Using Global Shocks to Understand the Level and Structure of Executive Compensation*

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Abstract

We build a model of CEO compensation that unites principal-agent and assignment models in the face of trade shocks that interact with CEO effort to change the value of the firm. The model predicts that globalization changes CEO compensation through scale, volatility, and ability-magnification channels. Using Danish matched worker-firm data, we find empirical support for these channels: (1) Exogenous shocks to trade increase the size and value of the firm and CEO compensation; (2) the share of firm value paid to the CEO is increasing in the size and value of the firm and increasing in the volatility induced by global shocks; (3) Higher-ability CEOs are paid more and generate value to the firm far in excess of that compensation through a combination of mitigating losses and maximizing the return to positive shocks.

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1 Introduction

We build a model of CEO compensation that unites principal-agent and assignment models in the face of trade shocks that interact with CEO effort to change the value of the firm. This yields predictions about the level and structure of CEO compensation, the returns to CEO ability, and how each is affected by the shocks to the value of the firm. We then use exogenous shocks to the importing and exporting activities of Danish firms as a laboratory to study executive compensation, including its effects on scale, volatility, and the returns to ability.

In the compensation model, CEOs are heterogeneous in ability, and the value of the firm is subject to both multiplicative shocks that interact with CEO effort and additive shocks that don't interact with effort. In the standard principal-agent solution with additive shocks (Edmans et al., 2017), CEOs are paid a fixed fee along with a share of firm value, where the share of value is falling in the variance of additive shocks hitting the firms. More volatile shocks make it more difficult to extract the signal of CEO effort from the noise of volatility, so firms share less of the changing value with the CEO.

In our setting, the CEO's share of firm value depends on the relative variance of the interactive and additive shocks. The larger the additive shock, the lower the CEO's share in firm value (as in the previous literature), but the larger the interactive shock, the higher the CEO's share in firm value. The reason is that, with an interactive shock, the firm wants the CEO to exert more effort precisely in the periods where the shock has the greatest value, i.e., to maximize the return on good news.

CEOs vary in their ability (the cost of exerting effort), and the return to a positive shock is greatest when effort is high. This has two implications. One, a higher ability CEO can transform a given shock into greater value for the firm. Two, the better the CEO and the larger the firm, the more weight one puts on interactive shocks, and the higher the share of value given to the CEO.

In our model, global shocks can affect CEO compensation in three ways. They can change the value of the firm, which translates to changes in pay the CEOs receives over the job-spell. They can increase the relative volatility of interactive shocks compared to additive shocks. This changes the structure of CEO compensation to put more weight on performance and leads to greater within job-spell variation in pay. And they change the return to effort, so that high ability CEOs have a larger effect on the resulting value of the firm.

We take these predictions to matched worker-firm data from Denmark that are unique in several ways relative to much of this literature. First, we observe both privately-held and

publicly traded firms. Second, we see executive transitions between firms, which provides us with measures of CEO premia, and an opportunity to measure individual ability prior to promotion to CEO. Three, we observe detailed offshoring and exporting activity by the firm, and can construct firm-specific instruments arising from shocks to the world trade environment. These shocks are particularly important in context as more than half of firm growth in our sample arises from export sales. We can then exploit exogenous variation in trade, as well as exogenous changes in firms' size and volatility, to test model predictions.

We find strong support for most of the model predictions and some provocative findings that differ from them. Larger firms pay CEOs more, and pay a larger CEO premia, with an elasticity remarkably similar to that found for publicly traded firms in the US. Changes in firm size and value arising from exogenous global shocks translate to rising CEO pay within job-spell. This identifies a key parameter highlighted in the literature—the share of firm value that is paid to a CEO to induce greater effort. Consistent with model predictions, this share is increasing in the size of firms and in the volatility of firm value arising from (interactive) global shocks.

Finally, we employ two pre-determined measures of CEO ability: experience (both prior experience in the job market and experience as CEO in this firm), and an estimated individual AKM fixed effect (Abowd et al., 1999) identified from worker transitions between firms. We find that better CEOs sort into larger and higher valued firms, consistent with assignment models, and that these measures of ability correspond to higher CEO pay.

We then examine whether better CEOs enable firms to translate exogenous shocks into greater success for the firm. We find that when firms transition to new CEOs with higher AKM fixed effects, the CEOs are paid more but do not generate higher value, or translate shocks into better outcomes. We find that when firms transition to more experienced CEOs (or within job spells, as the same CEO gains more experience) this experience translates to higher pay, and better sales and value. We also find find a strong interaction between ability and exogenous global shocks. More experienced CEOs generate larger increases in sales in the face of positive demand shocks, and also mitigate adverse outcomes in the face of negative demand shocks. They do not, however, generate better responses to supply shocks, or generate sustained changes in firm value in the face of demand or supply shocks.

Our research contributes to a broad literature that studies CEO compensation. We next discuss our relationship to three broad themes in that literature: studies of the level and structure of pay in principal-agent and assignment models; studies that measure CEO ability and its links to managerial approach and performance; and studies assessing the impact of

globalization on CEO pay.

The principal agent literature focuses on the structure of executive compensation when firm value depends on unobservable CEO effort and unobserved shocks to value that are additive with (not complementary to) CEO effort (Jin, 2002; Edmans et al., 2009, 2017). In this environment, increased volatility leads firms to weaken incentive pay, lowering the share of firm value paid to the CEO. Tests of this prediction have primarily used data from publicly traded firms in the US and yielded mixed results, depending on time periods examined and functional forms employed in estimation. Some researchers have shown that the CEO's incentive compensation is increasing in the volatility of firm performance or security market return (Yermack, 1995; Core and Guay, 1999; Oyer and Schaefer, 2005; Coles et al., 2006). Other researchers find a negative (Lambert and Larcker, 1987; Aggarwal and Samwick, 1999; Jin, 2002; Garen, 1994), or a mixed effect (Yermack, 1995; Bushman et al., 1996; Ittner et al., 1997; Conyon and Murphy, 2000; Cheng et al., 2015; Edmans et al., 2017).

An interesting theoretical explanation for these mixed results comes from Zabojnik (1996), who notes that if the shocks hitting the firms interact with CEO effort, then the CEO's share in value is increasing in the volatility of the shocks. We are unaware of any previous empirical efforts to identify the structure of shocks to validate this conjecture.

Assignment models of executive compensation focus on CEO ability, not the choice of effort, and on static firm size rather than shocks. They feature complementarity between CEO ability and firm size, and predict that higher ability CEOs will sort into larger firms and be paid more (Gabaix and Landier, 2008; Terviö, 2008). Empirical work shows that firm size and CEO compensation are positively correlated after 1980 (Gabaix and Landier, 2008; Terviö, 2008; Frydman and Saks, 2010; Gabaix et al., 2014). We will discuss evidence on CEO ability below.

Within this literature, our work is most closely related to Zabojnik (1996), and its emphasis on the distinction between interactive and additive shocks; and to Edmans et al. (2009) who incorporate complementarities between (time invariant) firm size and CEO ability embedded in a principal-agent model with additive shocks to firm value to yield predictions on both the level and structure of CEO pay.

We combine the insights of the principal-agent model and the assignment model, allowing for complementarities between ability and firm size, differences in both CEO ability and time-varying effort, and allow both interactive and additive shocks that affect firm value. We embed the CEO problem in an environment where interactive shocks are induced by exogenous shocks to the firm's trade environment. Unlike much of the literature, this enables us to identify the source and structure of shocks that affect the level and volatility of firm value, to study how

these affect the level and structure of CEO pay, and how all are affected by CEO ability.

A second important literature studies how CEO ability affects firm performance. We will organize our discussion in terms of how ability is measured.

Several papers extract measures of ability from firm performance. Demerjian et al. (2012) and Cheung et al. (2017) measure CEO ability as the residual after regressing net output on firm characteristics. They calculate CEO ability while an individual is employed in an initial firm and then relate that to stock market performance while employed in a subsequent firms. Chang et al. (2010) use the abnormal stock price reaction around the CEO departure announcement as a measure of ability, and relate this to the firm's performance prior to the CEO departure, and the relative pay of the CEO.

A challenge with these approaches is disentangling CEO ability from firm quality, particularly if these things might be correlated (as in assignment models) and particularly if there are time-varying shocks that interact either with CEO ability or effort. We directly measure CEOs' ability and study its interaction with exogenous shocks firm sales or value.

Several papers examine CEO experience as a measure of ability. Custódio et al. (2012) construct a composite ability index and link CEO pay to different types of experience. Using this index, Custódio and Metzger (2013) find that CEOs of acquiring firms capture more value for the firms if they have previous experience in the target industry, and Mishra (2014) shows that investors' expected return is increasing with CEO experience-ability. We relate CEO pay to prior experience and experience within the firm, and find that more experienced CEOs both increase the value of firms in all periods and mitigate the effect on sales of exogenous negative shocks.

Several papers rely on individuals who have had multiple CEO positions and regress some financial characteristic of firms on individual fixed effects. Bertrand and Schoar (2003) shows that CEO's individual fixed effect explains heterogeneity across firms in investment, financial, and organizational practices of firms, and Mackey (2008) relates it to the variance of return on assets. As these papers note, they do not establish a causal relationship between this measure of CEO ability and performance because of the possibility of sorting. We establish a causal relationship between CEO's ability and firm performance by employing exogenous demand and supply shocks.

Closest to us is Black (2019) who extract a measure of CEO ability from firm ability using worker-firm transitions in the manner of Abowd et al. (1999). This paper emphasizes the strength of CEO-firm complementarity, as in assignment models, and finds that a one-standard-deviation increase in CEO ability can lead to a 5% increase in sales. A key difference is that

we assess the performance of the AKM fixed effect in responding to exogenous shocks to the firm.

Finally, our research contributes to the literature studying international trade and executive compensation. Ma and Ruzic (2020) shows that exports and FDI increase firm size, which leads to an increase in executive compensation. Keller and Olney (2021) links globalization to the ability of powerful executives to extract rent in companies with poor governance. Cuñat and Guadalupe (2009) find that increased foreign competition increases executives' performance incentive pay and decreases fixed pay In this environment.

We find consistent evidence that exports increase the level of CEO compensation by increasing the size of firms. We complement this literature by identifying the impact of exogenous shocks to exporting and to offshoring at the firm-time level on changes in CEO compensation. Separately, we identify how global shocks change the volatility of shocks hitting the firm, with impacts on the structure of compensation. Finally, we show how employing high-ability CEOs magnifies the effect of global shocks on firm outcomes and on CEO compensation.

The paper proceeds as follows. Section 2 describes the model, first describing the firm's value function in the face of shocks to marginal costs and demand, then embedding that value function into a principal-agent model of compensation. Section 3 describes our data and instrumental variable strategy for isolating exogenous shocks. Section 4 provides empirical evidence. Sub-section 4.1 links global shocks to the size, volatility, and value of the firm, including specific channels. Sub-section 4.2 links pay to firm size. Sub-section 4.1 investigates how exogenous global shocks to the level and volatility of firm value affect the level and structure of CEO compensation. Section 4.4 provides evidence deriving the ability of the CEO from job transitions, the sorting of high ability CEOs into firms, and the extent to which CEO ability magnifies or mitigates the effect of global shocks on firm outcomes. Section 5 concludes.

2 The Model

We derive the firm's value function from profit maximization in a CES demand framework, with CEO effort functioning as a total factor productivity shifter analogous to an inverse iceberg cost. Profits vary across firms due to time-invariant and time-varying demand and marginal cost shifters, with the time-varying shocks arising from exogenous changes in the trade environment.

We show that this setup nests the firm value function setting in Zabojnik (1996), where the value of the firm depends on the CEO's (unobservable) effort, a multiplicative shock that interacts with that effort, and an additive shock. We then embed a principal-agent framework

for CEO compensation into this model and derive expressions for the level and structure of executive compensation, and how it depends on (a) time-invariant differences across firms; (b) time-varying trade shocks operating through both demand and marginal cost channels; and (c) CEO ability.

2.1 Trade Shocks and Firm Value

Denote i as a firm and t as a period. Utility in time t aggregates the goods produced by all firms:

$$U_t = \left(\sum_{i=1}^{N} (\lambda_{it} q_{it})^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}, \tag{1}$$

where λ_{it} denotes a firm-time specific demand shifter, $\rho \in (1, \infty)$ denotes the elasticity of substitution, and q_{it} is given by the following demand curve:

$$q_{it} = p_{it}^{-\rho} \lambda_{it} \frac{E_t}{P_t}, \tag{2}$$

where E_t/P_t is real expenditures over all goods, which we normalize to 1. The firm sets price p_{it} with a constant markup $\frac{\rho}{\rho-1}$ over marginal cost μ_{it}: $p_{it} = \frac{\rho}{\rho-1}\mu_{it}$.

Revenue can be written as $p_{it}q_{it} = \mu_{it}^{1-\rho}\lambda_{it}(\frac{\rho}{\rho-1})^{1-\rho}$. Therefore, the profit is a function of costs, demand shocks, and markups:

$$\pi_{it} = (p_{it} - \mu_{it})q_{it} - f = \frac{p_{it}q_{it}}{\rho} - f = \frac{\mu_{it}^{1-\rho}\lambda_{it}}{\bar{\rho}} - f, \tag{3}$$

where f is the fixed costs and $\bar{\rho} = \rho(\frac{\rho}{\rho-1})^{\rho-1}$ is increasing in ρ.

