicted values of each moment are equal.

Industry sector		M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}	M_{13}
Consumer nondurables	Actual	-1.90	0.39	0.47	1.85	1.29	1.50	1.27	2.83	2.19	2.67	5.02	0.12	1.16
	Predicted	-2.21	0.43	0.47	1.44	1.38	1.53	1.79	2.12	1.98	2.68	4.82	0.19	1.16
	t-statistics	-0.31	0.12	0.01	-0.63	0.14	0.04	0.61	-0.62	-0.23	0.02	-0.08	0.27	0.01
Consumer durables	Actual	-2.35	0.44	0.39	1.81	1.75	1.48	1.80	2.38	2.27	2.53	10.87	0.13	1.07
	Predicted	-2.68	0.45	0.26	1.44	1.45	1.38	2.70	2.16	2.20	2.01	16.97	0.11	1.09
	t-statistics	-0.29	0.003	-0.44	-0.33	-0.46	-0.15	0.95	-0.21	-0.08	-0.55	0.92	-0.10	0.04
Manufacturing	Actual	-2.61	0.48	0.57	1.80	1.22	1.62	1.65	2.49	2.28	1.92	5.38	0.22	1.12
	Predicted	-2.81	0.49	0.58	1.39	1.31	1.55	2.10	1.86	1.69	2.43	5.38	0.26	1.12
	t-statistics	-0.17	0.03	0.03	-0.65	0.15	-0.10	0.55	-0.68	-0.74	0.53	0.003	0.14	0.003
Energy	Actual	-2.46	0.46	0.28	1.56	1.25	1.72	1.77	2.42	2.36	2.62	6.07	0.09	1.12
	Predicted	-2.69	0.47	0.33	1.55	1.61	1.61	2.21	2.45	2.63	2.62	7.79	0.14	1.11
	t-statistics	-0.19	0.04	0.18	-0.02	0.48	-0.18	0.49	0.03	0.28	-0.004	0.54	0.19	-0.01
Chemicals	Actual	-2.33	0.45	0.39	1.86	1.62	1.20	1.79	1.85	2.76	2.73	5.67	0.12	1.16
	Predicted	-2.66	0.46	0.39	1.57	1.39	1.38	1.79	2.37	1.95	2.00	5.05	0.16	1.10
	t-statistics	-0.29	0.05	0.02	-0.36	-0.37	0.26	-0.01	0.50	-0.94	-0.76	-0.26	0.14	-0.12
Business equipment	Actual	-2.02	0.39	0.40	1.78	1.51	1.57	1.99	3.19	2.25	2.57	10.45	0.14	1.22
	Predicted	-2.04	0.44	0.67	1.47	1.40	1.54	2.29	2.19	2.00	2.63	8.89	0.27	1.10
	t-statistics	-0.02	0.18	0.79	-0.40	-0.17	-0.03	0.34	-0.92	-0.30	0.06	-0.41	0.54	-0.23
Shops	Actual	-2.09	0.40	0.50	2.19	1.31	1.46	1.57	2.86	2.04	2.64	5.99	0.16	1.06
	Predicted	-2.32	0.43	0.54	1.46	1.29	1.51	2.01	2.15	1.72	2.53	6.52	0.21	1.08
	t-statistics	-0.23	0.10	0.12	-1.07	-0.02	0.07	0.60	-0.72	-0.40	-0.12	0.20	0.19	0.06
Healthcare	Actual	-2.37	0.45	0.39	1.97	1.55	1.91	1.67	3.40	2.46	3.59	7.92	0.13	1.27
	Predicted	-2.01	0.42	0.47	1.40	1.37	1.42	2.31	2.10	2.01	2.27	11.46	0.18	1.25
	t-statistics	0.37	-0.12	0.29	-0.83	-0.26	-0.59	0.84	-1.19	-0.49	-1.18	0.78	0.19	-0.03

Table H2
CEO Impact: Different reference firms.

This table shows the results of the counterfactual experiment of CEO replacement at the 75th percentile firm and at the average firm, respectively, using the baseline parameter estimates in Table 5.

	Panel A: 75th percentile firm ($\bar{q}$=0.75)			Panel B: Average firm		
Industry sector	$\frac{\Delta\Pi}{\Pi[\bar{q}]}$(%)	$\frac{\Delta\mathcal{V}}{\mathcal{V}[\bar{q}]}$(%)	$\frac{\Delta u/(1-\beta\delta)}{\mathcal{V}[\bar{q}]}$(%)	$\frac{\Delta\Pi}{E[\Pi[q]]}$(%)	$\frac{\Delta\mathcal{V}}{E[\mathcal{V}[q]]}$(%)	$\frac{\Delta u/(1-\beta\delta)}{E[\mathcal{V}[q]]}$(%)
Consumer nondurables	0.47	0.48	1.34	1.73	1.74	1.38
Consumer durables	1.21	1.23	7.89	2.63	2.65	2.82
Manufacturing	0.92	0.93	3.26	2.07	2.09	2.58
Energy	0.52	0.53	2.21	1.25	1.26	1.40
Chemicals	0.98	0.99	3.47	2.34	2.37	3.47
Business equipment	1.86	1.93	6.58	5.43	5.52	4.41
Shops	0.53	0.54	1.69	1.54	1.55	1.34
Healthcare	1.74	1.79	9.70	3.96	4.01	4.14

Table H3
The elasticities and CEO impact at the aggregate and industry levels: A simple example.

As detailed in Appendix B.2, we consider two industries with the same firm size profile $S[m]$ characterized by a firm size-firm rank elasticity of 2.5. We assume the following CEO pay functions for the two industries: $w_1[m] = 0.135 \times S[m]^{0.3}$ for industry 1 and $w_2[m] = 0.007 \times S[m]^{0.7}$ for industry 2. We then construct different aggregate samples of firms by randomly choosing $\overline{m}_1$ and $\overline{m}_2$ firms ($\overline{m}_1 + \overline{m}_2 = 318$) from these two industries: (1) Aggregate sample 1: $\overline{m}_1 = 100$ firms from the top 3% of firms by size in industry 1 and $\overline{m}_2 = 218$ firms from the top 6% of firms by size in industry 2; (2) Aggregate sample 2: $\overline{m}_1 = 80$ firms from the top 25% of firms by size in industry 1 and $\overline{m}_2 = 238$ firms from the top 3% of firms by size in industry 2; (3) Aggregate sample 3: $\overline{m}_1 = 10$ firms from the top 75% of firms by size in industry 1 and $\overline{m}_2 = 308$ firms across the entire firm size distribution in industry 2. Using each aggregate sample, we run the regressions of log firm size on log firm rank, and log CEO pay on log firm size. We then compute the CEO impact measure using the coefficients of the regressions (that is, the elasticities) as in the GL analysis summarized in Appendix B.1.

	Firm size-firm rank elasticity	CEO pay-firm size elasticity	CEO impact ($\frac{\Delta\mathcal{V}}{\mathcal{V}[0.5]}$(%))
Industry 1	2.5	0.3	0.270
Industry 2	2.5	0.7	0.413
Agg. sample 1	0.466	0.167	0.004
Agg. sample 2	0.774	0.715	0.051
Agg. sample 3	2.561	0.692	0.516

Table H4
Aggregate and industry-level GL analyses.

This table shows the results of our replication of GL's aggregate analysis (Panel A) and our industry-level GL analysis (Panel B) using the panel data over the period 1993-2013. As described in Appendix B.1, we calibrate the GL parameters by running the regressions of log firm size on log firm rank, and log CEO pay on log reference firm size and log individual firm size. We compute the CEO impact measure (the percentage change in the median firm's value due to the CEO replacement) using the calibrated GL parameters.

	Panel A: Aggregate GL analysis		
	Firm size-firm rank elasticity	CEO pay-firm size elasticity	CEO impact ($\frac{\Delta\mathcal{V}}{\mathcal{V}[0.5]}$(%))
Top 500	1.056	0.311	0.016
	Panel B: Industry-level GL analysis		
	Firm size-firm rank elasticity	CEO pay-firm size elasticity	CEO impact ($\frac{\Delta\mathcal{V}}{\mathcal{V}[0.5]}$(%))
Consumer nondurables	1.497	0.429	0.111
Consumer durables	1.632	0.453	0.114
Manufacturing	1.296	0.471	0.123
Energy	1.420	0.484	0.093
Chemicals	1.411	0.474	0.093
Business equipment	1.518	0.423	0.136
Shops	1.312	0.422	0.096
Healthcare	1.619	0.442	0.147

Table H5

Statistical significance of negative misspecification bias in GL's aggregate analysis: Parametric bootstrapping.

As detailed in Appendix B.3, we use our model to generate fictitious industry-level samples by injecting random shocks. We then combine the industry samples to form an aggregate sample with the relative proportion of firms from each industry being the same as in GL's aggregate sample. We repeat the process to generate 5,000 simulated industry and aggregate samples. We compute the correlation between the ranks of firms by size and their ranks by CEO pay, the firm size-firm rank and CEO pay-firm size elasticities, and the CEO impact measure at the aggregate and industry levels. This table shows the means and standard deviations (in parentheses) of the moments across the 5,000 bootstrapped aggregate and industry samples in Panels A and B, respectively. In the third line of the results for each industry in Panel B, we report the t-statistics for the tests of the null hypothesis that the aggregate value of each moment is equal to its industry-level value.