We model CEO effort ($a_{it} \geq 1$) as a TFP shifter, reducing the use of other inputs needed to produce one unit of the good. Inclusive of CEO effort , q_{it} units of output are produced at a cost $\mu_{it}q_{it}/a_{it}$. [1] The profit function becomes

$$\pi_{it} = \frac{a_{it}^{\rho-1}\mu_{it}^{1-\rho}\lambda_{it}}{\bar{\rho}} - f, \tag{4}$$

where a_{it} governs the impact of CEO effort on prices. Note that because CEO effort lowers

[1] In standard trade models, trade costs are treated as "icebergs" in which some portion $\tau > 1$ of the good melts in transit, meaning that a proportionally greater quantity of the good $q\tau$ must be produced at a cost $\mu q\tau$ for q units to reach the destination. Here we treat CEO effort a_{it} as an inverse iceberg trade cost, lowering production costs.

marginal costs, the impact of effort on profits is multiplicative with the size of the firm, and its impact on sales and on profitability depends on the price elasticity of demand ρ. We return to this point below. Based on this profit function, we now introduce the structure of shocks and show how to rewrite this as a firm value function similar to the one in Zabojnik (1996). Assume both μ_{it} and λ_{it} have a component that is firm-specific but time invariant, and a component that varies with firm-time: $\mu_{it} = \mu_i z_{it}$, $\lambda_{it} = \lambda_i x_{it}$. Combining and rearranging, this yields a time-invariant and a time-varying component of the profit: $S_i = \mu_i^{1-\rho}\lambda_i$, $e_{it} = z_{it}^{1-\rho}x_{it}$. Define shocks to fixed costs $f = -\epsilon_{it}$. The profit-based firm's value can be expressed as:

$$V_{it} = A_{it}S_i e_{it} + \epsilon_{it}, \tag{5}$$

where $A_{it} = \frac{a_{it}^{\rho-1}}{\rho}$ governs the impact of CEO effort on firm value, and S_i represents the firm size. Shocks to marginal cost or demand e_{it} are interactive with CEO effort. The additive shocks ϵ_{it} represent any shocks to the fixed costs of operating the firms (e.g., financing costs for capital expenditures).

Assume the additive shocks follow a normal distribution $\epsilon_{it} \sim N(0, \sigma_i^2)$. Assume the interactive shocks follow a distribution with a mean equal to one and a variance equal to δ_i^2: $e_{it} \sim F_e(1, \delta_i^2)$. When the variance of the interactive shocks is zero, the firm value simplifies to $V_{it} = A_{it}S_i + \epsilon_{it}$. This is the standard case examined in the literature where shocks are additive and independent of CEO effort.

By taking the derivative of the firm's value with respect to firm size and the interactive shocks, respectively, we obtain two implications from equation (5):

$$E\left(\frac{\partial V_{it}}{\partial S_i}\right) = A_{it} \tag{6}$$

This implies that the expected value of larger firms is proportionally more valuable when the CEO exerts more effort.

$$\frac{\partial V_{it}}{\partial e_{it}} = A_{it}S_i \tag{7}$$

This implies that the firm profits increase more in response to a given positive shock when the CEO exerts more effort.

2.2 CEO Compensation in a Principal-Agent Model

Following Edmans et al. (2017), the principal's problem is:

$$\max_{c_{it}(\cdot),A_{it}} \mathrm{E}[V_{it}(A_{it}) - c_{it}(V(A_{it}))] \tag{8}$$

$$\text{s.t. } \mathrm{E}[u(c(V_{it}(A_{it})) - g_{it}(A_{it}))|e_{it}] \geq u(\bar{w}), \tag{9}$$

$$A_{it} \in \arg\max_{\widehat{A}_{it}} \mathrm{E}[u(c_{it}(V_{it}(\widehat{A}_{it})) - g(\widehat{A}_{it}))|e_{it}], \tag{10}$$

where c_{it} denotes the CEO compensation. A_{it} represents the CEO's effort. $u(\cdot)$ refers to the CEO's utility. $g(\widehat{A}_{it})$ denotes effort costs. Firm value is given by (5). Additive shocks are not observable by the principal or agent. The interactive shocks e are unobservable when the principal makes a contract, but are observable before the CEO takes action.

Equation (8) means that the principal chooses CEO compensation to maximize the expected net value of the firm. Equation (9) is the individual rationality (IR) constraint, and it ensures that the CEO's expected utility is larger than the reservation level ($\bar{w}$). Equation (10) is the incentive compatibility (IC) constraint, and it states that the CEO's effort should maximize the CEO's expected utility.

Assume the CEO's compensation consists of fixed pay and a share of firm value[2]:

$$c_{it}(V_{it}) = \phi_i + \theta_i V_{it}, \tag{11}$$

where ϕ_i is the fixed pay, and θ_i is the CEO's effective percentage ownership.

Assume the CEO's utility function is $u(\cdot) = -e^{-\eta(c_{it}(V(A_{it}))-g(A_{it}))}$, where η is the coefficient of absolute risk aversion. The effort cost function is $g(A_{it}) = \frac{1}{2}gA_{it}^2$, and for now, assume g is the same for all CEOs. Since the CEO observes the interactive shocks, her expected utility is a function of the level of the realized interactive shocks:

$$\mathrm{E}\left[-e^{-\eta(c_{it}(V(A_{it}))-g(A_{it}))}|e_{it}\right] = -e^{-\eta\widehat{c}_{it}(A_{it})}, \tag{12}$$

where $\widehat{c}_{it}(A_{it}|e_{it}) = \phi_i + \theta_i S_i A_{it} e_{it} - \frac{1}{2}gA_{it}^2 - \frac{\eta}{2}\theta_i^2\sigma_i^2$.

[2] Holmstrom and Milgrom (1987) proves that the optimal contract is linear if (1) the agent's utility is an exponential function; (2) "costs of actions can be expressed in monetary units", meaning the costs can be directly subtracted from the payment in the utility function; and (3) the shock is additive and follows normal distribution. Edmans et al. (2009), Cao and Wang (2013) and He et al. (2014) consider multiplicative shocks and assume a linear compensation. We follow this approach in the literature.

The first-order condition of the CEO's expected utility function yields optimal CEO effort:

$$A_{it}^{*} = \frac{\theta_i S_i e_{it}}{g}. \tag{13}$$

This tells us that CEOs work harder in larger firms, and they work harder in those periods with positive interactive shocks, because both increase the marginal return to CEO effort.

Setting the IR constraint (9) to bind ($\widehat{c}_{it}(\cdot) = \bar{w}$) gives:

$$\phi_i + \theta_i E[V_{it}] - \frac{1}{2} g A_{it}^{*2} - \frac{\eta}{2}\theta_i^2 \sigma_i^2 = \bar{w}. \tag{14}$$

Rearranging equation (14) and substituting the optimal effort level, the conditional expected compensation is:

$$E[c_{it}|e_{it}] = \phi_i + \theta_i E[V_{it}] = \bar{w} + \frac{(\theta_i S_i e_{it})^2}{2g} + \frac{\eta}{2}\theta_i^2 \sigma_i^2. \tag{15}$$

Equation (15) reflects that the CEO exerts more effort to increase expected compensation when she observes a positive shock e_{it}. On the other hand, the interactive shock is unobservable to the principal. The unconditional expected compensation is:

$$E[c_{it}] = \bar{w} + \frac{(\theta_i S_i)^2 E[e_{it}]^2}{2g} + \frac{\eta}{2}\theta_i^2 \sigma_i^2 = \bar{w} + \frac{(\theta_i S_i)^2 (\delta_i^2 + 1)}{2g} + \frac{\eta}{2}\theta_i^2 \sigma_i^2. \tag{16}$$

Substituting this equation and the optimal effort into the principal's objective function yields

$$\mathrm{E}_{\mathrm{e_{it}},\epsilon_{\mathrm{it}}}[V(A_{it}) - c_{it}(V(A_{it}))] = S_i \frac{\theta_i S_i \mathrm{E}[e_{it}^2]}{g} - \bar{w} - \frac{(\theta_i S_i)^2 \mathrm{E}[e_{it}^2]}{2g} - \frac{\eta}{2}\theta_i^2 \sigma_i^2, \tag{17}$$

where $\mathrm{E}[e_{it}^2] = var(e_{it}) + \mathrm{E}[e_{it}]^2 = \delta_i^2 + 1$.

The derivative of the expected net value to the percentage ownership gives the optimal percentage ownership:

$$\theta_i^{*} = \frac{1}{1 + g \frac{\sigma_i^2}{\delta_i^2 + 1} \frac{\eta}{S_i^2}}. \tag{18}$$

This equation relates percentage ownership to the variances of two risks. The optimal percentage ownership is increasing in the variance of the interactive shocks (δ_i^2) and decreasing in the variance of the additive shocks (σ_i^2). Firm size and CEO effort costs also affect this tradeoff, with the variance of the interactive shocks becoming more important in large firms and when effort costs are low. This is because a 10% increase in demand calls forward more effort (and more disutility) in a large firm than in a small firm.

Finally, by taking the expectation on both sides of the binding IR constraint (equation

(14)), we obtain the fixed component of income:

$$\phi_i = \bar{w} + \frac{\eta}{2}\theta_i^2\sigma_i^2 - \frac{(\theta_i S_i)^2(\delta_i + 1)^2}{2g}. \tag{19}$$

2.3 The CEO wage premium

To this point we have treated all CEOs as having the same effort costs, but it is a simple matter to adjust all the previous equations by allowing the effort cost to vary across CEOs g_j. In our data, we see individuals before, during, and after their job-spells as CEO and therefore we see the wage premium they earn when taking the CEO job. We assume that the effort cost g_j is also an inverse measure of that individual's ability before they become CEO. Assume that a worker of ability g_j can produce $1/g_j$ units of labor output per period. Then, if w represents the wage for a worker of average ability $g = 1$, an individual with above-average ability (lower g_j) receives payment:

$$\bar{w}_j = \frac{w}{g_j} \tag{20}$$

We treat this value as the CEO's reservation wage, and the CEO premium as the increase in compensation increase after transitioning to CEO, $c_{ijt} - \bar{w}_{ij}$. Based on equation 16, we can calculate the expected value of the CEO compensation premium:

$$E[c_{ijt} - \bar{w}_{ij}] = \left(\frac{\theta_{ij}^2}{2}\right)\left(\frac{S_i^2(\delta_i^2 + 1)}{g_j} + \eta\sigma_i^2\right). \tag{21}$$

Equation (21) implies that the average CEO premium tends to be higher for higher-ability CEOs (lower g_j), larger firms, and for firms that have higher volatility of the additive shock.

Note that this model does not provide a unique sorting pattern of the sort found in pure assignment models, such as Gabaix and Landier (2008) and Terviö (2008). In those models, the equilibrium is characterized by a rank ordering in which the largest firm pays the most to the best CEO, the second largest firm pays the second highest wage to the next best CEO, and so on. In our model, CEO utility and compensation depend on scale differences across firms, but also on differences in volatility and differences in markups. How higher ability CEOs sort themselves into firms on these dimensions is then an empirical question that we take up in Section 4.4.

2.4 Empirical Predictions: Linking Global Shocks to CEO Pay

From the key assumptions and the solutions for optimal effort and percentage ownership, we shed light on how trade shocks affect CEO pay through three channels. Let us recall the key equations. Firm value is

$$V_{ijt} = A_{ijt} S_i e_{it} + \epsilon_{it}, \tag{22}$$

where the optimal level of effort is

$$A^*_{ijt} = \frac{\theta_{ij} S_i e_{it}}{g_j} \tag{23}$$

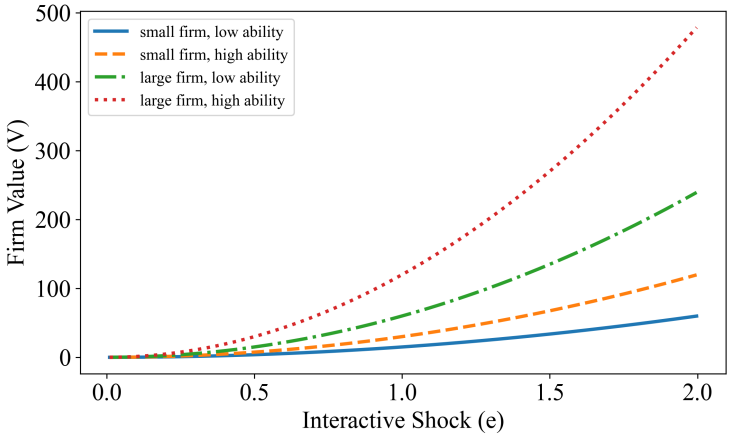
The derivatives of firm value with respect to the interactive shock (and firm size) are increasing in CEO ability $1/g_j$

$$\frac{\partial V_{ijt}}{\partial e_{it}} = \frac{2\theta_{ij} S_i^2 e_{it}}{g_j} \tag{24}$$

$$\frac{\partial V_{ijt}}{\partial S_i} = \frac{2\theta_{ij} S_i e_{it}^2}{g_j} \tag{25}$$

We show this effect in Figure 1, which graphs firm value against the interactive shock for large and small firms with high and low ability CEOs. The value function is increasing in the shock for all cases, but the increase in value is greater (conditional on size) with higher ability CEOs and greater (conditional on ability) for larger firms. The reason is that optimal effort is greater in large firms, greater with large interactive shocks, and greater when effort costs are low. The effort response magnifies the effect of the shock (or firm size) on value.

Figure 1: CEO Ability and Firm Size Change How Interactive Shocks Affect Firm Value



Notes: This figure draws the curve of firm value $V = ASe + \epsilon = \frac{\theta S^2 e^2}{g} + \epsilon$ to interactive shock e with different values of effort costs g and firm size S. $g = 2$ or 1. $S = 10$ or 20, $\theta = 0.3$. ϵ is set to 0.

CEO compensation is a linear combination of fixed pay and a share of firm value.

$$c_{ijt}(V_{ijt}) = \phi_{ij} + \theta_{ij} V_{ijt}. \tag{26}$$

The share of firm value is decreasing in effort costs and the variance of the additive shocks, but increasing in the variance of the interactive shocks weighted by firm size:

$$\theta_{ij} = \frac{1}{1 + g_j \frac{\sigma_i^2}{\delta_i^2+1} \frac{\eta}{S_i^2}}. \tag{27}$$

The CEO premium is increasing with the CEO's ability:

$$E[c_{ijt} - \bar{w}_{ij}] = \left(\frac{\theta_{ij}^2}{2}\right)\left(\frac{S_i^2(\delta_i^2+1)}{g_j} + \eta\sigma_i^2\right). \tag{28}$$

We now summarize our predictions for CEO pay, and how it is affected by global shocks through three channels:

1. **The scale effect**: CEO compensation includes a share in the value of the firm, and that share is increasing for larger firms because CEOs exert more effort in these firms. We can then compare differences in average compensation and CEO premiums across firms between CEO job spells and relate these to firm scale. In addition, global shocks lead to changes in compensation within CEO job-spells. Reductions in the cost of offshored inputs or increases in foreign demand lead to a rise in firm size and value, with a share θ_{ij} of that increased value compensating the CEO. Because CEO effort responds more to a given shock in a larger firm, the response of value and compensation to a given shock will be greater in large firms.

2. **The volatility effect**: Shocks to offshoring and exporting are interactive not additive shocks; they interact with firm size and CEO effort in determining changes in firm value. This means that a rise in volatility induced by global shocks then causes an increase in the value of θ_{ij}. CEO's in firms that experience more value volatility due to global shocks will receive compensation that is more responsive to changes in firm value within job spells.

3. **The ability effect**: Other things equal, the return to ability is higher in larger firms, and better CEOs receive both higher pay and a higher CEO premium in larger firms. We can examine this effect both across job-spells (with time invariant measures of ability)

and within job-spells (with time varying measures of ability). In addition, a better CEO translates positive global shocks into larger sales and value for the firm. We can examine this by looking at firms who switch CEOs to see if better CEOs increase value, and whether they translate a given shock into better changes in value. We can also compare any such gains to the premiums paid for higher abilty CEOs. As a result, they receive a higher share of firm value within job spells.

3 Data

In this section we explain our data sources and construction. This includes details on CEOs, their characteristics, and how we construct measures of ability. We also describe firms and their activities, including exporting and offshoring, and the instrumental variables we use to estimate the causal impact of global shocks on CEO compensation.

The dataset employed covers the universe of Danish firms, their exporting and offshoring activity, and their CEOs, along with the entire population of individuals in Denmark. Data are drawn from multiple administrative registers in Statistics Denmark. We combine firm data from the Firm Statistics Register (FirmStat), worker data from the Integrated Database for Labor Market Research (IDA), and data on CEOs from PERSBEST, administrative data collected by the Danish Business Authority (Ervhervs- og Selskabsstyrelsen). These are combined using the so-called FIDA link to match workers to firms using the workers' main employment relationships. Firm data are also linked to trade data using firm identifiers in the Danish Foreign Trade Statistics Register.

3.1 CEO Data

The data on CEOs in Danish firms (PERSBEST) comes from administrative data collected by the Danish Business Authority (Ervhervs- og Selskabsstyrelsen) and requires all firms to report, among other things, which individuals are members of the board or management of the firm. From this file, we select all records where the individual is a member of a firm's management, and retain only the managers classified as a CEO in the management role variable of the register.[3] We then match them via the person and firm identifier to the matched worker-firm

[3] Among managers we select individuals in roles corresponding to the Danish word for CEOs, e.g., "Administrerende direktør", "AdmDir", "Koncernchef" etc. If a firm does not have a CEO following this procedure we

data set.

Because these persons are also linked through the IDA, we obtain detailed information on individual characteristics in each year before, during, and after the CEO job spell. This includes age, gender, current employer, experience in the labor force, tenure in the current job, education, occupation, and annual labor market income, broken into base salary and bonuses.

Descriptive statistics on CEOs are captured in Appendix Table A.2. The average CEO is a 50-year-old male with 24.4 years of experience in the workforce. For the 3,103 CEO job spells in the data, 27% last only one year, with a median spell duration of 3 years and an average duration of 4.1 years. When we exploit cross-sectional variation in CEO compensation, we employ all CEO job-spells. When we exploit purely within-job spell variation, we require that the duration is at least 3 years. We lose half of the job-spells in this case, but far fewer observations.[4]

As a check on our definition of CEOs we use occupational codes based on the ISCO88 nomenclature. The occupation is observed for most of the CEOs, and most (80%) are assigned the one-digit ISCO88 classification for managers. A likely reason why 20% are not reported as managers is that occupation codes in administrative data are persistent. Firms tend to report the same code for each employee, even if the employee is assigned new tasks, including moving up to work as CEO (Kambourov and Manovskii, 2009). In this case we can think of these other occupations as representing what the CEO did in the firm prior to being named CEO.

Related to this, 58% of the CEOs are promoted internally, with 42% hired externally. Murphy and Zabojnik (2004) reports that 26.5% of newly appointed CEOs of large U.S. firms were recruited from other firms. This will be relevant when we assess measures of ability and the CEO premium.

3.2 CEO Ability

As the introduction details, previous efforts to extract CEO ability typically associate ability with changes in firm performance while an individual served as CEO. This runs into the problem of erroneously attributing to CEO ability changes in performance that arise from exogenous

define the CEO to be the highest paid manager among the individuals in the management of the firm. If the firm does not have any managers according to PERSBEST, we define the CEO to be the highest paid board member on the firms payroll.

[4] Weighting CEO tenure by the number of times that person appears in our sample, the average tenure is 9.2 years within the specific firm.

shocks to the firm, as in equation (5). Separating ability/effort from these exogenous shocks is a primary concern of this paper so we take a different approach. We are interested in assessing whether a measure of CEO ability, pre-determined before they became CEO, translates into higher compensation, and also whether that measure of ability is associated with translating a given exogenous shock into greater value for the firm.

We consider two measures of CEO ability, which in our model corresponds to having a low marginal cost of effort, i.e., a CEO can accomplish more, or make better decisions, in a given unit of time. The first is CEO experience, the total years working as a CEO up to the current year. This includes experience in industires outside the manufacturing sector and in years prior to our estimation sample.[5] Experience is plausibly linked to both the quality of decisions, and the ease with which decisions are made. Within a job-spell, changes in experience correspond to changes in tenure on this job which, in our data, ranges from 1 to 18 years. We show below that experience is correlated with significant changes in compensation within a CEO job-spell.

The second measure of ability is extracted from data on compensation before the individual became CEO. In our model, high ability both affects the returns the person generates while CEO and their productivity in roles prior to being CEO, following equation (20).

To extract this wage, we use the AKM model (Abowd et al., 1999), in which a worker j's income within firm i is decomposed into a worker fixed effect a_j and a firm fixed effect β_i,

$$ln(\text{Income})_{ijt} = a_j + \beta_i + \boldsymbol{X}\boldsymbol{\beta} + \epsilon_{ijt}, \tag{29}$$

$\boldsymbol{X}$ is a vector of control variables including age, age squared, age cubed, union membership dummy, and value added per worker of the firm. This estimation uses all workers and firms in the Danish economy, and the fixed-effects are identified by workers switching between firms. We restrict the estimation sample for our CEOs to include only the years and compensation they had in roles before they became CEO.

The AKM model identifies the extent to which a worker enjoys consistently higher wage rates throughout their career, after controlling for the tendency for some high productivity firms to pay all their workers higher wages. We denote the worker fixed-effect we extract from this equation as the CEO's ability prior to become CEO. Focusing on the population as a whole, the worker fixed effect from AKM ranges in value from -4.8 to 4.5 (with a mean value

[5] We have also experimented with years of experience working in the same 2-digit NACE industry as the current firm, with qualitatively similar results.

of zero by construction). Relative to this range, the mean CEO ability is 2.59 with a standard deviation of 1.93, with higher average values in large firms. We further explore its correlation with compensation paid while CEO and the size of firms into which the CEOs sort.

3.3 Firm Data

From FirmStat and the Account Statistics Register (FIRE), we extract data on the firm, including industry codes (NACE six-digit), number of full-time employees, and sales. We also collect value-added and well as variables needed to construct profits, markups and total factor productivity. This includes the wage bill, capital and materials. To avoid data reporting irregularities associated with small firms, we restrict the sample to firms with more than 50 employees. In some instances we will separate firms with 50-99 employees (44% of the sample) from those with 100 or more.

One of our key variables is firm value. In much of the executive compensation literature, authors are focused on publicly traded firms and employ the stock market valuation of firms as a measure of value. Since the large majority of firms in our sample are not publicly traded, we do not have a comparable value measure.

Instead, we construct a measure of value for unlisted firms following the approach that is used by Danish Tax Authorities for tax purposes when firms are inherited by the children of owners. For the publicly listed firms in our data, we compare the constructed value measure with the stock market valuation and find a strong positive correlation. Details are in Appendix A.2.

We also employ sales data, and in some cases, current-year profits data, as a proxy for value. Both are also highly correlated with the constructed value measures.

Our estimation makes use of detailed information on the trading activity of these firms to identify global shocks to firm size and value. Data on firm-level imports and exports disaggregated by eight-digit product codes (CN8) and origin or destination countries comes from the Danish Foreign Trade Statistics Register. We use the total value of exports (all products to all destinations), and firm-level imports of intermediate inputs (all products from all source countries) as a measure of offshoring. Intermediate inputs are defined as products that the firm does not sell (Hummels et al., 2014). We employ import and export data with the full product by partner country detail in constructing instruments, as described below.

3.4 Family Firms

Because we are working with firms that are both publicly traded and privately-held, a subset of our sample could be described as "family firms". This is relevant to our questions because family firms might differ in the nature of the principal-agent problem, the compensation structure, and the relevance of the larger market for CEO talent. While we do not see ownership explicitly, we can identify instances in which CEOs are related to board members following Bennedsen et al. (2007). In Appendix C we discuss these measures and the construction of a "family firm" sub-sample.

We find that these family firms differ on many dimensions: they are smaller, pay CEOs less, hold onto CEOs longer, and hire CEOs with more industry experience. However, once we condition on the size of the firm, these differences between family- and non-family firms go away. In the appendix we show that all of our main results hold (and are typically quantitatively similar) if we exclude family firms from the sample. Accordingly, for our main result tables we employ all firms.

3.5 Construction of Instrumental Variables

Examining the link between trade, firm value, and CEO ability and compensation is complicated by a host of sorting and endogeneity challenges. Larger, more productive firms engage in more trade; better CEOs may sort into more productive and larger firms; some of the increased firm value associated with increasing size or rising trade rising is shared with CEOs.

We want to exploit global shocks that change the level of exporting and offshoring in a firm, and as a result, affect firm scale and volatility. While the shocks themselves are exogenous to firm productivity, and to the CEO's ability and compensation, the response to those shocks may be magnified in the presence of a high abilty CEO.

To identify global shocks, we pursue a shift-share IV identification strategy. A detailed discussion of this IV and its validity is found in Hummels et al. (2014). Briefly, the demand instrument is defined in the following way.

We use the COMTRADE database to collect all bilateral trade worldwide, at the HS6 product level, in each year. From this we calculate world import demand WID_{ckt} as the value of imports into country c of product k at time t from the rest of the world except Denmark. We aggregate a vector of WID_{ckt} into shocks at the Danish firm level by weighting each by their presample share in export exports sales by firm i. That is, the instrument for firm i at

time t is

$$WID_{it} = \sum_{ck \in \Omega_{it_0}} s_{ickt_0} WID_{ckt}, \tag{30}$$

where s_{ickt_0} is the share of product k exported to country c in total exports for firm i in the presample year, $t_0 = 1998$, and Ω_{it_0} is firm i's set of product-country combinations exported in the presample year. We construct a world export supply, WES, cost instrument in an analogous way, only using purchases of firm i of product k from the origin country c.

The WID_{it} instrument exploits heterogeneity across firms in their initial product-level export mix. Hummels et al. (2014) shows that the initial product-country export mix of a firm is fairly stable over time and that Danish firms have only a few product-country exports in common (and similarly for offshoring). This means that over time changes in world import demand and world export supply at the product-country level will affect firms within Denmark differently. For example, exogenous changes in a particular importing country's trade costs or consumer expenditures will be reflected in changing imports into that country from the world. A Danish firm that exports to this country more than other Danish firms will benefit disproportionately from these changes.

The recent shift-share instrumental variable literature shows that this identification approach rests either on the shares being exogenous (Goldsmith-Pinkham et al., 2020) or the shifts being exogenous (Borusyak et al., 2022). In our setting, the shifts correspond to a country's import demand from (or export supply to) the world as a whole, which is arguably exogenous to the characteristics of an individual Danish firm or their CEO. In addition, there are many shifts (hundreds of partners times thousands of products), and they are idiosyncratic to the individual firm as noted above. Thus, this approach amounts to a share-weighted average of as-good-as-random shifts, which itself is as-good-as-random even if the presample shares are endogenous to characteristics of the firm (Borusyak et al., 2025).

3.6 Summary Statistics

After cleaning the data and imposing restrictions detailed above we have a panel of 12,852 CEO-year observations spanning 1,412 firms, 2,774 different CEOs, and 3,103 CEO job spells over the 19-year period from 1999 to 2017. The sampled firms capture 62% of total employment, 74% of total sales, and 79% of total exports in the manufacturing sector.

We capture additional key summary statistics in (Table 1), and Appendix Table A.1 for further details. The average CEO in the sample earns 2.1 million DKK in 2015 prices (corresponding to about 300,000 USD), about 5 times the income of the average worker in the firm.

Table 1: Summary Statistics

	Levels				Job Spell Demeaned (Log)				
	Income (1,000 DKK)	CEO Premium	Sales (1,000 DKK)	Value (1,000 DKK)	Income	Sales	Value	Offshoring	Exports
Mean	2,076	0.30	636,198	532,000	0.00	0.00	0.00	0.00	-0.00
p10	797	-0.06	58,320	8,957	-0.22	-0.24	-0.60	-0.85	-0.55
p25	1,105	0.10	96,148	21,300	-0.09	-0.10	-0.22	-0.26	-0.14
p50	1,547	0.29	189,117	59,900	0.00	0.00	0.00	0.00	0.01
p75	2,229	0.48	429,785	169,000	0.08	0.10	0.28	0.34	0.25
p90	3,330	0.70	1,027,479	507,000	0.21	0.25	0.60	0.92	0.69
Observations	12,854	7,077	12,854	12,448	12,854	12,854	12,448	10,545	12,854

Notes: The sample includes CEOs in manufacturing firms with at least 50 employees, non-missing exports, (broad) offshoring, capital, domestic sales, CEO demographics (gender, age etc) and positive CEO income, and covers the years 1999 to 2017. The CEO premium is the percentage increase in compensation after one becomes a CEO.

The average CEO earns a 30% premium (i.e. sees their wages rise 30%) when ascending to the top role, though this premium reaches 70% at the 90th percentile. CEO pay increases sharply with firm size. CEOs for firms with at least 500 employees earn an average of 5.2 million DKK or about 750,000 USD, 11.8 times the income of the average worker in the firm.[6]

Annual earnings can be decomposed into base salary and bonuses, which include fringe benefits and exercised stock options. While base salary accounts for the major part of total earnings (90% on average), bonuses exhibit considerably greater variation, both across CEOs and in year-to-year variation within job spells. This will be useful for identifying changes in compensation over time.