		Panel A: Moments from aggregate samples			
		Corr($q_{\mathcal{V}}, q_u$)	Firm size-firm rank elasticity	CEO pay-firm size elasticity	CEO impact ($\frac{\Delta\mathcal{V}}{\mathcal{V}[0.5]}$(%))
Aggregate	Mean	0.356	0.845	0.366	0.023
	Std. dev.	(0.054)	(0.030)	(0.061)	(0.006)

		Panel B: Moments from industry samples			
Industry sector		Corr($q_{\mathcal{V}}, q_u$)	Firm size-firm rank elasticity	CEO pay-firm size elasticity	CEO impact ($\frac{\Delta\mathcal{V}}{\mathcal{V}[0.5]}$(%))
Consumer nondurables	Mean	0.646	1.589	0.393	0.100
	Std. dev.	(0.051)	(0.051)	(0.043)	(0.023)
	t-statistics	-3.95	-13.48	-0.38	-3.33
Consumer durables	Mean	0.670	1.711	0.422	0.110
	Std. dev.	(0.074)	(0.060)	(0.060)	(0.033)
	t-statistics	-3.34	-13.82	-0.69	-2.64
Manufacturing	Mean	0.669	1.411	0.449	0.132
	Std. dev.	(0.034)	(0.032)	(0.033)	(0.020)
	t-statistics	-4.85	-13.48	-1.21	-5.37
Energy	Mean	0.660	1.602	0.431	0.082
	Std. dev.	(0.066)	(0.060)	(0.060)	(0.025)
	t-statistics	-3.60	-12.43	-0.81	-2.38
Chemicals	Mean	0.640	1.359	0.414	0.065
	Std. dev.	(0.077)	(0.065)	(0.067)	(0.020)
	t-statistics	-3.01	-7.53	-0.54	-2.04
Business equipment	Mean	0.512	1.611	0.395	0.188
	Std. dev.	(0.040)	(0.031)	(0.036)	(0.033)
	t-statistics	-2.41	-20.80	-0.45	-5.15
Shops	Mean	0.582	1.509	0.404	0.129
	Std. dev.	(0.043)	(0.032)	(0.038)	(0.023)
	t-statistics	-3.32	-15.98	-0.55	-4.49
Healthcare	Mean	0.577	1.650	0.371	0.140
	Std. dev.	(0.054)	(0.050)	(0.042)	(0.031)
	t-statistics	-2.86	-15.57	-0.08	-3.84

Table H6

Basic moral hazard model: Actual and model-predicted moments from estimation.

This table shows the actual and model-predicted values of the 18 moments that we match in the estimation of the basic moral hazard model in Appendix C.1. In addition to the 13 moments used in the estimation of the basic model, we include the ratios of CEO pay-performance sensitivities (PPS)—the dollar increase in CEO wealth in response to a $1,000 increase in shareholder value—as additional moments. Specifically, we compute the mean values of PPS in each firm value quintile and compute 4 ratios of the mean value of PPS in quintile Q_r (for $r \in \{2,3,4,5\}$) to its mean value in the bottom quintile Q_1 ($M_{14} - M_{17}$). The last moment is the ratio of the intra-industry PPS dispersion ($) to the firm value dispersion ($000) using the top and bottom deciles (M_{18}). To compute the empirical PPS measure for each firm, we follow the Core and Guay (2002) methodology to estimate the delta of the CEO's option holdings. The actual values of the moments are the time-series averages of the empirical moments over the sample period 1993-2013. We generate the model-predicted moments using the parameter estimates in Table H7. The table also reports the t-statistics for the tests of the null hypothesis that the actual and model-predicted values of each moment are equal. The last column shows the χ^2 statistics and corresponding p-values in parentheses for the J-test of the model's overidentifying restrictions.

Industry sector		M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}	M_{13}	M_{14}	M_{15}	M_{16}	M_{17}	M_{18}	χ^2 (p-value)
Consumer nondurables	Actual	-2.27	0.42	0.49	1.59	1.52	1.58	1.86	2.78	2.33	2.58	5.84	0.18	1.15	0.74	0.60	0.52	0.18	-1.16	171.99
		(0.39)	(0.04)	(0.07)	(0.42)	(0.40)	(0.56)	(0.54)	(0.32)	(0.23)	(0.25)	(0.86)	(0.06)	(0.01)	(0.32)	(0.19)	(0.13)	(0.08)	(0.78)	(0.00)
	Predicted	-2.40	0.46	0.53	1.64	1.51	1.58	2.07	2.81	2.35	2.61	6.27	0.23	1.13	0.80	0.62	0.44	0.24	-1.11	
	t-statistics	-0.15	0.12	0.14	0.07	-0.02	-0.002	0.27	0.02	0.01	0.03	0.19	0.24	-0.05	0.16	0.07	-0.27	0.28	0.09	
Consumer durables	Actual	-2.76	0.46	0.38	2.33	1.46	1.39	2.27	2.49	2.20	2.28	14.99	0.14	1.07	1.11	0.89	0.34	0.13	-0.56	340.69
		(0.37)	(0.05)	(0.35)	(0.99)	(0.74)	(0.37)	(0.65)	(0.53)	(0.38)	(0.26)	(6.58)	(0.13)	(0.03)	(0.59)	(0.28)	(0.25)	(0.11)	(0.79)	(0.00)
	Predicted	-2.59	0.49	0.56	1.21	1.61	1.51	2.37	1.41	2.46	2.27	8.13	0.25	1.07	0.90	0.67	0.50	0.26	-0.57	
	t-statistics	0.15	0.10	0.69	-1.22	0.25	0.21	0.11	-1.12	0.31	-0.01	-1.18	0.47	-0.02	-0.44	-0.55	0.57	0.59	-0.01	
Manuf.	Actual	-2.73	0.47	0.55	1.55	1.36	1.65	1.86	2.32	2.00	2.32	5.94	0.22	1.11	0.59	0.44	0.27	0.19	-1.04	189.90
		(0.25)	(0.04)	(0.09)	(0.32)	(0.21)	(0.42)	(0.45)	(0.24)	(0.23)	(0.22)	(1.29)	(0.06)	(0.02)	(0.26)	(0.21)	(0.10)	(0.10)	(0.79)	(0.00)
	Predicted	-2.74	0.51	0.59	1.58	1.39	1.57	2.13	2.29	1.86	2.35	5.59	0.27	1.12	0.74	0.59	0.43	0.25	-0.45	
	t-statistics	-0.01	0.16	0.14	0.06	0.06	-0.11	0.36	-0.03	-0.19	0.03	-0.15	0.23	0.02	0.45	0.53	0.64	0.25	1.20	
Energy	Actual	-2.92	0.48	0.30	1.58	1.52	1.65	2.08	2.40	2.30	2.55	7.97	0.11	1.11	0.72	0.48	0.28	0.29	-0.31	233.31
		(0.62)	(0.08)	(0.06)	(0.47)	(0.37)	(0.62)	(0.59)	(0.36)	(0.29)	(0.35)	(1.35)	(0.04)	(0.04)	(0.41)	(0.47)	(0.20)	(0.23)	(0.24)	(0.00)
	Predicted	-2.59	0.48	0.37	1.49	1.46	1.55	2.63	2.45	2.23	2.51	8.55	0.18	1.09	0.73	0.54	0.38	0.21	-0.21	
	t-statistics	0.29	-0.02	0.25	-0.13	-0.11	-0.16	0.67	0.06	-0.08	-0.05	0.19	0.30	-0.04	0.03	0.19	0.42	-0.33	0.38	
Chemicals	Actual	-2.68	0.47	0.41	2.00	1.37	1.58	1.72	2.41	2.21	2.37	5.72	0.14	1.14	1.15	0.91	0.35	0.26	-0.28	198.49
		(0.35)	(0.05)	(0.07)	(0.61)	(0.32)	(0.42)	(0.35)	(0.32)	(0.37)	(0.20)	(1.01)	(0.03)	(0.02)	(0.85)	(1.01)	(0.21)	(0.26)	(0.18)	(0.00)
	Predicted	-2.36	0.46	0.41	1.60	1.39	1.41	2.02	2.49	1.97	2.16	6.28	0.18	1.12	0.71	0.55	0.42	0.26	-0.24	
	t-statistics	0.31	-0.03	-0.01	-0.52	0.04	-0.26	0.45	0.08	-0.28	-0.23	0.26	0.18	-0.05	-0.81	-0.70	0.29	-0.01	0.15	
Business equipment	Actual	-2.48	0.44	0.61	1.82	1.45	1.70	2.11	2.66	2.09	2.57	8.77	0.23	1.13	0.96	0.67	0.55	0.46	-0.55	1,132.08
		(0.22)	(0.04)	(0.13)	(0.35)	(0.27)	(0.37)	(0.40)	(0.30)	(0.15)	(0.23)	(1.45)	(0.05)	(0.05)	(0.25)	(0.24)	(0.19)	(0.20)	(0.32)	(0.00)
	Predicted	-2.06	0.43	0.77	1.30	1.35	1.46	2.32	1.78	1.94	2.44	9.74	0.30	1.09	0.88	0.74	0.56	0.31	-1.06	
	t-statistics	0.45	-0.04	0.50	-0.73	-0.18	-0.35	0.26	-0.86	-0.19	-0.13	0.30	0.32	-0.10	-0.19	0.19	0.01	-0.52	-1.62	
Shops	Actual	-2.39	0.42	0.58	1.65	1.38	1.59	1.79	2.48	1.93	2.36	6.62	0.21	1.05	0.99	0.76	0.65	0.34	-0.81	216.72
		(0.26)	(0.03)	(0.05)	(0.33)	(0.20)	(0.48)	(0.31)	(0.30)	(0.11)	(0.17)	(1.08)	(0.06)	(0.003)	(0.26)	(0.18)	(0.17)	(0.12)	(0.66)	(0.00)
	Predicted	-2.22	0.41	0.53	1.38	1.31	1.36	1.94	2.02	1.87	2.06	6.89	0.19	1.05	0.86	0.72	0.57	0.32	-1.29	
	t-statistics	0.18	-0.05	-0.14	-0.42	-0.12	-0.36	0.21	-0.48	-0.09	-0.34	0.11	-0.09	-0.02	-0.31	-0.11	-0.25	-0.05	-1.18	
Healthcare	Actual	-2.33	0.43	0.42	1.60	1.63	2.02	1.71	2.82	2.31	2.84	10.78	0.14	1.24	0.92	0.58	0.46	0.16	-0.53	477.61
		(0.26)	(0.04)	(0.06)	(0.46)	(0.39)	(0.46)	(0.43)	(0.51)	(0.23)	(0.47)	(2.26)	(0.02)	(0.03)	(0.41)	(0.20)	(0.19)	(0.05)	(0.31)	(0.00)
	Predicted	-2.27	0.46	0.38	1.65	1.53	1.53	2.63	3.00	2.44	2.56	11.59	0.17	1.23	0.80	0.61	0.45	0.22	-0.39	
	t-statistics	0.07	0.08	-0.12	0.08	-0.14	-0.61	1.36	0.17	0.15	-0.27	0.20	0.16	-0.01	-0.29	0.10	-0.02	0.27	0.46	

Table H7

Basic moral hazard model: Parameter estimates, firm quality and CEO talent ratios, as well as firm size and CEO factor ratios.