We see similar patterns if we focus only on changes within job-spells. A p90 year in compensation is 21 percent above the job-spell average; a p10 year is 22 percent below. These magnitudes are comparable to the within job-spell changes in sales, while changes in offshoring, exports and value within job-spell are considerably larger. Combined this suggests that there is ample variation from which to identify the effects of global shocks on firm size and value and CEO compensation, both across and within job-spells.

[6] How do these numbers compare to US data on publicly traded firms? Frydman and Saks (2008) report that in the 1970s the ratio of CEO pay to the top worker was 30, and reach 110 by 2005. Danish ratios are likely smaller for two reasons. One, average worker pay is higher in Denmark, possibly due to strong union influence in wage formation. Two, Danish firms are on average much smaller than publicly traded firms in the US, and CEO pay correlates positively with firm size.

4 Empirical Results

In this section we examine the empirical predictions of the model. We begin by establishing a link between exogenous global shocks and the size, value and volatility of firms. We link CEO compensation to firm size and then to exogenous changes in firm size and volatility induced by global shocks. Finally, we examine CEO ability, how it affects compensation and whether high CEO ability enables firms to translate a given shock into increased sales or value.

4.1 Trade Shocks and Firm Size, Value and Volatility

It is well established in the trade literature that more productive firms are larger and more likely to both export and import goods. This is different from a claim that firms grow larger or more productive as a result of exogenous changes in the trade environment.

We are interested in the following causal chain. First, exogenous changes in the trade environment (foreign demand for the firm's products, the cost of foreign inputs) lead the firm to increase its exporting and/or its offshoring behavior. Second, these changes lead the firm to sell more and to increase its profitability and value. Third, changes in the firm's sales and value are shared with the CEO in the form of higher compensation. In this section, we establish the first two links in the causal chain.

Table 2 provides IV estimates of global shocks on firm sales and value. In the first stage, we use the WID and WES instruments (separately or together) to explain over time changes in firm level exporting and offshoring. Note that the WID instrument increases firm-level exporting but not offshoring, whereas the WES instrument increases both offshoring and exporting.

Table 2: Offshoring and Exporting Increases Sales and Firm Values

Second Stage

	Sales			Value		
	(1)	(2)	(3)	(4)	(5)	(6)
Export	0.2470***		0.2617***	0.4066***		0.4284**
	(0.0456)		(0.0686)	(0.1020)		(0.1788)
Offshoring		0.2996***	0.1349		0.5432**	0.1626
		(0.0883)	(0.0899)		(0.2458)	(0.3126)
Observations	12,229	10,248	10,027	11,857	9,948	9,740
Firm	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year	Yes	Yes	Yes	Yes	Yes	Yes

First Stage

	(1)	(2)	(3)	(4)
	Export	Export	Offshoring	Offshoring
World Import Demand	0.3749***	0.3520***		0.0977
	(0.0426)	(0.0431)		(0.0691)
World Export Supply		0.2767***	0.3828***	0.3359***
		(0.0504)	(0.0774)	(0.0801)
F-stat, WID	77.29	66.75		2.00
F-stat, WES		30.11	24.49	17.57
Observations	12,229	12,164	10,248	10,027
R-squared	0.8481	0.8490	0.7912	0.7906
Firm	Yes	Yes	Yes	Yes
Industry-Year	Yes	Yes	Yes	Yes

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All variables are log-transformed.

In the second stage, we show that exogenous increases in exporting and offshoring increase sales and value. For each regression, we incorporate firm fixed effects to absorb time-invariant differences in the level of sales and levels of the instruments, and industry-year fixed effects to absorb trends in, e.g., technology or consumer demands that are common to many firms within an industry.

Appendix Table A.3 lays out specific channels through which offshoring affects sales. First, we decompose sales into domestic and foreign sales. Columns 1-3 show that the sales increase occurs primarily through the exporting channel. A plausible reason for this effect is that Danish purchases of any particular good are limited by the relatively small size of the market. Export sales potentially encompass the entirety of world markets, and so the room for expansion is greater abroad.

Columns 4-5 of Table A.3 employ more detailed trade data, which provide both quantities and unit values (prices), and moves from regressions with a firm-year dimension to incorporate product (8-digit Common Nomenclature) by destination country. They also incorporate a rich set of fixed effects at the firm-export destination-product and export destination-product-year level. Exogenous increases in offshoring lower unit values (consistent with a fall in input costs,

lowering marginal costs of production for the firm) and increase export quantities.

In Appendix Table A.4, we use the same first stage but then employ a number of different dependent variables in second stage regressions to show the response of other firm characteristics to exogenous trade shocks. We focus on measures that are strongly related to both firm sales and value, including the labor share of value added, markups, TFP, and profits. Exogenous increases in offshoring and exporting raise markups, TFP, and firm profits. They also lower the labor share in value added, implying a greater share of value-added accrues to owners of capital. Note that the effect of offshoring on profit is especially large as it both reduces costs and increases the scale of the firm.

To get a sense of the magnitudes of the scale changes associated with trade, Table 3 provides a growth accounting exercise. Sales growth for a firm between the first and last years of our sample can be decomposed into growth in domestic sales and foreign sales as follows.

$$1 = \frac{\Delta \text{Foreign Sales}}{\Delta \text{Total Sales}} + \frac{\Delta \text{Domestic Sales}}{\Delta \text{Total Sales}} \tag{31}$$

We can then describe the contribution of foreign sales to overall growth using the first ratio. A value of 0 means that there was no growth in foreign sales while overall sales grew. A value of 1 means that all of the sales growth took place through foreign sales. (Negative values mean foreign sales shrank; values greater than 1 mean domestic sales shrank.)

Table 3 provides this growth accounting averaging over all firms within a given quintile of firm size, grouped according to initial sales. In the first two columns we include all Danish manufacturing firms regardless of size. In the last two columns we include only those firms included in our broader estimation sample (i.e. those who meet our sample restrictions focused on firm size, and data quality).

Table 3: Export Shares Grouped by Initial or Last Period Sales

	All Firms		Sample Firms	
	N	Mean	N	Mean
1	831	0.0902	101	0.2928
2	832	0.1624	101	0.9406
3	831	0.1864	101	0.8059
4	831	0.3611	101	0.5644
5	831	1.2475	100	0.5617
Total	4156	0.4095	504	0.6332

When we look at all manufacturing firms in the "All Firms" columns, foreign sales contribute a relatively small share of overall sales growth for the smallest 60% of firms. But for the largest 20% of firms (based on initial sales), foreign sales contributed more than 100% of sales growth.

Put another way, foreign sales substantially increased the variance in the firm size distribution between the initial and final periods.

Our estimation samples includes just over 500 firms who were in the data in the first and last years of the sample. These correspond to firms in the 4th and 5th bins of the "All Firms" sample. For the largest 80% of our estimation sample firms, export sales are responsible for more than half of overall sales growth. We do not see the monotonically increasing relationship between initial firm size and importance of exports in overall sales growth shown in the All Firms sample. Put another way, within our estimation sample, exports are the primary channel through which almost all firms increase in size, but not a channel that leads to an increased variance in the firm size distribution over time.

Firms within our sample face both positive and negative shocks to trade. As a final exercise in this section, we examine the relationship between sales and value volatility for a firm and the extent to which that firm relies on foreign markets (Table 4).

Table 4: Global Firms Are More Volatile

	Sample Firms		Large Firms	
	(1)	(2)	(3)	(4)
	Sales Volatility	Value Volatility	Sales Volatility	Value Volatility
Average Export Share	0.1410***	0.1282***	0.2579***	0.1764**
	(0.0317)	(0.0478)	(0.0485)	(0.0695)
Average Offshoring Share	0.0642	0.1779	0.0876	0.4325*
	(0.1095)	(0.1649)	(0.1593)	(0.2281)
Average Size	0.0062	-0.0579***	0.0310*	-0.0573**
	(0.0106)	(0.0160)	(0.0180)	(0.0257)
Observations	927	926	453	452
R-squared	0.1864	0.1790	0.2891	0.2459
Industry	Yes	Yes	Yes	Yes

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Firms that are observed at least five times between 1999-2017 enter the sample. Regressions 1 and 2 include firms with more than 50 employees. Regressions 3 and 4 only include large firms with at least 100 employees in the first year of the sample. Volatility is measured by the standard deviation of log sales or log value. There is one observation per firm.

We calculate the standard deviation in sales and value over the 19 years of our sample for each firm, then regress this on the average export and average offshored input share in sales. Because we are calculating volatility over time, we have one observation per firm, and we incorporate industry fixed effects in the regression. Size matters for volatility, so we experiment both with including a control for the average size of the firm (number of employees), and separating the sample into all firms and only firms with more than 100 employees.

When looking at all firms, firms that sell a greater share of their output abroad experience greater volatility in both sales and value, and firms that rely more on offshored inputs as a share of sales also experience greater volatility (there is no significant effect on value). When

focused only on large firms, greater reliance on exporting translates to greater volatility in both sales and value, and more offshoring translates to greater value volatility.

Some previous authors have argued that foreign markets might reduce volatility facing firms if shocks are negatively correlated across countries. We have not explored the specific channels through which trade induces greater volatility for our firms. However, it likely stems from the size of Denmark relative to the rest of the world. For example, one of the biggest markets for Danish firms is Germany, which has 10 times the GDP of Denmark. A given shock to German purchasing is likely to generate a greater impact on a firm that sells primarily to Germany rather than Denmark.

We have now established the first two links in our causal chain. One, favorable shocks to the global trade environment lead to greater exporting and offshoring activity. Two, exogenous increases in trade increase the scale and value of firms through plausible channels, including the labor share of output, markups, productivity, and profitability. In addition, firms who export and offshore more on average experience greater year-to-year volatility in overall sales and value.

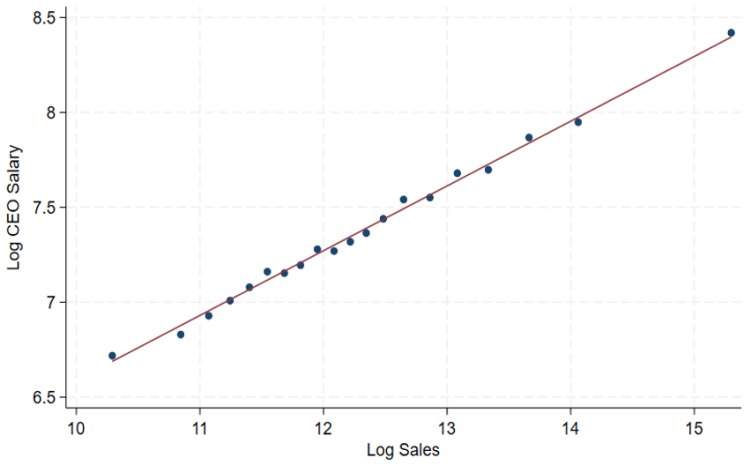
4.2 Linking Compensation to Firm Size

In this section, we examine how CEO compensation and its components respond to changes in scale and volatility. To begin, Figure 2 reports bin scatters of CEO salary on firm sales without firm fixed effects, with firm fixed effects, and measured as a CEO premium relative to previous wages. Whether we examine variation across firms (panel a), or variation within the same firm over time (panel b), we see a tight relationship between compensation and firm size.

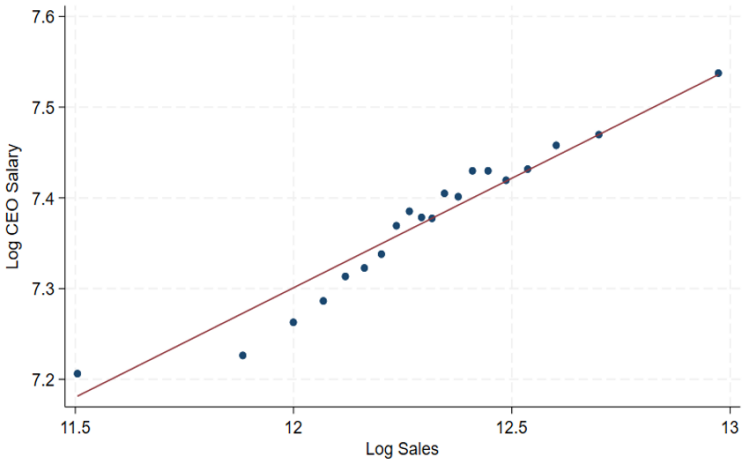
A novel feature of our data is that we have employment and compensation data for our CEOs before, during, and after their time as CEOs. This enables us to estimate a "CEO Premium", that is, the percentage increase in their compensation associated with ascending to the top spot. In panel c for Figure 2 , we provide a bin scatter of the CEO premium against firm sales. Not only do larger firms pay CEOs more, but they also pay a premium relative to the CEOs of smaller firms.

Table 5 explores these patterns with additional covariates and alternative measures of compensation. The first four columns report regressions of CEO total compensation on sales and value of firms, including industry-year fixed effects and experience controls. Columns 1 and 3 omit firm fixed effects and so capture both cross- and within-firm variation in sales or value. The elasticity of 0.34 is remarkably similar to that identified from US publicly traded firms

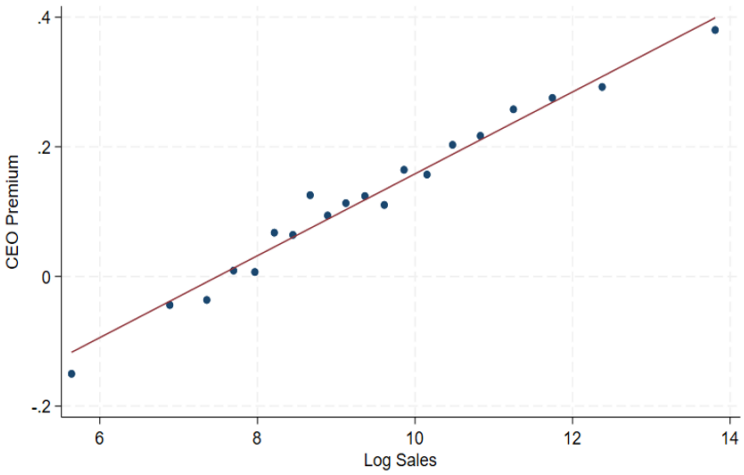
Figure 2: CEO Pay or Premium on Firm Sales



(a) CEO Salary - No Fixed Effects



(b) CEO Salary - With Firm Fixed Effects



(c) CEO Premium - No Firm Fixed Effects

(see survey evidence by Edmans et al. (2017)).

Table 5: CEO Earnings Are Higher in Large Firms

	Income				Bonus			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sales	0.3449***	0.1927***			0.2805***	0.1178***		
	(0.0043)	(0.0106)			(0.0103)	(0.0301)		
Value			0.2167***	0.0584***			0.1767***	0.0393***
			(0.0031)	(0.0046)			(0.0071)	(0.0126)
Experience	0.0054***	0.0769***	0.0002	0.0798***	0.0036	0.1193***	0.0011	0.1162***
	(0.0018)	(0.0042)	(0.0019)	(0.0043)	(0.0042)	(0.0117)	(0.0043)	(0.0118)
$(\text{Experience})^2$	-0.0001***	-0.0007***	-0.0000	-0.0007***	-0.0001	-0.0008***	-0.0001	-0.0007***
	(0.0000)	(0.0001)	(0.0000)	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0002)
Observations	12,834	11,991	12,429	11,610	12,486	11,667	12,114	11,315
R-squared	0.4315	0.8796	0.3865	0.8774	0.1209	0.7391	0.1142	0.7388
Job-spell	No	Yes	No	Yes	No	Yes	No	Yes
Industry-year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All variables are log-transformed.

Incorporating a firm fixed effect in columns 2 and 4 restricts variation to changes in sales or value over time within the firm. That is, it asks whether CEO's annual compensation responds to changes in firm sales and value, equivalent to the θ coefficient captured in equation (11) from theory. Elasticities using our constructed measure of firm value are also positive, but somewhat smaller than the sales elasticity.

While we lack the richness of compensation details found in, e.g., SEC declarations for publicly traded firms, we can see various bonuses paid to executives on an annual basis. As is clear from Table A.2 bonuses are smaller on average than total compensation, but they exhibit substantially greater variation across executives and over time. In columns 5-8 of Table 5, we employ annual bonuses paid to CEOs as our dependent variable. The elasticities of bonuses with respect to sales and value are slightly smaller than total compensation, but broadly consistent.

Estimates of the correlation between compensation and sales or value are similar with or without including the experience control. However, the experience measure itself is inherently interesting. Across job-spells there is no discernible effect, meaning that firms do not pay more for a CEO with more years of actual work experience.[7] However, within job-spells there is a large effect. Using the estimates from column 2, a CEO with 2.5 more years of experience within this firm receives a compensation increase comparable to doubling firm sales. Using column 6, one more year of experience within this firm yields bonuses equivalent to doubling firm sales. A plausible reason for this effect is that firms perceive experience as an indicator of

[7] Including the quadratic term, the compensation is very similar for CEOs with average experience and CEOs one standard deviation above the experience mean.

the CEOs ability. We return to this below.

The cross-sectional evidence in Figure 2 and Table 5 linking the level of pay and the CEO premium to the size of firms is consistent with assignment models. These models assume that CEO ability is complementary to firm scale, and also features prominently in our value function in equation (5). The within-firm changes over time in compensation featured in Table 5 are also consistent with principal-agent models, which predict that changes in the value of the firm over time will be shared with the CEO.

There are two challenges with these inferences. First, we do not know whether the direction of causation runs from changes in sales and value to compensation, or in the opposite direction, or if both are induced by some third factor such as changes in firm productivity. Second, we can see from these regressions that CEOs in larger firms are paid more, and that more experienced CEOs are paid more. However, we do not have direct evidence that their pay is linked to higher ability that offers greater value to the firm. We address these two concerns in the next two sections.

4.3 Exogenous Trade Shocks and Their Effect on Compensation

To what extent do exogenous increases in sales and value increase CEO compensation? Here, we can use shocks to the global trading environment that change the sales and value of the firm to understand the causal impact.

Our first stage follows Table 2 in relating sales and value changes over time to our WID and WES instruments. Our second stage relates CEO compensation (in total, and bonuses only) to exogenous changes in sales and value. We augment both by including an interaction between these instruments and a dummy for firm size (=1 if the firm has more than 100 employees) so that we can evaluate model predictions regarding how size affects optimal compensation. We report results in Table 6.

Table 6: Exogenous Changes in Sales or Value Induced by Globalization Lead to Higher Pay

Second Stage

	Income				Bonus			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sales	0.7913***	0.4690***			2.3524***	1.5090***		
	(0.1584)	(0.1522)			(0.5205)	(0.3930)		
Sales × Large Firm Sales		0.7883***				1.0045**		
		(0.1940)				(0.5002)		
Value			0.4441***	0.2762***			1.2148***	0.7458***
			(0.1074)	(0.0872)			(0.3047)	(0.2123)
Value × Large Firm Value				0.3544***				0.4753**
				(0.0742)				(0.1869)
Experience	0.0626***	0.0619***	0.0625***	0.0578***	0.0723**	0.0781***	0.0719**	0.0725***
	(0.0116)	(0.0129)	(0.0110)	(0.0115)	(0.0307)	(0.0285)	(0.0280)	(0.0260)
(Experience)^2	-0.0006***	-0.0006***	-0.0004***	-0.0004***	-0.0004	-0.0006**	0.0000	-0.0002
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Observations	11,518	11,545	11,163	11,191	11,208	11,235	10,879	10,907
Job-Spell FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

First Stage

	(1) Sales	(2) Sales	(3) Large Firm Sales	(4) Value	(5) Value	(6) Large Firm Value
World Import Demand	0.0559***	0.0602***	-0.0079	0.1118***	0.1569***	-0.0581*
	(0.0134)	(0.0172)	(0.0130)	(0.0337)	(0.0434)	(0.0310)
World Import Demand × Large Firm Dummy		-0.0090	0.0615***		-0.0958	0.1710***
		(0.0232)	(0.0175)		(0.0584)	(0.0417)
World Export Supply	0.1245***	0.1280***	0.0042	0.2180***	0.2022***	-0.0436
	(0.0169)	(0.0193)	(0.0146)	(0.0429)	(0.0490)	(0.0350)
World Export Supply × Large Firm Dummy		-0.0111	0.1081***		0.0401	0.3153***
		(0.0263)	(0.0199)		(0.0664)	(0.0474)
Experience	0.0196***	0.0198***	0.0082***	0.0361***	0.0367***	0.0291***
	(0.0040)	(0.0040)	(0.0030)	(0.0101)	(0.0101)	(0.0072)
(Experience)^2	-0.0001**	-0.0001**	0.0001*	-0.0006***	-0.0006***	-0.0003***
	(0.0001)	(0.0001)	(0.0000)	(0.0001)	(0.0001)	(0.0001)
Observations	11,518	11,518	11,518	11,163	11,163	11,163
R-squared	0.9666	0.9666	0.9994	0.8994	0.8994	0.9984
F-stat WID	17.44	12.22	0.37	10.98	13.08	3.52
F-stat WID × Large Firm	.	0.15	12.34	.	2.70	16.85
F-stat WES	54.24	43.86	0.08	25.87	17.00	1.55
F-stat WES × Large Firm	.	0.18	29.59	.	0.37	44.26
Job-Spell	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Income, bonus, and value are log-transformed. The explanatory variable "Large Firm Dummy" is a binary indicator that takes the value of 1 if the firm employs more than 100 people, and 0 otherwise.

First note that the first stage relationship between global shocks and increased sales or value are fundamentally similar whether we look at all firms (column 1, 4) or allow the relationship to be different for large firms (columns 2,3,5,6). Focusing on the second stage, columns 1 and 3 report the response of compensation to exogenous changes in sales and value. These elasticities are much larger than those found in Table 5. Columns 2 and 4 include interactions with the firm size dummy and indicate that these responses are much larger for large firms than for small firms. This is consistent with the prediction of our model, which emphasizes that large firms must compensate the CEO with a progressively larger share of value to account for the proportionally larger effort (and associated disutility) it takes to run a large firm.

Columns 5-8 of Table 6 repeat these regressions, but now using only bonus payments. Here we see that bonuses are substantially more responsive than overall compensation to changes in sales and value, and again, that these elasticities are considerably larger for larger firms. In our theory, compensation has a fixed and variable component. While our bonuses do not precisely

map into the variable component of compensation since base salary also changes somewhat over time, their responsiveness to exogenous shocks to firm value is suggestive.

A key component of the theory is that the amount of compensation shared with the CEO depends on the volatility of shocks facing the firm. When those shocks are interactive (additive) with CEO effort, greater volatility causes the firm to compensate CEOs with a larger (smaller) share of firm value. Since global shocks affect the scale of the firm and interact with CEO effort, the model predicts that exogenous increases in volatility should be associated with CEOs earning a larger share of firm value.

To implement this, we return to our first stage in which we project value onto WID and WES instruments to generate fitted values for firm value in each year. For each firm, we then construct a measure of fitted value volatility by calculating the variance in fitted firm value over time. This takes a single value for each firm. Finally, we regress CEO compensation on value and an interaction between value and value volatility, including industry-year and CEO job-spell fixed effects. Note that the job-spell fixed effects absorb the level of value volatility, leaving only the interaction. This interaction tells us whether firms with greater (exogenous interactive) volatility pay firms a different share of time-varying value than those firms with lower volatility.

The results are reported in Columns 1-4 of Table 7 using first total compensation and then bonus compensation. Comparing the value coefficient to Table 6, the direct effect is much smaller, while the interaction with fitted value volatility is quite large. More volatile firms pay a substantially larger share of value to their CEOs. The effect is even larger when using bonus compensation. We also report in the table a slightly different way to calculate fitted value volatility, in which the first stage either incorporates or excludes firm fixed effects when estimating firm-year variation in value. Incorporating firm fixed effects in the first stage cuts the interaction effect in half, but it still dominates the direct effect.

Inspection of equation (18) shows that the relative importance of interactive shocks will be greater when firms are large. We can re-estimate the effects in Columns 5-8 of Table 7 using only a sample of larger firms. When we do that, the impact of volatility on the compensation elasticity grows even larger. That is, firms reward CEOs with a higher share of compensation in volatile markets, and the extent of that reward is greater for large firms and high ability CEOs.

One might look at these estimates and conclude that boards are unreasonably compensating CEOs for changes in value that they did not directly affect. After all, the idea of the instrument is that we are picking up shocks to trade that exogenously move firm sales and value. Why

Table 7: Volatility Changes the Structure of Compensation

	All Firms				Large Firms			
	(1) Income	(2) Income	(3) Bonus	(4) Bonus	(5) Income	(6) Income	(7) Bonus	(8) Bonus
Value	0.0748***	0.0746***	0.0397***	0.0392**	0.0564***	0.0569***	0.0308	0.0316
	(0.0054)	(0.0054)	(0.0153)	(0.0152)	(0.0080)	(0.0080)	(0.0221)	(0.0221)
Value × Fitted Value Volatility	1.2066***		4.0734***		1.9374***		5.9501***	
	(0.3103)		(0.8657)		(0.5921)		(1.6058)	
Value × Fitted Value Volatility (FE)		0.6674***		2.0695***		0.6571***		2.2150***
		(0.1315)		(0.3709)		(0.2034)		(0.5576)
Observations	8,072	8,072	7,868	7,868	4,310	4,310	4,233	4,233
Job-Spell	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Income, bonus, and value are log-transformed. Industry-year fixed effects are based on two-digit NACE industries. The data includes only job spells with at least five observations. Regressions 1 to 4 include firms with fewer than 50 employees. Large firms refer to those that have at least 100 employees in the first year of the sample. Fitted Value Volatility is calculated as the within job spell standard deviation of predicted (log) value from a first-stage regression of (log) value on the WID and WES instruments and job spell and industry-year fixed effects. Fitted Value Volatility (FE) is constructed similarly, but the predicted values include the first-stage fixed effects.

then should a CEO be compensated for this increased value?

The model's answer is that CEO effort interacts with these global shocks. That is, it is precisely when the global trade environment offers opportunities for lower costs through offshoring and expanded sales through exporting that you want a CEO working especially hard to seize these opportunities. But is that happening in the data? We can't measure time varying CEO effort, but we can measure CEO ability to see if higher ability CEOs generate more value from a given shock. We tackle this next.

4.4 Do High Ability CEOs Maximize Returns to Global Shocks?

In our data section we describe two measures of CEO ability: experience; and an AKM fixed effect – the amount this individual was paid in jobs prior to becoming CEO, conditioning on average wages paid in those firms. We next establish the extent to which these measures are regarded by firms as representing higher ability.

First, firms pay more for experience and for higher AKM fixed effects. We can see the experience premium in Table 5. While experience captured there is total job market experience, if we replace that with CEO experience we find similar estimates.[8] Similarly, if we regress CEO compensation on the AKM fixed effects, we find a precisely estimated elasticity of 0.089.

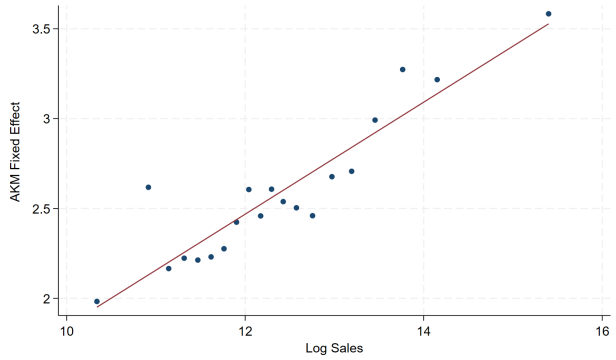
Our theory predicts that higher ability CEOs will sort into larger firms. The left two panels of Figure 3 display bin scatters of the AKM fixed effect on firm sales, and CEO experience (in

[8] Within job-spells, prior experience is differenced out so only the accumulation of experience as CEO within this job spell is relevant.