This table shows the parameter estimates from the estimation of the basic moral hazard model, along with their standard errors in parentheses, for each industry. In addition to the parameters included in the basic model, there are additional parameters: (i) κ: the coefficient in the CEO effort cost function, $\kappa(e)$; (ii) h and l: high and low values of firm idiosyncratic productivity shock, ϕ. We set the high value (h) of ϕ to 1 and estimate its low value (l) only because the equilibrium variables only depend on their spread, $h^{\sigma-1} - l^{\sigma-1}$. The next two columns report the ratios of the firm qualities and CEO talents of the largest and smallest S&P 1500 firms in the industry. The last two columns show the ratios of their sizes and CEO factors.

Industry sector	$\widetilde{u}$	φ	σ	α	ν	c_1	c_2	κ	l	$x[1]/x[0]$	$y[1]/y[0]$	$\tilde{x}[1]/\tilde{x}[0]$ $= (x[1]/x[0])^{\sigma-1}$	$\tilde{y}[1]/\tilde{y}[0]$ $= (y[1]/y[0])^{\sigma-1}$
Consumer nondurables	0.199	0.932	8.788	0.523	1.885	0.915	16.501	0.123	0.9993	2.164	1.008	408.8	1.064
		(0.004)	(1.584)	(0.131)	(0.036)	(0.008)	(3.780)	(0.022)	(0.0008)				
Consumer durables	0.155	0.940	16.019	0.193	1.504	0.941	60.213	0.057	0.9995	1.419	1.003	190.9	1.050
		(0.006)	(2.497)	(0.038)	(0.063)	(0.013)	(12.169)	(0.022)	(0.0011)				
Manufacturing	0.188	0.939	9.304	0.420	1.474	0.915	28.118	0.007	0.9999	1.829	1.006	150.7	1.054
		(0.007)	(0.223)	(0.017)	(0.017)	(0.004)	(2.618)	(0.001)	(0.0015)				
Energy	0.217	0.932	11.680	0.303	2.033	0.960	31.437	0.096	0.9958	1.741	1.002	373.1	1.025
		(0.016)	(2.305)	(0.082)	(0.156)	(0.003)	(4.501)	(0.046)	(0.0040)				
Chemicals	0.191	0.961	9.075	0.409	1.891	0.938	19.428	0.142	0.9970	2.019	1.009	291.3	1.072
		(0.003)	(1.972)	(0.119)	(0.129)	(0.007)	(5.432)	(0.048)	(0.0023)				
Business equipment	0.151	0.946	12.057	0.202	1.599	0.976	21.519	0.333	0.9975	1.669	1.007	288.9	1.075
		(0.005)	(3.411)	(0.073)	(0.107)	(0.004)	(6.896)	(0.108)	(0.0008)				
Shops	0.164	0.936	22.314	0.132	1.683	0.954	73.499	0.108	0.9999	1.287	1.002	217.3	1.041
		(0.006)	(4.377)	(0.031)	(0.022)	(0.004)	(12.674)	(0.013)	(0.0003)				
Healthcare	0.176	0.950	5.289	0.692	1.610	0.976	4.350	0.183	0.9977	4.808	1.020	841.5	1.088
		(0.002)	(0.760)	(0.152)	(0.073)	(0.002)	(0.892)	(0.024)	(0.0025)				

Table H8

Basic moral hazard model: CEO pay decomposition.

This table shows the median and best CEOs' base salary (Υ) and incentive pay (z) at their own firm. The last column shows incentive pay that the median-sized firm would offer the best CEO in the firm-specific contract. We express all pay variables in units of one million dollars.

Industry sector	$\Upsilon[0.5]$	$z[0.5]$	$\Upsilon[1]$	$z[1]$	$z(x[0.5], y[1])$
Consumer nondurables	2.67	0.08	10.51	2.37	0.09
Consumer durables	3.00	0.11	14.75	2.51	0.12
Manufacturing	3.38	0.02	15.90	0.27	0.02
Energy	2.21	0.83	6.48	14.81	0.83
Chemicals	3.60	0.45	11.53	6.57	0.45
Business equipment	2.09	0.13	7.38	7.45	0.14
Shops	2.05	0.03	7.00	1.24	0.03
Healthcare	3.02	0.12	16.70	6.42	0.12

Table H9

Basic moral hazard model: CEO Impact.

This table shows the results of the counterfactual experiment of CEO replacement at the median-sized firm using the parameter estimates in Table H7. In particular, when calculating the ratio of additional compensation costs in the third column, we assume that the median-sized firm provides the best CEO with the same base salary as the largest firm ($\Upsilon[1]$), but the firm-specific incentive pay ($z(x[0.5], y[1])$) that depends upon the firm's quality and the CEO's talent.

Industry sector	$\frac{\Delta E[\tilde{\Pi}]}{E[\tilde{\Pi}[0.5]]}(\%)$	$\frac{\Delta \mathcal{V}}{\mathcal{V}[0.5]}(\%)$	$\frac{\Delta u/(1-\beta\delta)}{\mathcal{V}[0.5]}(\%)$
Consumer nondurables	1.41	1.44	6.64
Consumer durables	1.95	2.01	10.52
Manufacturing	1.94	1.98	8.99
Energy	0.55	0.56	2.55
Chemicals	1.36	1.39	5.74
Business equipment	2.63	2.77	13.96
Shops	1.24	1.27	5.73
Healthcare	2.17	2.24	14.99

Table H10

Extended moral hazard model with CEO risk aversion: Actual and model-predicted moments from estimation.

This table shows the actual and model-predicted values of the 18 moments that we match in the estimation of the extended moral hazard model in Appendix C.2. The definition of the moments, as well as the actual values of the moments computed from the data over the period 1993-2013, are the same as in Table H6. We generate the model-predicted moments using the parameter estimates in Table H11. We also report the t-statistics for the tests of the null hypothesis that the actual and model-predicted values of each moment are equal. The last column shows the χ^2 statistics and corresponding p-values in parentheses for the J-test of the model's overidentifying restrictions.

Industry sector		M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}	M_{13}	M_{14}	M_{15}	M_{16}	M_{17}	M_{18}	χ^2 (p-value)
Consumer nondurables	Actual	-2.27	0.42	0.49	1.59	1.52	1.58	1.86	2.78	2.33	2.58	5.84	0.18	1.15	0.74	0.60	0.52	0.18	-1.16	244.34
		(0.39)	(0.04)	(0.07)	(0.42)	(0.40)	(0.56)	(0.54)	(0.32)	(0.23)	(0.25)	(0.86)	(0.06)	(0.01)	(0.32)	(0.19)	(0.13)	(0.08)	(0.78)	(0.00)
	Predicted	-2.26	0.46	0.60	1.75	1.58	1.56	1.71	2.46	2.28	2.81	5.72	0.23	1.10	0.83	0.62	0.35	0.11	-0.97	
	t-statistics	0.02	0.12	0.38	0.26	0.10	-0.03	-0.21	-0.31	-0.06	0.23	-0.06	0.22	-0.10	0.25	0.05	-0.59	-0.31	0.35	
Consumer durables	Actual	-2.76	0.46	0.38	2.33	1.46	1.39	2.27	2.49	2.20	2.28	14.99	0.14	1.07	1.11	0.89	0.34	0.13	-0.56	110.88
		(0.37)	(0.05)	(0.35)	(0.99)	(0.74)	(0.37)	(0.65)	(0.53)	(0.38)	(0.26)	(6.58)	(0.13)	(0.03)	(0.59)	(0.28)	(0.25)	(0.11)	(0.79)	(0.00)
	Predicted	-2.77	0.50	0.40	1.38	1.56	1.52	2.42	1.70	2.23	2.37	12.81	0.17	1.08	0.87	0.63	0.38	0.16	-0.56	
	t-statistics	-0.02	0.12	0.10	-1.03	0.17	0.24	0.18	-0.82	0.04	0.11	-0.38	0.14	0.01	-0.49	-0.62	0.13	0.13	0.02	
Manufacturing	Actual	-2.73	0.47	0.55	1.55	1.36	1.65	1.86	2.32	2.00	2.32	5.94	0.22	1.11	0.59	0.44	0.27	0.19	-1.04	275.96
		(0.25)	(0.04)	(0.09)	(0.32)	(0.21)	(0.42)	(0.45)	(0.24)	(0.23)	(0.22)	(1.29)	(0.06)	(0.02)	(0.26)	(0.21)	(0.10)	(0.10)	(0.79)	(0.00)
	Predicted	-2.50	0.47	0.59	1.66	1.49	1.37	1.64	2.30	2.12	2.03	4.07	0.24	1.08	0.77	0.53	0.33	0.12	-0.78	
	t-statistics	0.22	0.02	0.13	0.19	0.24	-0.43	-0.31	-0.02	0.15	-0.33	-0.83	0.08	-0.06	0.55	0.31	0.24	-0.31	0.52	
Energy	Actual	-2.92	0.48	0.30	1.58	1.52	1.65	2.08	2.40	2.30	2.55	7.97	0.11	1.11	0.72	0.48	0.28	0.29	-0.31	128.91
		(0.62)	(0.08)	(0.06)	(0.47)	(0.37)	(0.62)	(0.59)	(0.36)	(0.29)	(0.35)	(1.35)	(0.04)	(0.04)	(0.41)	(0.47)	(0.20)	(0.23)	(0.24)	(0.00)
	Predicted	-2.35	0.43	0.30	1.47	1.49	1.54	2.02	2.16	2.44	2.89	7.85	0.11	1.09	0.73	0.42	0.19	0.06	-0.39	
	t-statistics	0.51	-0.19	-0.03	-0.18	-0.06	-0.17	-0.08	-0.26	0.16	0.34	-0.04	0.01	-0.05	0.01	-0.18	-0.37	-0.92	-0.31	
Chemicals	Actual	-2.68	0.47	0.41	2.00	1.37	1.58	1.72	2.41	2.21	2.37	5.72	0.14	1.14	1.15	0.91	0.35	0.26	-0.28	103.93
		(0.35)	(0.05)	(0.07)	(0.61)	(0.32)	(0.42)	(0.35)	(0.32)	(0.37)	(0.20)	(1.01)	(0.03)	(0.02)	(0.85)	(1.01)	(0.21)	(0.26)	(0.18)	(0.00)
	Predicted	-2.35	0.44	0.37	1.51	1.49	1.37	1.69	2.08	2.18	2.15	5.89	0.13	1.09	0.80	0.54	0.33	0.13	-0.33	
	t-statistics	0.32	-0.11	-0.15	-0.63	0.23	-0.33	-0.05	-0.36	-0.03	-0.24	0.08	-0.03	-0.12	-0.65	-0.72	-0.07	-0.53	-0.22	
Business equipment	Actual	-2.48	0.44	0.61	1.82	1.45	1.70	2.11	2.66	2.09	2.57	8.77	0.23	1.13	0.96	0.67	0.55	0.46	-0.55	1,684.13
		(0.22)	(0.04)	(0.13)	(0.35)	(0.27)	(0.37)	(0.40)	(0.30)	(0.15)	(0.23)	(1.45)	(0.05)	(0.05)	(0.25)	(0.24)	(0.19)	(0.20)	(0.32)	(0.00)
	Predicted	-1.79	0.44	1.00	1.56	1.47	1.58	2.02	2.17	1.97	2.47	10.90	0.35	1.10	0.94	0.85	0.66	0.24	-1.08	
	t-statistics	0.73	-0.01	1.24	-0.37	0.03	-0.17	-0.12	-0.48	-0.15	-0.11	0.65	0.49	-0.08	-0.06	0.51	0.36	-0.77	-1.68	
Shops	Actual	-2.39	0.42	0.58	1.65	1.38	1.59	1.79	2.48	1.93	2.36	6.62	0.21	1.05	0.99	0.76	0.65	0.34	-0.81	923.00
		(0.26)	(0.03)	(0.05)	(0.33)	(0.20)	(0.48)	(0.31)	(0.30)	(0.11)	(0.17)	(1.08)	(0.06)	(0.00)	(0.26)	(0.18)	(0.17)	(0.12)	(0.66)	(0.00)
	Predicted	-1.90	0.39	0.51	1.86	1.47	1.41	1.41	2.83	2.03	2.35	5.99	0.15	1.05	0.84	0.67	0.45	0.14	-1.07	
	t-statistics	0.54	-0.12	-0.22	0.31	0.15	-0.28	-0.55	0.36	0.13	-0.02	-0.26	-0.26	0.00	-0.34	-0.25	-0.63	-0.78	-0.66	
Healthcare	Actual	-2.33	0.43	0.42	1.60	1.63	2.02	1.71	2.82	2.31	2.84	10.78	0.14	1.24	0.92	0.58	0.46	0.16	-0.53	283.76
		(0.26)	(0.04)	(0.06)	(0.46)	(0.39)	(0.46)	(0.43)	(0.51)	(0.23)	(0.47)	(2.26)	(0.02)	(0.03)	(0.41)	(0.20)	(0.19)	(0.05)	(0.31)	(0.00)
	Predicted	-2.40	0.46	0.45	1.67	1.61	1.65	2.08	2.61	2.32	2.69	10.67	0.17	1.26	0.93	0.82	0.61	0.21	-0.54	
	t-statistics	-0.07	0.09	0.12	0.11	-0.02	-0.46	0.54	-0.19	0.02	-0.14	-0.03	0.15	0.04	0.03	0.76	0.54	0.22	-0.06	

Table H11

Extended moral hazard model with CEO risk aversion: Parameter estimates, firm quality and CEO talent ratios, as well as firm size and CEO factor ratios.

This table shows the parameter estimates from the estimation of the extended moral hazard model with CEO risk aversion, along with their standard errors in parentheses, for each industry. There are two additional parameters relative to the basic model: (i) κ: the coefficient in the CEO effort cost function, $\kappa(e)$; (ii) γs^2 : the coefficient of CEO absolute risk aversion, γ, multiplied by the variance of firm idiosyncratic shock, s^2, that follows a normal distribution. The next two columns report the ratios of the firm qualities and CEO talents of the largest and smallest S&P 1500 firms in the industry. The last two columns show the ratios of their sizes and CEO factors.

Industry sector	$\widetilde{u}$	φ	σ	α	ν	c_1	c_2	κ	γs^2	$x[1]/x[0]$	$y[1]/y[0]$	$\tilde{x}[1]/\tilde{x}[0]$ $= (x[1]/x[0])^{\sigma-1}$	$\tilde{y}[1]/\tilde{y}[0]$ $= (y[1]/y[0])^{\sigma-1}$
Consumer nondurables	0.199	0.948	10.653	0.379	1.482	0.929	46.841	11.648	0.0009	1.861	1.004	402.2	1.042
		(0.003)	(1.960)	(0.088)	(0.100)	(0.005)	(16.281)	(2.631)	(0.0004)				
Consumer durables	0.155	0.954	14.220	0.351	1.386	0.918	46.940	11.156	0.0020	1.659	1.004	806.3	1.054
		(0.005)	(2.492)	(0.076)	(0.169)	(0.007)	(20.243)	(3.940)	(0.0004)				
Manufacturing	0.188	0.960	12.965	0.564	1.580	0.765	53.515	11.526	0.0011	1.500	1.003	127.9	1.039
		(0.002)	(1.046)	(0.052)	(0.073)	(0.009)	(12.468)	(1.266)	(0.0002)				
Energy	0.217	0.948	12.214	0.303	1.453	0.956	51.595	17.596	0.0013	1.771	1.003	607.8	1.036
		(0.003)	(1.965)	(0.062)	(0.142)	(0.004)	(20.284)	(8.071)	(0.0004)				
Chemicals	0.191	0.971	12.708	0.326	1.490	0.917	55.085	10.235	0.0017	1.626	1.004	295.4	1.042
		(0.002)	(5.461)	(0.173)	(0.123)	(0.008)	(32.559)	(3.768)	(0.0007)				
Business equipment	0.151	0.957	11.289	0.292	1.789	0.965	9.888	8.882	0.0010	1.866	1.010	614	1.111
		(0.003)	(1.540)	(0.050)	(0.083)	(0.002)	(1.622)	(0.478)	(0.0002)				
Shops	0.164	0.948	20.059	0.251	2.711	0.873	65.479	12.180	0.0006	1.343	1.001	277.4	1.015
		(0.002)	(1.923)	(0.030)	(0.427)	(0.005)	(16.802)	(2.246)	(0.0002)				
Healthcare	0.176	0.964	4.895	0.745	1.611	0.985	4.863	14.746	0.0005	5.634	1.019	840.4	1.075
		(0.002)	(0.326)	(0.088)	(0.039)	(0.003)	(0.423)	(1.928)	(0.00003)				

Table H12
Extended moral hazard model with CEO risk aversion: CEO pay decomposition.

This table shows the median and best CEOs' base salary (Υ), risk-premium (ζ), and incentive pay (z), the last of which includes both the effort cost and risk premium, at their own firm. The last column shows incentive pay that the median-sized firm would offer the best CEO in the firm-specific contract. We express all pay variables in units of one million dollars.

Industry sector	$\Upsilon[0.5]$	$\zeta[0.5]$	$z[0.5]$	$\Upsilon[1]$	$\zeta[1]$	$z[1]$	$z(x[0.5], y[1])$
Consumer nondurables	1.49	0.92	1.94	9.46	3.93	4.01	1.95
Consumer durables	1.00	0.51	1.02	20.23	1.99	2.00	1.03
Manufacturing	1.90	1.33	2.12	7.81	3.19	3.30	2.13
Energy	1.77	0.65	0.89	16.13	1.20	1.21	0.89
Chemicals	1.66	1.04	1.70	10.96	2.72	2.75	1.71
Business equipment	1.88	0.30	1.38	8.24	5.95	6.14	1.42
Shops	0.93	0.93	2.29	1.60	5.19	5.40	2.29
Healthcare	1.37	0.25	1.06	8.67	4.29	4.39	1.08

Table H13
Extended moral hazard model with CEO risk aversion: CEO Impact.

This table shows the results of the counterfactual experiment of CEO replacement at the median-sized firm using the parameter estimates in Table H11. In particular, when calculating the ratio of additional compensation costs in the third column, we assume that the median-sized firm provides the best CEO with the same base salary as the largest firm ($\Upsilon[1]$), but the firm-specific incentive pay ($z(x[0.5], y[1])$) that depends upon the firm's quality and the CEO's talent.

Industry sector	$\frac{\Delta E[\widetilde{\Pi}]}{E[\widetilde{\Pi}[0.5]]}$ (%)	$\frac{\Delta \mathcal{V}}{\mathcal{V}[0.5]}$ (%)	$\frac{\Delta u/(1-\beta\delta)}{\mathcal{V}[0.5]}$ (%)
Consumer nondurables	1.40	1.44	9.26
Consumer durables	2.77	2.86	41.96
Manufacturing	1.24	1.27	4.57
Energy	1.35	1.38	12.37
Chemicals	1.60	1.65	10.47
Business equipment	3.23	3.46	20.62
Shops	0.23	0.24	0.70
Healthcare	2.07	2.15	18.06

Table H14

Long-term effects of CEOs ($\lambda = 0.1$): Parameter estimates, firm quality and CEO talent ratios, as well as firm size and CEO factor ratios.

As detailed in Appendix D, we extend the basic model by allowing for long-term effects of CEOs on firm earnings and quantitatively analyze the extended model. We set the additional parameter λ (the rate at which CEO influence on firm earnings fades over time) to 0.1 and 0.5 as in Terviö (2008). This table shows the results of the estimation of the extended model with $\lambda = 0.1$.