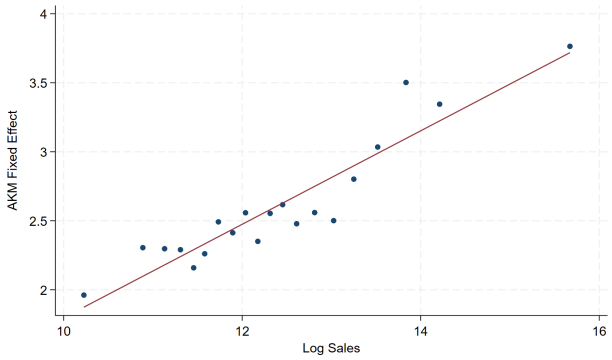
the first year of the job spell) on firm sales. The former shows a strong positive relationship: workers who were the best paid before they became CEO (consistent with having the most ability) sort into the largest firms. However, there is a (weaker) negative correlation for prior CEO experience.

One concern could be that many CEOs are promoted internally, which could confound our ability to separate what they were paid before they became CEO with what they are paid after they became CEO. It is also likely to affect prior years of accumulated experience as CEO since by definition an internal CEO hire will not have been in a CEO role in this firm immediately prior to their promotion. The right two bin scatters in Figure 3 again relates our two measures of CEO ability to firm sales, but only for those CEOs who were hired externally. The same pattern holds for the AKM fixed effect and we now see no relationship between firm size and prior CEO experience.

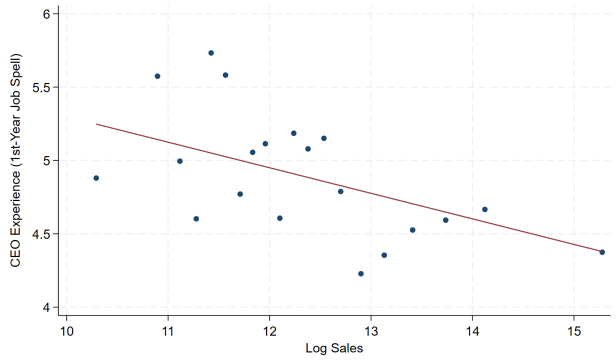
Figure 3: CEO Sorting Pattern



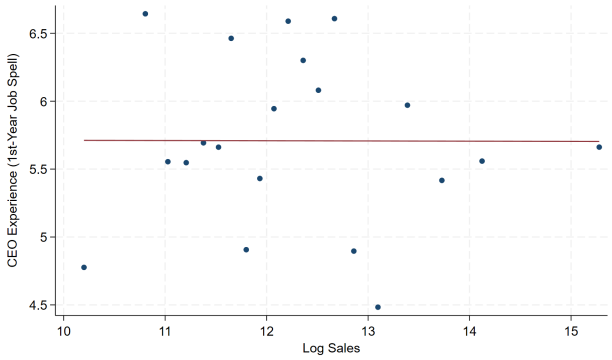
(a) AKM Fixed Effect, All Sample



(b) AKM Fixed Effect, Externally Hired



(a) CEO experience, All Sample



(b) CEO experience, Externally Hired

In section 4.1, we provided evidence linking trade shocks to firm outcomes. Firms that enjoy positive exogenous shocks to the world demand for their products enjoy greater exports, sales, markups, productivity, and profitability, and similarly for positive shocks to world supply of their intermediate inputs.

Our model suggests that these exogenous shocks interact with CEO effort, meaning that CEO effort should increase in the face of positive shocks. Since high ability CEOs have lower effort costs, they should respond by increasing effort more than low ability CEOs. That translates to a larger firm response to a given global shock (see Figure 1 and equation (24)). Moreover, firms compensate CEOs in a manner consistent with this model of interactive effort. They pay more for experience, they pay more in larger and more valuable firms, they pay more when firm size or value rises in response to a global shock, they pay more as a share of value when firms are large and when these shocks increase the volatility of firm sales and value.

But are they getting what they are paying for? We next examine whether high ability CEOs translate positive exogenous shocks into greater sales and value for the firm. We again relate our world import demand and world export supply shocks to firm outcomes, but this time using sales and value as a direct dependent variable rather than taking the intermediate step of linking shocks to trade and trade to sales and value as in Table 2.

A simple version of this table is provided in Appendix Table (A.5), using continuous variation to show that the global shocks do a good job of explaining within job-spell variation in sales and value. For our main focus we want to explore a more subtle interaction. Rather than assuming that the response of firm sales or value to the shock is identical all along the distribution of shocks, we want to allow these responses to vary depending on whether the shocks are positive or negative, large or small. We also want to see whether ability interactions occur in different ways at different levels of shocks. Figure 1 and equation (24) show that the effect of high ability should primarily be felt when shocks are large and positive.

To get at this we generate a distribution of world import and export shocks relative to job-spell means, then group these into quintiles. First and second quintile shocks correspond to large and small negative shocks. Fourth and fifth quintile shocks correspond to small and large positive shocks. For each firm and year, their world export and import shocks are characterized as belonging to one of these quintiles, captured as dummy variables.

We perform two sorts of regressions. In the first, we regress firm sales (or value) on the shock quintiles and an ability measure for the CEO, either the AKM fixed effect or job experience. This tells us whether a high ability CEO generates higher sales (or value) in all periods relative to a low ability CEO in that firm. In the second specification, we also interact ability with the shock quintiles. This tells us whether higher ability CEOs generate progressively larger value in the face of positive relative to negative shocks, as the theory predicts.

We incorporate two fixed-effects strategies. In the first we employ firm fixed-effects, which allows us to subtract out firm-specific levels of sales or value and shocks. For the AKM ability

measure, the CEO effect is identified from firms switching between CEOs with higher/lower AKM ability. For the experience measure, the effect is identified from a combination of firm switching between CEOs with different initial experience and the accumulation of additional experience within a job-spell by an individual CEO.

For the experience measure we also employ job-spell fixed effects. This means that the effects are identified by comparing how the same CEO changes value within the firm as they become more experienced, and how their impact on the firm's response to shocks changes as they become more experienced.

We report results using the AKM fixed effect for ability in Table 8. Odd columns capture just the shock quintiles, and the even columns capture interactions with ability. Note first that the discrete version of the shocks behaves in a similar manner to the continuous measures, in the sense that the effect of the shock on sales and value is increasing in the shock quintile.

Table 8: Do Better CEOs Generate Different Return on Shocks?

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	Sales	Sales	Value	Value	Sales	Sales	Value	Value
	Shock (World Import Demand)				Shock (World Export Supply)			
Ability (AKM Fixed Effect)	0.0005	-0.0062	-0.0057	-0.0053	0.0006	0.0234***	-0.0038	0.0113
	(0.0038)	(0.0090)	(0.0092)	(0.0218)	(0.0038)	(0.0089)	(0.0092)	(0.0217)
Shock Quintile 1	-0.0722***	-0.0659***	-0.1248***	-0.1167***	-0.0533***	-0.0490***	-0.1548***	-0.1362***
	(0.0164)	(0.0171)	(0.0401)	(0.0418)	(0.0165)	(0.0173)	(0.0405)	(0.0426)
Shock Quintile 2	-0.0160	-0.0179	-0.0146	-0.0207	-0.0056	-0.0072	-0.0446	-0.0492
	(0.0126)	(0.0128)	(0.0308)	(0.0312)	(0.0126)	(0.0127)	(0.0309)	(0.0311)
Shock Quintile 4	0.0196	0.0173	0.0678**	0.0615**	0.0213*	0.0203*	0.0759***	0.0800***
	(0.0121)	(0.0123)	(0.0294)	(0.0299)	(0.0121)	(0.0122)	(0.0294)	(0.0298)
Shock Quintile 5	0.0294**	0.0369***	0.1524***	0.1576***	0.0442***	0.0368***	0.1072***	0.0957***
	(0.0131)	(0.0135)	(0.0319)	(0.0329)	(0.0130)	(0.0134)	(0.0317)	(0.0325)
Shock Quintile 1×Ability		-0.0021		-0.0111		-0.0300**		-0.0400
		(0.0121)		(0.0294)		(0.0121)		(0.0295)
Shock Quintile 2×Ability		0.0144		0.0230		-0.0219*		0.0012
		(0.0124)		(0.0302)		(0.0122)		(0.0299)
Shock Quintile 4×Ability		-0.0010		-0.0188		-0.0195*		0.0074
		(0.0116)		(0.0280)		(0.0117)		(0.0284)
Shock Quintile 5×Ability		0.0225*		0.0109		-0.0362***		-0.0372
		(0.0119)		(0.0289)		(0.0115)		(0.0279)
Observations	5,014	5,014	4,894	4,894	5,011	5,011	4,891	4,891
R-squared	0.1674	0.1687	0.1433	0.1439	0.1666	0.1686	0.1425	0.1435
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Job-Spell FE	No	No	No	No	No	No	No	No
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Income, bonus, and value are log-transformed.

The regressions featuring the AKM ability measure shows no direct effect of ability on sales or value, and its interaction generally shows no significant interaction with the shock quintiles (except in column 6 where the direct effect is exactly counteracted by the interaction effects). Even though firms pay more to attract CEOs with high AKM ability, and higher AKM CEOs strongly sort into larger firms, these individuals neither raise sales or value directly or translate exogenous shocks into better outcomes.

Table 9 employs experience as CEO ability, with the top panel utilizing firm fixed effects and the bottom job-spell fixed effects. Across nearly all specifications we see a positive direct effect of experience on firm sales and value. Using firm FE, we see that each additional year of experience translates to 0.32% higher sales and 1.57% higher value. For a CEO at the sample mean of 9 years of experience, this means 2.88% higher sales and 14% higher value. Using job-spell effects we see larger direct effects. The same CEO in year 9 generates 4.6% greater sales and 37.6% greater value.

Experience also interacts with shock quintiles. In the firm FE specification, more experienced CEOs increase sales and value in response to positive demand shocks. They also significantly mitigate the loss in sales and value associated associated with negative demand shocks. Consider a first quintile (negative) shock to demand. This lowers values by 14.9%, an effect that would be entirely counteracted by having a CEO with 5 more years of experience. In the job-spell fixed effects, we again see both large positive demand shocks on sales magnified by experience and large negative demand shocks on sales mitigated by experience.[9]

It is useful to compare the magnitudes of these effects to the compensation paid to these CEOs. Recall from Table 6 that, conditioning on exogenous changes in firm size or value, each additional year of experience within a job-spell results in a 6.2% increase in compensation. A CEO with 9 years of experience enjoys a pay premium of 55.8% relative to a first year CEO. At sample means this translates to an increase of 1.16 million DKK.

The mean firm has a value of 514 million DKK. A CEO with 9 years of experience has a direct effect on value of 14.1%, or 72.47 million DKK, or 62 times the CEO pay premium. Focusing on shocks, the CEO with 9 years of experience turns the effect of a fifth quintile (large positive) demand shock from a 12% increase in value to a 24% increase in value. The incremental value for a mean firm is 61.68 million DKK. That 9-years experienced CEO turns a first quintile (large negative) demand shock from a loss of 14.9% of value to an increase in value of 12%. The incremental value is 139.7 million DKK.

[9] We do not see similar interaction effect with respect to supply shocks that raise or lower the firms costs in either FE specification.

Table 9: Do More Experienced CEOs Generate Different Return on Shocks?

Firm Fixed Effect

Dependent Variable	(1) Sales	(2) Sales	(3) Value	(4) Value	(5) Sales	(6) Sales	(7) Value	(8) Value
	Shock (World Import Demand)				Shock (World Export Supply)			
Ability (CEO Experience)	0.0032***	-0.0041	0.0157***	0.0011	0.0031***	0.0044*	0.0156***	0.0143**
	(0.0011)	(0.0027)	(0.0026)	(0.0064)	(0.0011)	(0.0025)	(0.0026)	(0.0058)
Shock Quintile 1	-0.0858***	-0.0772***	-0.1680***	-0.1491***	-0.0715***	-0.0631***	-0.1824***	-0.1610***
	(0.0130)	(0.0134)	(0.0307)	(0.0317)	(0.0132)	(0.0138)	(0.0314)	(0.0328)
Shock Quintile 2	-0.0187*	-0.0225**	-0.0190	-0.0301	-0.0146	-0.0142	-0.0614**	-0.0647**
	(0.0107)	(0.0107)	(0.0252)	(0.0254)	(0.0107)	(0.0108)	(0.0254)	(0.0256)
Shock Quintile 4	0.0095	0.0118	0.0426*	0.0327	0.0184*	0.0226**	0.0701***	0.0717***
	(0.0106)	(0.0109)	(0.0249)	(0.0258)	(0.0105)	(0.0110)	(0.0247)	(0.0259)
Shock Quintile 5	0.0212*	0.0143	0.1254***	0.1209***	0.0369***	0.0412***	0.1001***	0.1001***
	(0.0114)	(0.0121)	(0.0269)	(0.0288)	(0.0113)	(0.0120)	(0.0266)	(0.0283)
Shock Quintile 1×Ability		0.0149***		0.0302***		0.0030		0.0129
		(0.0036)		(0.0085)		(0.0035)		(0.0082)
Shock Quintile 2×Ability		0.0080**		0.0069		-0.0014		-0.0053
		(0.0037)		(0.0088)		(0.0034)		(0.0081)
Shock Quintile 4×Ability		0.0029		0.0170**		-0.0038		-0.0008
		(0.0034)		(0.0081)		(0.0032)		(0.0076)
Shock Quintile 5×Ability		0.0092***		0.0135*		-0.0031		0.0005
		(0.0034)		(0.0080)		(0.0032)		(0.0076)
Observations	7,454	7,454	7,285	7,285	7,452	7,452	7,283	7,283
R-squared	0.1455	0.1483	0.1287	0.1306	0.1447	0.1454	0.1285	0.1292
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Job-Spell FE	No	No	No	No	No	No	No	No
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Job Spell Fixed Effect

Dependent Variable	(1) Sales	(2) Sales	(3) Value	(4) Value	(5) Sales	(6) Sales	(7) Value	(8) Value
	Shock (World Import Demand)				Shock (World Export Supply)			
Ability (CEO Experience)	0.0051***	-0.0042	0.0418***	0.0398***	0.0045***	0.0055	0.0403***	0.0502***
	(0.0014)	(0.0044)	(0.0036)	(0.0117)	(0.0014)	(0.0040)	(0.0036)	(0.0106)
Shock Quintile 1	-0.0523***	-0.0455***	-0.0216	-0.0087	-0.0453***	-0.0413***	-0.0524**	-0.0361
	(0.0094)	(0.0102)	(0.0249)	(0.0269)	(0.0098)	(0.0106)	(0.0259)	(0.0282)
Shock Quintile 2	-0.0125	-0.0162*	0.0126	0.0100	-0.0054	-0.0055	-0.0078	-0.0083
	(0.0086)	(0.0087)	(0.0226)	(0.0230)	(0.0089)	(0.0089)	(0.0235)	(0.0236)
Shock Quintile 4	-0.0043	-0.0032	0.0313	0.0410*	-0.0004	-0.0007	0.0379	0.0415*
	(0.0086)	(0.0088)	(0.0227)	(0.0233)	(0.0089)	(0.0091)	(0.0236)	(0.0240)
Shock Quintile 5	0.0016	0.0005	0.0349	0.0336	0.0158*	0.0206**	0.0298	0.0419
	(0.0093)	(0.0103)	(0.0245)	(0.0272)	(0.0095)	(0.0104)	(0.0252)	(0.0275)
Shock Quintile 1×Ability		0.0125***		0.0078		0.0005		-0.0037
		(0.0048)		(0.0127)		(0.0045)		(0.0118)
Shock Quintile 2×Ability		0.0034		-0.0015		-0.0021		-0.0153
		(0.0053)		(0.0141)		(0.0048)		(0.0127)
Shock Quintile 4×Ability		0.0080		-0.0107		-0.0002		-0.0142
		(0.0051)		(0.0135)		(0.0048)		(0.0125)
Shock Quintile 5×Ability		0.0100**		0.0033		-0.0031		-0.0146
		(0.0048)		(0.0127)		(0.0044)		(0.0117)
Observations	7,454	7,454	7,285	7,285	7,452	7,452	7,283	7,283
R-squared	0.1617	0.1629	0.1280	0.1285	0.1614	0.1616	0.1287	0.1292
Firm FE	No	No	No	No	No	No	No	No
Job-Spell FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Income, bonus, and value are log-transformed.