Industry sector	φ	σ	α	ν	c_1	c_2	χ^2	$x[1]/x[0]$	$y[1]/y[0]$	$\tilde{x}[1]/\tilde{x}[0]$	$\tilde{y}[1]/\tilde{y}[0]$
							(p-value)			$= (x[1]/x[0])^{\sigma-1}$	$= (y[1]/y[0])^{\sigma-1}$
Consumer nondurables	0.933	6.895	0.623	1.782	0.918	10.404	10.34	2.526	1.016	235.6	1.096
	(0.004)	(0.973)	(0.126)	(0.018)	(0.006)	(2.260)	(0.17)				
Consumer durables	0.910	10.535	0.275	1.412	0.962	45.496	37.52	1.983	1.007	685.4	1.071
	(0.025)	(3.668)	(0.121)	(0.030)	(0.007)	(16.950)	(0.00)				
Manufacturing	0.915	9.068	0.454	1.650	0.915	23.982	89.02	2.040	1.008	315.3	1.070
	(0.006)	(1.855)	(0.124)	(0.027)	(0.010)	(8.187)	(0.00)				
Energy	0.944	9.113	0.369	1.522	0.962	18.557	27.13	2.059	1.009	351.1	1.079
	(0.002)	(3.126)	(0.164)	(0.018)	(0.006)	(8.534)	(0.00)				
Chemicals	0.971	8.412	0.428	1.647	0.940	16.779	89.98	2.219	1.016	368.4	1.122
	(0.002)	(1.582)	(0.111)	(0.021)	(0.007)	(4.660)	(0.00)				
Business equipment	0.972	13.691	0.258	1.741	0.935	6.032	201.45	1.533	1.021	226.5	1.296
	(0.003)	(3.149)	(0.077)	(0.019)	(0.006)	(1.474)	(0.00)				
Shops	0.896	8.949	0.367	1.559	0.942	23.981	56.13	2.069	1.010	324	1.080
	(0.011)	(1.442)	(0.080)	(0.030)	(0.005)	(5.773)	(0.00)				
Healthcare	0.958	5.574	0.690	1.650	0.966	3.291	60.25	4.227	1.032	729.9	1.155
	(0.005)	(0.771)	(0.157)	(0.028)	(0.004)	(0.991)	(0.00)				

Table H15

Long-term effect of CEOs ($\lambda = 0.1$): CEO Impact.

This table shows the results of the counterfactual experiment of CEO replacement at the median-sized firm using the parameter estimates in Table H14.

Industry sector	$\frac{\Delta\Pi}{\Pi[0.5]}$ (%)	$\frac{\Delta\mathcal{V}}{\mathcal{V}[0.5]}$ (%)	$\frac{\Delta u/(1-\beta\delta)}{\mathcal{V}[0.5]}$ (%)
Consumer nondurables	2.37	2.42	6.29
Consumer durables	2.50	2.54	11.30
Manufacturing	2.36	2.40	7.37
Energy	2.32	2.37	9.09
Chemicals	3.13	3.23	13.66
Business equipment	9.44	10.43	38.68
Shops	2.57	2.62	7.01
Healthcare	4.43	4.62	22.50

Table H16

Long-term effects of CEOs ($\lambda = 0.5$): Parameter estimates, firm quality and CEO talent ratios, as well as firm size and CEO factor ratios.

This table shows the results of the estimation of the extended model with $\lambda = 0.5$.

Industry sector	φ	σ	α	ν	c_1	c_2	χ^2 (p-value)	$x[1]/x[0]$	$y[1]/y[0]$	$\tilde{x}[1]/\tilde{x}[0]$ $= (x[1]/x[0])^{\sigma-1}$	$\tilde{y}[1]/\tilde{y}[0]$ $= (y[1]/y[0])^{\sigma-1}$
Consumer nondurables	0.944	7.202	0.562	1.747	0.937	13.127	7.62	2.637	1.014	409.2	1.090
	(0.003)	(1.138)	(0.125)	(0.017)	(0.005)	(3.199)	(0.37)				
Consumer durables	0.962	11.393	0.231	1.386	0.978	51.988	44.28	1.896	1.006	771.5	1.065
	(0.015)	(6.341)	(0.165)	(0.038)	(0.008)	(28.937)	(0.00)				
Manufacturing	0.925	9.482	0.352	1.399	0.934	41.637	40.15	1.916	1.006	248.2	1.054
	(0.009)	(1.004)	(0.046)	(0.023)	(0.006)	(9.539)	(0.00)				
Energy	0.953	9.195	0.386	1.568	0.966	17.793	19.32	2.161	1.008	551.7	1.069
	(0.003)	(3.343)	(0.184)	(0.020)	(0.005)	(8.356)	(0.00)				
Chemicals	0.963	10.748	0.264	1.457	0.954	43.935	50.52	1.729	1.006	208.1	1.065
	(0.003)	(3.264)	(0.102)	(0.018)	(0.006)	(15.457)	(0.00)				
Business equipment	0.970	11.039	0.348	1.709	0.929	6.260	205	1.736	1.021	254.5	1.228
	(0.004)	(1.996)	(0.085)	(0.018)	(0.005)	(1.296)	(0.00)				
Shops	0.892	10.119	0.395	1.636	0.926	30.667	45.88	1.898	1.005	344.7	1.050
	(0.012)	(1.691)	(0.092)	(0.030)	(0.007)	(7.894)	(0.00)				
Healthcare	0.949	4.927	0.696	1.461	0.980	3.995	118.23	5.517	1.029	818.2	1.117
	(0.005)	(0.429)	(0.109)	(0.026)	(0.002)	(0.968)	(0.00)				

Table H17

Long-term effects of CEOs ($\lambda = 0.5$): CEO Impact.

This table shows the results of the counterfactual experiment of CEO replacement at the median-sized firm using the parameter estimates in Table H16.

Industry sector	$\frac{\Delta\Pi}{\Pi[0.5]}$ (%)	$\frac{\Delta\mathcal{V}}{\mathcal{V}[0.5]}$ (%)	$\frac{\Delta u/(1-\beta\delta)}{\mathcal{V}[0.5]}$ (%)
Consumer nondurables	1.96	2.01	8.95
Consumer durables	2.50	2.57	23.60
Manufacturing	1.98	2.02	10.00
Energy	2.00	2.05	13.02
Chemicals	1.83	1.88	8.26
Business equipment	7.56	8.30	39.69
Shops	1.58	1.61	7.14
Healthcare	3.35	3.48	24.73

Table H18

Imperfect intra-industry transferability of CEO ability: Sensitivities of moments with respect to parameters.

This table shows the signs of the sensitivities of the 13 moments (see Table 3 for their definitions) with respect to the parameters of the extended model in Appendix E.1, including those in the basic model and the additional parameter τ (the degree of imperfect transferability of CEO ability).

	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}	M_{13}
φ	-	0	-	0	0	0	0	0	0	0	0	-	0
σ	-	+	-	+	+	+	+	+	+	+	+	-	-
α	-	+	-	+	+	+	+	+	+	+	+	-	0
ν	+	-	-	-	-	-	-	?	?	?	?	-	0
c_1	-	-	-	+	+	+	+	+	+	+	+	-	0
c_2	-	-	-	-	-	-	-	?	?	?	?	-	0
τ	-	+	?	+	+	+	+	+	+	+	+	+	0

Table H19

Imperfect intra-industry transferability of CEO ability: Parameter estimates, firm quality and CEO talent ratios, as well as firm size and CEO factor ratios.

This table shows the parameter estimates along with their standard errors in parentheses from the estimation of the extended model in Appendix E.1 that incorporates imperfect transferability of CEO ability across firms within the same industry. We also report the χ^2 statistics and corresponding p-values in parentheses for the J-test of the model's overidentifying restrictions. The next two columns report the ratios of the firm qualities and CEO talents of the largest and smallest S&P 1500 firms in the industry. The last two columns show the ratios of their sizes and CEO factors.

Industry sector	φ	σ	α	ν	c_1	c_2	τ	χ^2 (p-value)	$x[1]/x[0]$	$y[1]/y[0]$	$\tilde{x}[1]/\tilde{x}[0]$ $= (x[1]/x[0])^{\sigma-1}$	$\tilde{y}[1]/\tilde{y}[0]$ $= (y[1]/y[0])^{\sigma-1}$
Consumer nondurables	0.941	7.283	0.536	2.050	0.945	17.553	0.011	9.82	2.673	1.007	481.5	1.044
	(0.003)	(1.151)	(0.128)	(0.277)	(0.008)	(4.382)	(0.003)	(0.13)				
Consumer durables	0.958	8.190	0.364	1.592	0.986	30.970	0.010	44.50	2.843	1.006	1,832.3	1.043
	(0.075)	(4.275)	(0.248)	(1.055)	(0.026)	(16.327)	(0.011)	(0.00)				
Manufacturing	0.940	10.366	0.321	1.433	0.929	45.274	0.001	32.51	1.771	1.006	211.1	1.053
	(0.010)	(2.717)	(0.114)	(0.257)	(0.007)	(27.982)	(0.002)	(0.00)				
Energy	0.934	9.301	0.340	1.591	0.968	43.001	0.005	32.92	2.168	1.004	615.6	1.030
	(0.007)	(3.014)	(0.134)	(0.264)	(0.006)	(18.459)	(0.002)	(0.00)				
Chemicals	0.965	10.791	0.275	1.496	0.952	42.320	1.00E-06	70.45	1.757	1.006	249.1	1.063
	(0.027)	(3.065)	(0.115)	(0.044)	(0.063)	(24.052)	(5.98E-06)	(0.00)				
Business equipment	0.970	11.137	0.244	1.507	0.972	9.670	0.009	199.75	1.801	1.017	388.3	1.191
	(0.006)	(2.480)	(0.068)	(0.179)	(0.008)	(2.758)	(0.006)	(0.00)				
Shops	0.909	13.647	0.262	1.658	0.931	51.745	1.01E-06	49.46	1.591	1.004	354.6	1.047
	(0.019)	(5.311)	(0.125)	(0.043)	(0.054)	(23.264)	(4.79E-06)	(0.00)				
Healthcare	0.972	4.907	0.709	1.677	0.981	3.455	0.049	124.43	5.580	1.025	825.6	1.101
	(0.006)	(0.563)	(0.135)	(0.197)	(0.004)	(1.115)	(0.016)	(0.00)				

Table H20

Imperfect intra-industry transferability of CEO ability: CEO Impact.

This table shows the results of the counterfactual experiment of CEO replacement at the median-sized firm using the parameter estimates in Table H19.

Industry sector	$\frac{\Delta\Pi}{\Pi[0.5]}(\%)$	$\frac{\Delta\mathcal{V}}{\mathcal{V}[0.5]}(\%)$	$\frac{\Delta u/(1-\beta\delta)}{\mathcal{V}[0.5]}(\%)$
Consumer nondurables	0.83	0.85	13.81
Consumer durables	1.40	1.44	44.91
Manufacturing	1.90	1.95	11.53
Energy	0.79	0.80	11.48
Chemicals	1.81	1.86	9.28
Business equipment	5.35	5.85	46.62
Shops	1.31	1.34	6.71
Healthcare	3.12	3.33	63.00

Table H21

Imperfect inter-industry transferability of CEO ability: Model parameters.

This table provides the description of additional parameters in the extended model with imperfect inter-industry transferability of CEO ability in Appendix E.2 that incorporates both general and industry-specific components of CEO ability.

Parameter	Description
$\underline{y}_1, \underline{y}_2, \underline{y}\ (= \underline{y}_1 + \underline{y}_2)$	Minimum levels of general, industry-specific, and total CEO ability
$\overline{y}_1, \overline{y}_2, \overline{y}\ (= \overline{y}_1 + \overline{y}_2)$	Maximum levels of general, industry-specific, and total CEO ability
ν_1, ν_2	Tail indices in the distributions of general and industry-specific CEO talent components

Table H22

Imperfect inter-industry transferability of CEO ability: Sensitivities of moments with respect to industry-specific parameters.

This table shows the signs of the sensitivities of the 13 moments (see Table 3 for their definitions) with respect to the industry-specific parameters of the model.

	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}	M_{13}
$\overline{y}_2$	+	-	+	?	?	?	-	+	+	+	+	+	0
φ	-	0	-	0	0	0	0	0	0	0	0	-	0
σ	-	+	-	+	+	+	+	+	+	+	+	-	-
α	-	+	-	+	+	+	+	+	+	+	+	-	0
c_1	-	-	-	+	+	+	+	+	+	+	+	-	0
ν_2	+	-	-	-	-	-	-	-	-	-	-	-	0

Table H23

Imperfect inter-industry transferability of CEO ability: Sensitivities of moments with respect to general ability parameters.

This table shows the signs of the sensitivities of the 13 moments (see Table 3 for their definitions) across different industries with respect to the general ability parameters.

Industry sector		M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}	M_{13}
Consumer nondurables	$\overline{y}_1$	-	+	+	+	+	+	+	-	+	+	+	+	0
	ν_1	+	-	-	-	-	-	-	0	0	0	-	-	0
Consumer durables	$\overline{y}_1$	-	-	-	-	-	-	+	-	-	-	-	-	0
	ν_1	+	-	-	-	-	-	-	0	0	0	-	-	0
Manufacturing	$\overline{y}_1$	-	+	-	-	-	-	+	-	-	-	-	-	0
	ν_1	+	-	-	-	-	-	-	0	0	0	-	-	0
Energy	$\overline{y}_1$	-	+	-	+	+	+	+	-	-	-	-	+	0
	ν_1	+	-	-	-	-	-	-	0	0	0	-	-	0
Chemicals	$\overline{y}_1$	-	-	-	-	-	-	+	-	-	-	-	-	0
	ν_1	+	-	-	-	-	-	-	0	0	0	-	-	0
Business equipment	$\overline{y}_1$	-	+	+	-	-	+	+	-	-	-	+	+	0
	ν_1	+	-	-	-	-	-	-	0	0	0	-	-	0
Shops	$\overline{y}_1$	-	+	-	+	+	+	+	-	-	-	+	+	0
	ν_1	+	-	-	-	-	-	-	0	0	0	-	-	0
Healthcare	$\overline{y}_1$	-	+	+	-	-	+	+	-	-	-	+	+	0
	ν_1	+	-	-	-	-	-	-	0	0	0	-	-	0

Table H24

Imperfect inter-industry transferability of CEO ability: Parameter estimates, firm quality and CEO talent ratios, as well as firm size and CEO factor ratios.

This table shows the parameter estimates, along with their standard errors in parentheses, from the estimation of the extended model with imperfect inter-industry transferability of CEO ability in Appendix E.2. The estimation jointly matches the moments that we employ in our baseline estimation (see Table 3 for their definitions) across industries. The definition of the additional parameters in this extended model is in the description of Table H21. We set the minimum levels of the general and industry-specific components of CEO ability to 0.5, $\underline{y}_1 = \underline{y}_2 = 0.5$, because the equilibrium variables depend only on the dispersion of each talent component. Panels A and B report the estimates of the general ability and industry-specific parameters, respectively. In Panel B, we also report the ratios of the firm qualities and total CEO talents of the largest and smallest S&P 1500 firms in the industry. The last two columns of Panel B show the ratios of their sizes and CEO factors. Panel C reports the χ^2 statistic and corresponding p-value in parenthesis for the J-test of the model's overidentifying restrictions.

Panel A: General ability parameters

$\overline{y}_1$	ν_1
0.506	4.173
(0.002)	(0.083)

Panel B: Industry-specific parameter estimates, firm quality and CEO talent ratios, as well as firm size and CEO factor ratios

Industry sector	$\overline{y}_2$	φ	σ	α	c_1	ν_2	$x[1]/x[0]$	$y[1]/y[0]$	$\tilde{x}[1]/\tilde{x}[0]$ $= (x[1]/x[0])^{\sigma-1}$	$\tilde{y}[1]/\tilde{y}[0]$ $= (y[1]/y[0])^{\sigma-1}$
Consumer nondurables	0.564	0.931	7.412	0.607	0.914	1.771	2.561	1.009	416	1.061
	(0.010)	(0.005)	(0.777)	(0.089)	(0.006)	(0.125)				
Consumer durables	0.511	0.884	13.600	0.242	0.967	1.757	1.714	1.003	890.9	1.035
	(0.009)	(0.058)	(10.099)	(0.227)	(0.015)	(0.059)				
Manufacturing	0.515	0.905	9.342	0.379	0.928	1.531	1.952	1.004	265	1.036
	(0.007)	(0.015)	(1.892)	(0.095)	(0.007)	(0.112)				
Energy	0.520	0.912	9.173	0.366	0.961	1.484	2.125	1.004	474.3	1.031
	(0.013)	(0.010)	(4.021)	(0.209)	(0.006)	(0.162)				
Chemicals	0.513	0.976	19.717	0.131	0.961	1.686	1.336	1.004	226.8	1.075
	(0.008)	(0.007)	(11.141)	(0.087)	(0.008)	(0.087)				
Business equipment	0.694	0.963	7.486	0.473	0.955	1.104	2.431	1.033	317.5	1.236
	(0.027)	(0.003)	(0.793)	(0.070)	(0.002)	(0.033)				
Shops	0.517	0.911	15.703	0.227	0.930	2.024	1.489	1.003	348	1.048
	(0.008)	(0.018)	(5.621)	(0.100)	(0.007)	(0.094)				
Healthcare	0.835	0.959	4.641	0.849	0.975	1.146	6.135	1.038	738.7	1.144
	(0.094)	(0.004)	(0.421)	(0.118)	(0.002)	(0.035)				

Panel C: J-test of overidentifying restrictions

$\chi^2 = 325.95$ (p-value = 0.00)

Table H25

Imperfect inter-industry transferability of CEO ability: CEO Impact.

This table shows the results of the counterfactual experiment of CEO replacement at the median-sized firm that we compute using the parameter estimates in Table H24.

Industry sector	$\frac{\Delta\Pi}{\Pi[0.5]}$ (%)	$\frac{\Delta\mathcal{V}}{\mathcal{V}[0.5]}$ (%)	$\frac{\Delta u/(1-\beta\delta)}{\mathcal{V}[0.5]}$ (%)
Consumer nondurables	1.51	1.54	8.15
Consumer durables	1.20	1.22	10.06
Manufacturing	1.39	1.41	6.95
Energy	1.05	1.06	6.27
Chemicals	2.29	2.38	9.90
Business equipment	8.39	9.12	44.98
Shops	1.38	1.41	7.63
Healthcare	4.37	4.61	32.36

Table H26

Parametric bootstrapping: Parameter estimates, firm quality and CEO talent ratios, as well as firm size and CEO factor ratios.

As described in Appendix F.1, we use our model to generate fictitious data panels by injecting random noise in each period. We then run our baseline estimation for each of the 5,000 bootstrapped samples. The first column reports the actual correlation between firm size ranks and CEO pay ranks from the data over the period 1993-2010 (first line) and the mean correlation across the bootstrapped samples (second line). The next columns report the means and standard errors (second line) of parameter estimates. The last four columns report the mean ratios of firm qualities, CEO talents, firm sizes, and CEO factors between the largest and smallest S&P 1500 firms in the industry across the 5,000 bootstrapped estimation results.