It is important to note that this loss mitigation effect is not what the theory predicts, nor is it consistent with how firms compensate their CEOs. Taken literally the theory suggests that the value of high ability CEOs is most strongly felt in the presence of large positive shocks, and for sufficiently large adverse shocks (as $e => 0$), there is no difference in value to the firm between a high and low ability CEO. Both types of CEOs should reduce their effort in bad times and high ability CEOs should reduce their effort more! A version of TAble 9 that replaces

sales with CEO compensation reveals that firms pay high ability CEOs more in all periods and they pay more for good news, not for mitigating bad news.

What could explain these findings? A key is that the theory does not contemplate the possibility that a firm could go out of business, essentially taking firm value to zero permanently and losing the CEO the continuation value of their CEO premium in subsequent years. In an appendix we explore an extension to the theory that incorporates the possiblity of firm death and show that CEO effort is U-shaped. High end shocks bring forth more CEO effort to capitalize on a strong earnings potential. Low end shocks also bring forth more CEO effort to ensure that firm value does not fall below a critical threshold where the firm fails.

5 Conclusion

We build a model of CEO compensation that combines the insights from both principal-agent models with unobservable effort and the assignment models with heterogeneous CEOs and firms. We nest this model in an environment in which exogenous trade shocks interact with CEO ability and firm size to change the value of the firm.

The model predicts that globalization changes CEO compensation in three channels. It increases the level of CEO compensation by increasing the size of the firm. It leads to a higher share of incentive compensation, as the firm induces greater CEO effort in a more volatile environment. It increases the returns to ability, as a higher-ability CEO translates positive trade shocks to higher firm value and, as a result, is rewarded with a higher percentage ownership.

Using Danish employee-firm matched data, and instruments for trade at the firm level, we find empirical evidence that supports these channels predicted by the model. We find that exogenous shocks to the external trade environment increase the exporting and offshoring of the firm, resulting in higher sales and value, along with greater profits, markups, profitability, and lower labor share in value-added. These shocks also induce greater sales and value volatility for more globally exposed firms.

Higher sales and value lead to a higher level of executive compensation. This is true across firms (larger firms pay more, and pay a larger CEO premium relative to previous wages) as well as within CEO job-spells. Within job-spells, the elasticity of CEO pay with respect to firm value corresponds to the theory's predictions for how firms share value with CEOs. Consistent with the theory, this elasticity is greater for larger firms and firms facing greater value volatility induced by trade shocks that interact with firm size and CEO ability.

We measure CEO ability in two ways. First, using experience. Second, using job transitions to identify how CEOs are compensated before becoming CEOs. These measures strongly correlate with the level of pay while CEO, and higher ability CEOs sort into larger firms. We also show that more experienced CEOs generate greater value for the firm in all periods. They magnify the returns to positive shocks and mitigate the effect of adverse shocks. While more experienced CEOs are better compensated, the increase in value they offer is 72-120 times greater than what they are paid.

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A Data Description

A.1 Samples

Table A.1: Sample Restrictions

	CEO-years Obs.	Sales	Exports	Offshoring	Value Added	Employees
		Share of Total				
All manufacturing firms	122,398	1.00	1.00	1.00	1.00	1.00
At least 50 employees	15,335	0.80	0.87	0.85	0.78	0.70
Non-missing exports and offshoring	13,485	0.78	0.87	0.84	0.75	0.66
Non-missing capital and domestic sales	12,958	0.76	0.81	0.80	0.71	0.63
Non-missing CEO demographics and positive income	12,854	0.74	0.79	0.78	0.70	0.62

Notes: The final sample includes CEOs in manufacturing firms with at least 50 employees, non-missing exports, (broad) offshoring, capital, domestic sales, CEO demographics (gender, age etc) and positive CEO income, and covers the years 1999 to 2017.

Table A.2: Sample Means

	Full Sample			Size < 100 employees			Size >= 100 employees		
	Obs.	Mean	Std.Dev.	Obs.	Mean	Std.Dev.	Obs.	Mean	Std.Dev.
CEO characteristics:									
Age	12,854	49.95	8.49	5,648	50.29	9.02	7,206	49.68	8.04
Female	12,854	0.02	0.16	5,648	0.03	0.16	7,206	0.02	0.15
Experience	12,854	24.35	10.20	5,648	25.93	9.70	7,206	23.11	10.41
Tenure	12,797	9.24	8.26	5,630	10.90	8.83	7,167	7.93	7.52
High skilled	12,854	0.69	0.46	5,648	0.61	0.49	7,206	0.75	0.43
Income (1,000 DKK)	12,854	2,076	3,686	5,648	1,381	920	7,206	2,620	4,786
- Base salary (1,000 DKK)	12,854	1,895	2,943	5,648	1,284	871	7,206	2,373	3,787
- Bonus (1,000 DKK)	12,854	181	1,722	5,648	97	200	7,206	247	2,291
AKM Fixed Effect	9,330	2.59	1.93	3,844	2.30	1.93	5,486	2.79	1.90
ISCO one-digit occupations:									
- Managers	11,906	0.80	0.40	5,156	0.79	0.41	6,750	0.81	0.39
- Professionals	11,906	0.06	0.24	5,156	0.06	0.24	6,750	0.07	0.25
- Technicians	11,906	0.05	0.22	5,156	0.06	0.24	6,750	0.05	0.21
- Other occupation	11,906	0.08	0.27	5,156	0.09	0.28	6,750	0.07	0.26
Internally promoted	8,596	0.58	0.49	3,443	0.62	0.49	5,153	0.56	0.50
Firm characteristics:									
Employees	12,854	259.76	715.37	5,648	78.28	51.22	7,206	402.00	929.96
Wage bill (1,000 DKK)	12,854	107,972	378,004	5,648	29,372	27,697	7,206	169,579	495,638
Capital (1,000 DKK)	12,854	158,559	742,467	5,648	34,964	120,038	7,206	255,431	975,056
Sales (1,000 DKK)	12,854	636,198	2,550,445	5,648	140,975	265,566	7,206	1,024,349	3,347,485
Exports (1,000 DKK)	12,854	263,984	1,061,276	5,648	59,758	131,429	7,206	424,053	1,391,891
Narrow offshoring (1,000 DKK)	10,545	45,760	158,051	4,277	11,078	23,727	6,268	69,426	200,656
Firm value (1,000 DKK)	12,854	514,431	4,548,485	5,648	53,239	136,471	7,206	875,910	6,049,346

Notes: The sample includes CEOs in manufacturing firms with at least 50 employees, non-missing exports, (broad) offshoring, capital, domestic sales, CEO demographics (gender, age etc) and positive CEO income, and covers the years 1999 to 2017. Experience is measured as time spent employed since 1980. Tenure is measured as time spent at the current firm. Annual income is labor income including bonusses. Internally promoted is a dummy indicating for all job spells starting after 1999 if the CEO is hired by the firm before the CEO is registered as a CEO. Nominal CEO income variables are measured in year 2015 DKK using the CPI deflator and nominal firm variables are measured in year 2015 DKK using the PPI deflator.

A.2 Constructing Firm Value

The literature that uses data on compensation from publicly traded firms can utilize the stock market valuation of these firms as a measure of value. Since the large majority of firms in our sample are not publicly traded, we do not have a comparable value measure. Instead, we employ a measure of value for unlisted firms that is used by Danish Tax Authorities when firms are inherited by children of owners.

The estimation method defines firm value as the sum of equity capital and goodwill. Equity capital (EGUL) is available from annual accounts and is adjusted for stock of unlisted assets in associated companies, postponed tax payments and the most recent value of real estate. Equity capital accounts for the stock of financial assets (FAAT), debt including debt to the tax authorities (AKG) and value of land and buildings (MAAT).

Goodwill is intended to measure the difference between the true traded value of the firm and equity capital, and it includes the value of intangible assets and other hard-to-measure assets. As a main component of goodwill, the tax authorities base their estimation on the last three years of pretax profits (RFEP) adjusted for financial income and expenses and some extraordinary costs. The profit measure, ARFS, from the Account statistics subtracts financial net income and extraordinary costs from RFEP. The extraordinary costs include "depreciation of purchased goodwill".

The tax authorities then calculate a weighted average of the last three years of ARFS as follows:

$$\pi_t^R = \frac{ARFS_{t-2} + 2ARFS_{t-1} + 3ARFS_t}{6}. \tag{32}$$

To the weighted regulated profits an adjustment for trend growth, calculated as $\pi_t^T = (ARFS_t - ARFS_{t-2})/2$, is then added.

The next step is to subtract return to capital by multiplying the firm's total assets observed in the annual accounts (AT) with the current official return to capital rate, r_t, according to "virksomhedsskattelovens § 9" plus 3%. This will produce a residual amount, $\pi_t^R + \pi_t^T - r_t AT_t$, to calculate the return to goodwill from.

The tax authorities also calculate a capitalization factor using the current official return to capital rate according to "virksomhedsskattelovens § 9" plus 8% and accounting for the longevity of goodwill in the firm. The tax authorities use the following formula for the capitalization factor, C_t in year t:

$$C_t = \sum_{k=1}^{n} \frac{\left(1 - \frac{k-1}{n}\right) + \frac{n-k}{n}}{2} (1 + r_t^C)^k, \tag{33}$$

where n is expected life of goodwill, r_t^C is the official return to capital plus 8% in year t.

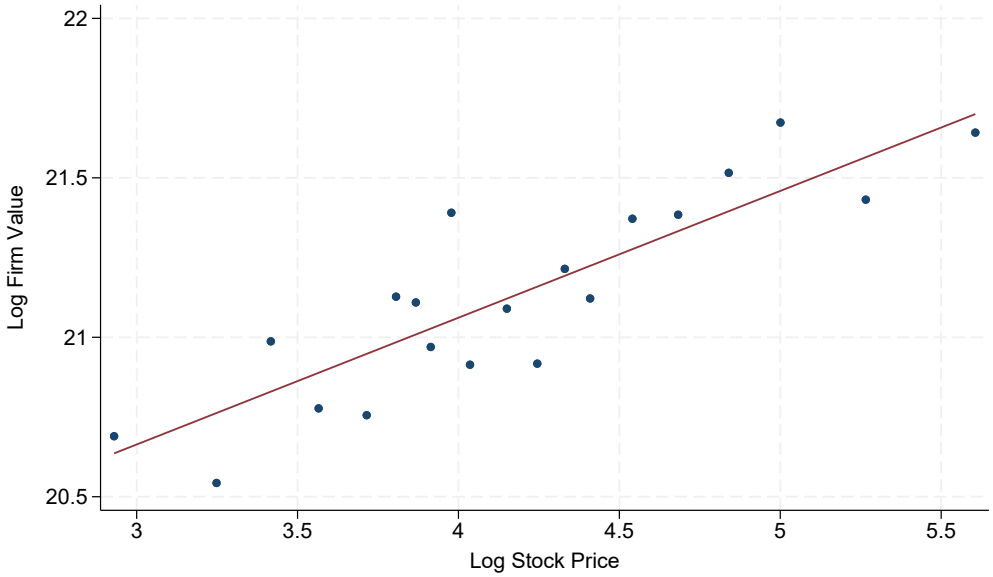
For example, the capitalization factor is 2.76 if expected life of goodwill is 7 years and the official return to capital rate is 1% (as was the case in 2017). Skatteministeriet (2021) explain that the applied lifetime of goodwill should account for firm specific factors such as product differentiation etc., and that the default lifetime of goodwill is 7 years, which we apply here.[10]

The residual amount to calculate the return to goodwill from is simply multiplied by the capitalization factor to get the estimated value of goodwill. That is, goodwill is calculated as $G_t = (\pi_t^R + \pi_t^T - r_t AT_t)C_t$ if $\pi_t^R + \pi_t^T > 0$ and is otherwise set to zero. The final step is then to add goodwill to the equity capital of the firm to arrive at the estimated total value of the firm.

As mentioned above the vast majority of the firms in our sample are unlisted firms. However, a minor portion are publicly traded and for those firms we can compare the constructed value with the storck market valuation. The figure belows shows that constructed value and stock market price covary strongly within firms over time.

[10] The tax authorities can adjust this lifetime on a case by case basis if warranted by special circumstances. We cannot evaluate this on a case-by-case basis, so we set the lifetime of goodwill the default, i.e., 7 years. Skatteministeriet (2021) note that the authorities can, according to current legislation (the so-called Goodwill circulære from 2000), more broadly deviate from the assessment of goodwill on a case-by-case basis if, for example, some extraordinary expenses for, e.g., R&D are observed. Again, we cannot implement such adjustments on a case-by-case basis.