Industry sector	Corr($q_{\mathcal{V}}, q_u$)	φ	σ	α	ν	c_1	c_2	$x[1]/x[0]$	$y[1]/y[0]$	$\tilde{x}[1]/\tilde{x}[0]$ $= (x[1]/x[0])^{\sigma-1}$	$\tilde{y}[1]/\tilde{y}[0]$ $= (y[1]/y[0])^{\sigma-1}$
Consumer nondurables	0.694	0.903	7.420	0.597	1.758	0.918	18.811	2.587	1.009	446.7	1.057
	0.697	(0.008)	(0.291)	(0.032)	(0.073)	(0.002)	(0.656)				
Consumer durables	0.746	0.938	12.283	0.255	1.535	0.972	37.674	1.825	1.006	888.1	1.065
	0.713	(0.007)	(0.253)	(0.005)	(0.054)	(0.001)	(1.484)				
Manufacturing	0.723	0.914	9.429	0.350	1.379	0.935	44.331	1.918	1.006	242.3	1.052
	0.725	(0.006)	(0.263)	(0.011)	(0.055)	(0.002)	(2.183)				
Energy	0.745	0.896	9.988	0.378	1.471	0.952	39.123	2.027	1.004	573.5	1.040
	0.700	(0.024)	(0.600)	(0.025)	(0.185)	(0.005)	(7.257)				
Chemicals	0.809	0.961	9.303	0.273	1.421	0.967	47.581	1.898	1.006	204.4	1.054
	0.738	(0.010)	(1.050)	(0.040)	(0.149)	(0.008)	(11.628)				
Business equipment	0.625	0.937	10.549	0.276	1.458	0.966	11.905	1.804	1.012	279.7	1.123
	0.573	(0.014)	(0.643)	(0.020)	(0.077)	(0.002)	(1.843)				
Shops	0.620	0.879	13.549	0.268	1.610	0.930	51.013	1.599	1.004	362.1	1.050
	0.632	(0.011)	(0.490)	(0.012)	(0.057)	(0.002)	(2.021)				
Healthcare	0.735	0.939	4.872	0.760	1.618	0.978	3.439	5.590	1.026	783.3	1.105
	0.643	(0.007)	(0.113)	(0.022)	(0.075)	(0.001)	(0.188)				

Table H27

Parametric bootstrapping: CEO Impact.

This table shows the mean results of the counterfactual experiment of CEO replacement at the median-sized firm that we obtain using the 5,000 sets of bootstrapped parameter estimates.

Industry sector	$\frac{\Delta\Pi}{\Pi[0.5]}$ (%)	$\frac{\Delta\mathcal{V}}{\mathcal{V}[0.5]}$ (%)	$\frac{\Delta u/(1-\beta\delta)}{\mathcal{V}[0.5]}$ (%)
Consumer nondurables	1.26	1.28	5.93
Consumer durables	2.10	2.16	20.10
Manufacturing	1.92	1.97	11.32
Energy	1.29	1.31	10.00
Chemicals	1.67	1.72	8.20
Business equipment	4.42	4.70	27.12
Shops	1.45	1.48	7.74
Healthcare	3.20	3.35	26.94

Table H28

Non-parametric bootstrapping: Parameter estimates, firm quality and CEO talent ratios, as well as firm size and CEO factor ratios.

As described in Appendix F.2, we apply our baseline estimation approach described in Section 4.2.2 for each of the 5,000 bootstrapped samples drawn from the actual data with replacement. The table reports the means and standard errors (second line) of parameter estimates, and the mean ratios of firm qualities, CEO talents, firm sizes, and CEO factors between the largest and smallest S&P 1500 firms in the industry across the 5,000 bootstrapped estimation results.

Industry sector	φ	σ	α	ν	c_1	c_2	$x[1]/x[0]$	$y[1]/y[0]$	$\tilde{x}[1]/\tilde{x}[0]$	$\tilde{y}[1]/\tilde{y}[0]$
									$= (x[1]/x[0])^{\sigma-1}$	$= (y[1]/y[0])^{\sigma-1}$
Consumer nondurables	0.935	8.519	0.555	1.761	0.905	18.388	2.435	1.010	805.1	1.080
	(0.029)	(3.035)	(0.153)	(0.251)	(0.054)	(10.908)				
Consumer durables	0.952	15.259	0.242	1.469	0.936	35.698	1.660	1.010	1,374.8	1.152
	(0.043)	(6.610)	(0.102)	(0.265)	(0.084)	(27.212)				
Manufacturing	0.941	11.302	0.327	1.459	0.918	44.462	1.787	1.006	395	1.067
	(0.024)	(3.619)	(0.092)	(0.172)	(0.050)	(17.498)				
Energy	0.929	10.821	0.354	1.478	0.946	39.201	1.995	1.006	882.6	1.057
	(0.046)	(3.584)	(0.114)	(0.265)	(0.040)	(25.049)				
Chemicals	0.966	11.849	0.280	1.553	0.934	40.813	1.776	1.008	508	1.088
	(0.018)	(4.238)	(0.101)	(0.250)	(0.065)	(19.588)				
Business equipment	0.973	11.879	0.276	1.488	0.946	10.484	1.673	1.019	269.7	1.223
	(0.017)	(3.647)	(0.088)	(0.201)	(0.041)	(6.598)				
Shops	0.920	14.054	0.270	1.621	0.912	51.925	1.555	1.005	318.5	1.062
	(0.039)	(3.588)	(0.078)	(0.173)	(0.042)	(24.566)				
Healthcare	0.964	5.956	0.701	1.665	0.968	3.366	4.294	1.029	1,368.4	1.151
	(0.014)	(1.557)	(0.163)	(0.230)	(0.017)	(1.775)				

Table H29

Non-parametric bootstrapping: CEO Impact.

This table shows the mean results of the counterfactual experiment of CEO replacement at the median-sized firm that we obtain using the 5,000 sets of bootstrapped parameter estimates.

Industry sector	$\frac{\Delta\Pi}{\Pi[0.5]}$ (%)	$\frac{\Delta\mathcal{V}}{\mathcal{V}[0.5]}$ (%)	$\frac{\Delta u/(1-\beta\delta)}{\mathcal{V}[0.5]}$ (%)
Consumer nondurables	1.78	1.85	8.64
Consumer durables	4.99	5.90	37.18
Manufacturing	2.39	2.51	12.68
Energy	1.82	1.91	12.28
Chemicals	2.53	2.72	13.03
Business equipment	7.90	9.64	44.12
Shops	1.80	1.88	8.18
Healthcare	4.26	4.57	34.76

Table H30

Alternate CEO pay measure: Parameter estimates, firm quality and CEO talent ratios, as well as firm size and CEO factor ratios.

This table shows the results of the estimation of the basic model using the alternate CEO pay measure that includes the value of stock and option grants in the year they are vested, not in the year they are granted (Taylor, 2013). We also report the χ^2 statistics and corresponding p-values in parentheses for the J-test of the model's overidentifying restrictions. The next two columns report the ratios of the firm qualities and CEO talents of the largest and smallest S&P 1500 firms in the industry. The last two columns show the ratios of their sizes and CEO factors.

Industry sector	$\tilde{u}$	φ	σ	α	ν	c_1	c_2	χ^2 (p-value)	$x[1]/x[0]$	$y[1]/y[0]$	$\tilde{x}[1]/\tilde{x}[0]$ $= (x[1]/x[0])^{\sigma-1}$	$\tilde{y}[1]/\tilde{y}[0]$ $= (y[1]/y[0])^{\sigma-1}$
Consumer nondurables	0.215	0.939	7.948	0.601	1.761	0.901	13.076	13.19	2.177	1.010	222.8	1.073
		(0.004)	(1.320)	(0.129)	(0.038)	(0.004)	(3.185)	(0.07)				
Consumer durables	0.163	0.938	9.957	0.351	1.393	0.957	33.268	79.77	2.108	1.007	797.1	1.060
		(0.010)	(2.403)	(0.108)	(0.032)	(0.003)	(10.899)	(0.00)				
Manufacturing	0.194	0.927	8.289	0.392	1.373	0.947	34.198	91.28	2.130	1.007	247.2	1.050
		(0.007)	(1.063)	(0.069)	(0.020)	(0.004)	(5.589)	(0.00)				
Energy	0.224	0.924	8.858	0.377	1.432	0.964	33.282	25.57	2.201	1.005	492.3	1.038
		(0.009)	(2.896)	(0.164)	(0.038)	(0.004)	(12.878)	(0.00)				
Chemicals	0.224	0.955	8.056	0.429	1.352	0.935	38.431	47.82	1.936	1.007	105.9	1.052
		(0.011)	(1.315)	(0.096)	(0.024)	(0.009)	(17.988)	(0.00)				
Business equipment	0.182	0.952	9.186	0.455	1.434	0.938	7.577	168.38	2.015	1.017	309.9	1.152
		(0.008)	(1.342)	(0.098)	(0.024)	(0.005)	(1.192)	(0.00)				
Shops	0.195	0.910	14.721	0.245	1.402	0.916	54.179	53.45	1.437	1.004	145.2	1.051
		(0.018)	(3.539)	(0.077)	(0.033)	(0.009)	(12.344)	(0.00)				
Healthcare	0.205	0.970	5.884	0.580	1.542	0.983	3.730	164.04	3.618	1.025	534.0	1.130
		(0.002)	(0.789)	(0.128)	(0.024)	(0.002)	(1.024)	(0.00)				

Table H31

Alternate CEO pay measure: CEO Impact.

This table shows the results of the counterfactual experiment of CEO replacement at the median-sized firm using the parameter estimates in Table H30.

Industry sector	$\frac{\Delta\Pi}{\Pi[0.5]}$(%)	$\frac{\Delta\mathcal{V}}{\mathcal{V}[0.5]}$(%)	$\frac{\Delta u/(1-\beta\delta)}{\mathcal{V}[0.5]}$(%)
Consumer nondurables	1.64	1.68	6.42
Consumer durables	2.25	2.30	22.13
Manufacturing	1.93	1.98	11.87
Energy	1.07	1.09	6.70
Chemicals	1.46	1.49	5.35
Business equipment	5.34	5.63	34.32
Shops	1.80	1.84	8.11
Healthcare	3.59	3.78	27.18

Table H32

Alternate price-cost margin measure: Parameter estimates, firm quality and CEO talent ratios, as well as firm size and CEO factor ratios.

This table shows the results of the estimation of the basic model using the alternate measure of price-cost margin in which operating costs includes only the costs of goods sold. We also report the χ^2 statistics and corresponding p-values in parentheses for the J-test of the model's overidentifying restrictions. The next two columns report the ratios of the firm qualities and CEO talents of the largest and smallest S&P 1500 firms in the industry. The last two columns show the ratios of their sizes and CEO factors.

Industry sector	φ	σ	α	ν	c_1	c_2	χ^2 (p-value)	$x[1]/x[0]$	$y[1]/y[0]$	$\tilde{x}[1]/\tilde{x}[0] = (x[1]/x[0])^{\sigma-1}$	$\tilde{y}[1]/\tilde{y}[0] = (y[1]/y[0])^{\sigma-1}$
Consumer nondurables	0.978	4.295	0.711	1.734	0.991	6.309	283.62	5.090	1.025	213.1	1.084
	(0.004)	(0.547)	(0.155)	(0.033)	(0.004)	(1.597)	(0.00)				
Consumer durables	0.969	8.314	0.348	1.597	0.986	23.783	50.85	2.393	1.008	591.1	1.057
	(0.016)	(4.177)	(0.263)	(0.090)	(0.016)	(12.827)	(0.00)				
Manufacturing	0.813	4.026	0.805	1.234	0.954	48.530	26.55	5.695	1.006	193.2	1.018
	(0.042)	(0.140)	(0.038)	(0.025)	(0.005)	(13.455)	(0.00)				
Energy	0.947	9.399	0.390	1.622	0.953	29.308	57.95	1.999	1.004	336.7	1.034
	(0.004)	(3.762)	(0.212)	(0.026)	(0.006)	(15.755)	(0.00)				
Chemicals	0.929	4.162	1.000	1.692	0.917	30.650	228.22	4.982	1.009	160.4	1.028
	(0.007)	(0.286)	(0.133)	(0.022)	(0.008)	(7.443)	(0.00)				
Business equipment	0.869	3.540	0.784	1.262	0.985	14.188	529.47	9.641	1.013	316.2	1.034
	(0.025)	(0.070)	(0.028)	(0.022)	(0.001)	(2.770)	(0.00)				
Shops	0.931	13.457	0.217	1.801	0.962	47.314	179.38	1.620	1.003	407.6	1.036
	(0.016)	(3.932)	(0.080)	(0.032)	(0.004)	(11.836)	(0.00)				
Healthcare	0.963	6.227	0.475	1.460	0.984	4.495	244.22	3.168	1.023	415	1.125
	(0.008)	(1.720)	(0.175)	(0.035)	(0.003)	(0.805)	(0.00)				

Table H33

Alternate price-cost margin measure: CEO Impact.

This table shows the results of the counterfactual experiment of CEO replacement at the median-sized firm using the parameter estimates in Table H32.

Industry sector	$\frac{\Delta\Pi}{\Pi[0.5]}$ (%)	$\frac{\Delta\mathcal{V}}{\mathcal{V}[0.5]}$ (%)	$\frac{\Delta u/(1-\beta\delta)}{\mathcal{V}[0.5]}$ (%)
Consumer nondurables	2.53	2.67	13.65
Consumer durables	2.09	2.16	18.43
Manufacturing	0.63	0.64	3.22
Energy	1.05	1.06	5.93
Chemicals	0.75	0.76	3.04
Business equipment	1.41	1.44	9.64
Shops	1.02	1.04	5.07
Healthcare	4.12	4.38	30.13

Table H34

Alternate industry classification (Hoberg-Phillips industries): Parameter estimates, firm quality and CEO talent ratios, as well as firm size and CEO factor ratios.

This table shows the parameter estimates from the estimation of the basic model, along with their standard errors in parentheses, for HP 10-K Text-based Fixed Industry Classifications (FIC) 50 industries. Among them, we consider only 12 different industry sectors that have a sufficient number of observations per year over the sample period 1996-2008 and do not include firms in the financial, regulated, or miscellaneous industries predominantly. The next two columns report the ratios of the firm qualities and CEO talents of the largest and smallest S&P 1500 firms in the industry. The last two columns show the ratios of their sizes and CEO factors.

Industry sector	No. of firms (n)	$\tilde{u}$	φ	σ	α	ν	c_1	c_2	χ^2 (p-value)	$x[1]/x[0]$	$y[1]/y[0]$	$\tilde{x}[1]/\tilde{x}[0]$ $= (x[1]/x[0])^{\sigma-1}$	$\tilde{y}[1]/\tilde{y}[0]$ $= (y[1]/y[0])^{\sigma-1}$
HP 1	53	0.148	0.936	12.300	0.298	1.691	0.930	54.724	5.66	1.712	1.004	435.7	1.050
			(0.008)	(2.245)	(0.087)	(0.040)	(0.026)	(8.888)	(0.58)				
HP 2	61	0.165	0.932	6.937	0.499	1.477	0.969	13.557	17.91	3.069	1.013	779	1.079
			(0.007)	(0.948)	(0.121)	(0.041)	(0.007)	(2.959)	(0.01)				
HP 3	99	0.162	0.963	10.338	0.301	1.392	0.919	25.261	58.57	1.758	1.016	194.1	1.158
			(0.008)	(1.535)	(0.054)	(0.015)	(0.006)	(4.798)	(0.00)				
HP 5	61	0.183	0.928	10.495	0.359	1.263	0.905	46.897	90.54	1.684	1.007	141.2	1.064
			(0.020)	(4.108)	(0.187)	(0.031)	(0.009)	(29.151)	(0.00)				
HP 6	88	0.160	0.940	11.904	0.282	1.528	0.943	55.810	28.65	1.597	1.003	164.5	1.032
			(0.010)	(4.088)	(0.127)	(0.031)	(0.008)	(20.151)	(0.00)				
HP 7	91	0.175	0.928	13.629	0.260	1.394	0.863	77.160	69.95	1.414	1.004	79.5	1.058
			(0.026)	(3.577)	(0.083)	(0.032)	(0.009)	(12.745)	(0.00)				
HP 8	81	0.170	0.943	11.428	0.269	1.540	0.970	42.832	61.67	2.026	1.006	1,579.7	1.065
			(0.007)	(3.327)	(0.099)	(0.015)	(0.003)	(11.229)	(0.00)				
HP 10	69	0.188	0.962	5.251	0.775	1.687	0.974	3.382	57.86	5.399	1.025	1,297.3	1.113
			(0.008)	(0.453)	(0.124)	(0.023)	(0.006)	(0.809)	(0.00)				
HP 11	55	0.171	0.912	12.641	0.217	1.040	0.929	91.996	43.83	1.431	1.004	64.9	1.045
			(0.021)	(1.523)	(0.034)	(0.046)	(0.004)	(31.036)	(0.00)				
HP 14	59	0.173	0.966	4.973	0.776	1.584	0.967	3.334	73.84	5.439	1.042	835.8	1.177
			(0.003)	(0.566)	(0.138)	(0.027)	(0.003)	(0.824)	(0.00)				
HP 25	57	0.182	0.942	13.298	0.193	1.292	0.979	107.439	58.75	1.844	1.004	1,859.2	1.049
			(0.018)	(5.632)	(0.100)	(0.023)	(0.005)	(22.216)	(0.00)				
HP 42	61	0.214	0.921	8.686	0.377	1.537	0.937	42.727	41.75	2.035	1.006	235.2	1.047
			(0.005)	(0.742)	(0.037)	(0.029)	(0.003)	(5.933)	(0.00)				

Table H35

Alternate industry classification (Hoberg-Phillips industries): CEO Impact.

This table shows the results of the counterfactual experiment of CEO replacement at the median-sized firm using the parameter estimates in Table H34.

Industry sector	$\frac{\Delta\Pi}{\Pi[0.5]}(\%)$	$\frac{\Delta\mathcal{V}}{\mathcal{V}[0.5]}(\%)$	$\frac{\Delta u/(1-\beta\delta)}{\mathcal{V}[0.5]}(\%)$
HP 1	1.55	1.58	9.55
HP 2	2.19	2.25	17.25
HP 3	4.34	4.57	20.51
HP 5	2.88	2.95	16.65
HP 6	1.04	1.05	4.77
HP 7	2.00	2.05	7.19
HP 8	2.18	2.24	23.82
HP 10	3.00	3.12	27.09
HP 11	1.99	2.03	8.31
HP 14	4.96	5.28	40.60
HP 25	1.60	1.63	20.38
HP 42	1.12	1.14	4.87

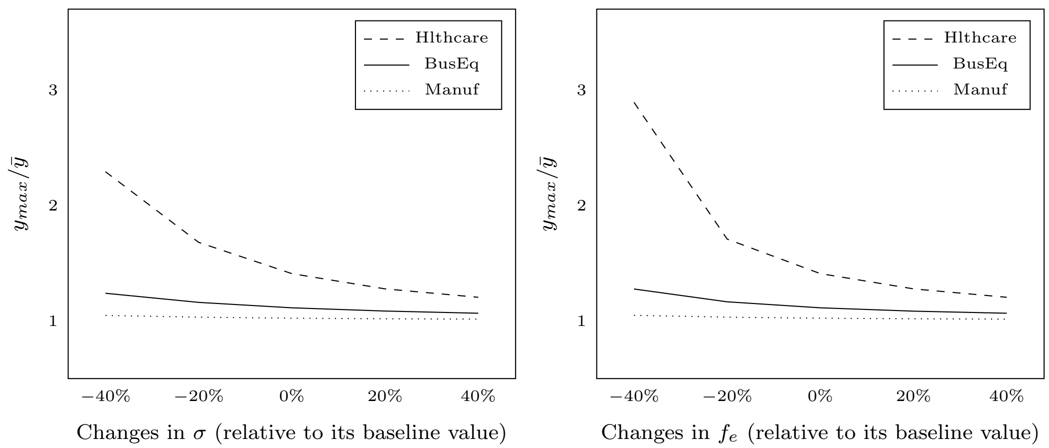

Fig. H1. CEO-firm matching and the product market: Ex post CEO talent dispersions. In Appendix G, we extend the basic model by incorporating the possibility that the mass of potential CEOs exceeds the mass of actual CEOs who successfully match with firms operating in the product market. Under reasonable assumptions, there is a unique equilibrium in which only CEOs with abilities above a cutoff level ($\bar{y}$) are matched to firms, which endogenizes the talent profile of actual CEOs, that is, ex post talent profile. This figure shows the variation in the ex post talent dispersion of matched CEOs ($y_{max}/\bar{y}$) for the manufacturing, business equipment, and healthcare industries when product market characteristics (σ and f_e) change in the respective industry.