Figure A.1: Firm Value and Stock Price for Listed Firms



Notes: The figure shows a binned scatter plot of Log Firm Value against Log Stock Price for listed firms in the sample. The scatter plot controls for firm fixed effects. The regression coefficient is 0.40 with a t-stat of 6.87.

B Channels Linking Trade to Firm Value

Table A.3: Channels Through Which Offshoring Increases Sales and Value

	(1) Sales	(2) Domestic Sales	(3) Export	(4) Export Quantity	(5) Unit Value
Offshoring	0.2996***	0.0992	0.6084***	0.5041***	-0.1684***
	(0.0883)	(0.1073)	(0.2312)	(0.0767)	(0.0435)
Observations	10,248	10,248	10,248	675,743	675,743
Firm	Yes	Yes	Yes		
Industry-Year	Yes	Yes	Yes		
Firm-CN8plus-Country				Yes	Yes
CN8plus-Country-Year				Yes	Yes
First-stage F stats				849.3992	849.3992

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All variables are log-transformed.

Table A.4: Trade Shocks and Changes in Firm Characteristics

	(1) Labor Share of Sales	(2) Labor Share of Value Added	(3) Markup	(4) TFP	(5) Profit
Offshoring	-0.0442***	-0.0613***	0.0502*	0.0124*	0.5168**
	(0.0151)	(0.0234)	(0.0286)	(0.0070)	(0.2260)
Observations	10,228	8,818	8,887	8,887	8,404
Firm FE	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes
Number of firms	1057	970	933	933	952
Cragg-Donald Wald F	25.3222	23.4744	29.7027	29.7027	19.4055
Kleibergen-Paap F	14.0464	12.5529	17.7014	17.7014	10.1456

	(1) Labor Share of Sales	(2) Labor Share of Value Added	(3) Markup	(4) TFP	(5) Profit
Export	-0.0041	-0.0476***	0.0684*	0.0643***	0.3315**
	(0.0077)	(0.0144)	(0.0384)	(0.0140)	(0.1415)
Observations	12,200	10,555	8,891	8,891	9,926
Firm FE	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes
Number of firms	1213	1130	933	933	1101
Cragg-Donald Wald F	76.6725	64.1274	32.8376	32.8376	51.8817
Kleibergen-Paap F	43.2134	36.9247	23.8559	23.8559	26.7540

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Markup, profit, offshoring, and export are log-transformed. Markup and TFP are constructed following De Loecker and Warzynski (2012).

Table A.5: Global Shocks Increase Sales and Value

	Sales			Value		
	(1)	(2)	(3)	(4)	(5)	(6)
World Import Demand	0.0926***		0.0812***	0.1483***		0.1350***
	(0.0141)		(0.0142)	(0.0309)		(0.0314)
World Export Supply		0.1586***	0.1422***		0.2415***	0.2036***
		(0.0164)	(0.0167)		(0.0363)	(0.0371)
Observations	12,229	12,462	12,164	11,857	12,076	11,796
R-squared	0.9377	0.9366	0.9382	0.8568	0.8557	0.8570
Firm	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All variables are log-transformed.

Table A.6: Exogenous Changes in Sales or Value Induced by Globalization Lead to Higher Pay (By Firm Size)

	Income				Bonus			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Large	Small	Large	Small	Large	Small	Large	Small
Sales	1.2752***	0.6961***			4.6537**	1.7547***		
	(0.3989)	(0.1696)			(1.9914)	(0.4267)		
Value			0.7968**	0.3059***			2.0274*	0.8267***
			(0.3437)	(0.0983)			(1.1787)	(0.2304)
Experience	0.0627***	0.0557***	0.0540**	0.0698***	0.0735	0.0221	0.0720	0.0481
	(0.0225)	(0.0117)	(0.0212)	(0.0124)	(0.0637)	(0.0356)	(0.0574)	(0.0374)
Experience Squared	-0.0007***	-0.0004***	-0.0003	-0.0004**	-0.0017***	0.0006	-0.0006	0.0007
	(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0006)	(0.0004)	(0.0006)	(0.0004)
Observations	6,412	5,086	6,226	4,919	6,286	4,902	6,115	4,746
Job-Spell FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All variables except experience are log-transformed.

C Results Excluding Family Firms

Family firms in our sample are smaller than other firms, and their CEOs have longer average tenures. This section shows how we define family firms, the summary statistics of the family firms, and the empirical results for the main tables excluding family firms.

We define family firms as follows: A firm is a family firm if it ever has a board member who is the CEO's relative, or the CEO is the only board member.[11] The relative relation considers the first-degree and second-degree connections, including spouses, children, grandchildren, moms, dads, grandparents, aunts, uncles, cousins, siblings, nieces, and nephews. We also consider step-relatives. Our approach separates firms into three types: Firms where we can clearly identify family connections (5745 observations, 44.69% of the main sample); Firms where we can clearly identify the absence of family connections (744 observations, 5.79% of the main sample); And in a final 50% of cases, we cannot clearly identify whether a CEO is related to a board member[12]. Not being identifiable is due to missing information about the CEOs' or

[11] We also try a more relaxed definition. We define a firm as a family firm if it ever has over 50% of board members who are the CEO's relatives or CEOs themselves. Using this definition, we identify 5043 observations belonging to family firms, 5003 belonging to non-family firms, and 2808 observations are not identifiable. The summary statistics of family firms and the regression results for the main tables dropping family firms based on these 2 definitions are similar.

[12] If some board members are not CEO's relatives and we cannot identify if other board members are CEO's relatives, this case is classified as not identifiable. For CEO-board member pairs that cannot identify whether they are relatives, we classify a small share of pairs as not relatives if the CEO is an immigrant or the CEO is Danish but the board member is an immigrant.

board members' parents or grandparents, or missing board member information [13]. We have not dropped these cases because they represent too large a share of the overall sample. However, we have compared the summary stats for firms in this third category and find that unidentifiable firms have similar average CEO income, firm sizes, import and exports with non-family firms (Table A.7). The distributions for those variables are also similar for unidentifiable firms and non-family firms (Figures available upon request). The remaining part of this section shows the main tables in the empirical section with the sample excluding family firms.

Table A.7: Summary Statistics

	Family Firms			Non-Family Firms			Not Identifiable		
Variable	Obs.	Mean	SD	Obs.	Mean	SD	Obs.	Mean	SD
CEO Income	5,745	1,563.48	2,763.09	744	2,458.35	2,461.36	6,365	2,493.47	4,406.67
CEO Premium	2,870	0.25	0.37	449	0.42	0.38	3,758	0.32	0.35
AKM Fixed Effect	3,713	2.38	2.07	584	2.79	1.95	5,033	2.72	1.80
Tenure	5,734	11.14	8.85	739	6.14	6.32	6,324	7.88	7.48
Experience	5,745	25.44	9.76	744	19.02	12.59	6,365	23.98	10.05
CEO Experience	5,745	9.06	5.32	744	5.95	4.09	6,365	7.57	4.84
Industry experience	5,715	13.98	8.54	738	9.55	7.48	6,347	11.55	7.60
Sales (1,000 DKK)	5,745	275.39	1,285.08	744	1,799.20	5,423.43	6,365	825.92	2,810.88
Firm value (1,000,000 DKK)	5,539	99.65	310.80	719	652.32	1,915.59	6,190	905.25	6,490.30
Exports (1,000 DKK)	5,745	145.85	994.32	744	676.24	2,020.32	6,365	322.42	932.72
Imports (1,000 DKK)	5,745	48.35	195.31	744	279.60	560.14	6,365	173.16	710.87
Number of Board Menbers	5,745	2.16	1.80	744	4.19	2.13	6,365	3.58	2.27

[13] According to the Danish Civil Registration System, the share of parental links recorded before 1960 is low. Given that the average CEO age in our sample period (1999–2017) is 50, many of them were born before 1960, and we therefore lack information about their parents and grandparents.

Table A.8: Offshoring and Exporting Increases Sales and Firm Values

Second Stage

	(1) Sales	(2) Sales	(3) Sales	(4) Value	(5) Value	(6) Value
Export	0.2212***		0.3490***	0.2216		0.4363**
	(0.0633)		(0.1072)	(0.1394)		(0.1986)
Offshoring		0.3290***	0.1835*		0.4596*	0.2183
		(0.1202)	(0.1053)		(0.2635)	(0.2181)
Observations	6,693	5,809	5,668	6,510	5,646	5,514
R-squared	0.0243	-0.9860	-0.6725	-0.0395	-0.5398	-0.3778
Firm	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year	Yes	Yes	Yes	Yes	Yes	Yes

First Stage

	(1) Export	(2) Export	(3) Offshoring	(4) Offshoring
World Import Demand	0.3569***	0.3629***		-0.1332
	(0.0588)	(0.0601)		(0.0862)
World Export Supply		0.0492	0.3706***	0.4082***
		(0.0758)	(0.1065)	(0.1108)
Observations	6,693	6,671	5,809	5,668
R-squared	0.8666	0.8665	0.8243	0.8254
F-stat WID	36.86	36.50	.	2.38
F-stat WES	.	0.42	12.11	13.57
Firm	Yes	Yes	Yes	Yes
Industry-Year	Yes	Yes	Yes	Yes

Note: This table excludes family firms and corresponds to Table 2 in the empirical section. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All variables are log-transformed.

Table A.9: Global Firms Are More Volatile

	Sample Firms		Large Frims	
	(1) Sales Volatility	(2) Value Volatility	(3) Sales Volatility	(4) Value Volatility
Average Export Share	0.0143	-0.0407	0.0601	-0.0277
	(0.0462)	(0.0710)	(0.0433)	(0.0879)
Average Offshoring Share	0.0527	0.1813	0.2220*	0.5060*
	(0.1482)	(0.2278)	(0.1335)	(0.2711)
Average Size	0.0007	-0.0566***	0.0200	-0.0394
	(0.0135)	(0.0208)	(0.0139)	(0.0281)
Observations	472	472	306	306
R-Squared	0.1990	0.1936	0.2809	0.2353
Industry FE	Yes	Yes	Yes	Yes

Note: This table excludes family firms and corresponds to Table 4 in the empirical section. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Firms that are observed at least five times between 1999-2017 enter the sample. Regressions 1 and 2 include firms with more than 50 employees. Regressions 3 and 4 only include large firms with at least 100 employees in the first year of the sample. Volatility is measured by the standard deviation of log sales or log value. There is one observation per firm.

Table A.10: CEO Earnings Are Higher in Large Firms

	Income				Bonus			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sales	0.3225***	0.1624***			0.2645***	0.0756*		
	(0.0052)	(0.0148)			(0.0127)	(0.0404)		
Value			0.2119***	0.0400***			0.1755***	0.0395**
			(0.0037)	(0.0062)			(0.0088)	(0.0167)
Experience	0.0008	0.0424***	-0.0052**	0.0464***	0.0116**	0.1092***	0.0071	0.1047***
	(0.0020)	(0.0073)	(0.0021)	(0.0074)	(0.0050)	(0.0198)	(0.0051)	(0.0199)
(Experience)^2	-0.0000	-0.0004***	0.0001	-0.0004***	-0.0003***	-0.0009***	-0.0002**	-0.0008***
	(0.0000)	(0.0001)	(0.0000)	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0002)
Observations	7,080	6,527	6,878	6,347	6,985	6,443	6,789	6,268
R-Squared	0.4904	0.8884	0.4665	0.8860	0.1725	0.7701	0.1737	0.7726
Job-Spell FE	No	Yes	No	Yes	No	Yes	No	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: This table excludes family firms and corresponds to Table 5 in the empirical section. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All variables are log-transformed.

Table A.11: Exogenous Changes in Sales or Value Induced by Globalization Lead to Higher Pay

Second Stage

	Income				Bonus			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sales	1.0979**	0.2514			2.8704*	2.3647***		
	(0.4636)	(0.2433)			(1.4673)	(0.7873)		
Sales × Large Firm Sales		0.9352***				0.6210		
		(0.1846)				(0.6232)		
Value			1.0829	0.3819*			2.2718	1.3009**
			(0.9880)	(0.2284)			(2.3729)	(0.6077)
Value × Large Firm Value				0.4131***				0.1298
				(0.1186)				(0.3088)
Experience	0.0131	0.0182	0.0148	0.0207	0.0200	0.0215	0.0378	0.0595
	(0.0200)	(0.0226)	(0.0345)	(0.0207)	(0.0608)	(0.0617)	(0.0822)	(0.0558)
(Experience)^2	-0.0006***	-0.0005***	-0.0001	-0.0002	-0.0014***	-0.0013***	-0.0003	-0.0007
	(0.0001)	(0.0001)	(0.0004)	(0.0002)	(0.0004)	(0.0003)	(0.0008)	(0.0004)
Observations	6,263	6,304	6,090	6,132	6,179	6,220	6,011	6,053
Job-Spell FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

First Stage

	(1) Sales	(2) Sales	(3) Large Firm Sales	(4) Value	(5) Value	(6) Large Firm Value
World Import Demand	0.0236	0.0543*	-0.0541**	0.0356	0.1015	-0.1905***
	(0.0193)	(0.0306)	(0.0254)	(0.0498)	(0.0794)	(0.0639)
World Import Demand × Large Firm Dummy		-0.0440	0.0844***		-0.0941	0.2338***
		(0.0346)	(0.0288)		(0.0896)	(0.0722)
World Export Supply	0.0721***	0.0929***	-0.0274	0.0690	0.0828	-0.1205*
	(0.0260)	(0.0344)	(0.0286)	(0.0675)	(0.0897)	(0.0723)
World Export Supply × Large Firm Dummy		-0.0380	0.1189***		-0.0255	0.2555***
		(0.0392)	(0.0326)		(0.1015)	(0.0817)
Experience	0.0315***	0.0324***	0.0157***	0.0298*	0.0312*	0.0111
	(0.0069)	(0.0069)	(0.0057)	(0.0177)	(0.0177)	(0.0142)
(Experience)^2	0.0001**	0.0001*	0.0002***	-0.0003*	-0.0004**	-0.0003*
	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0001)
Observations	6,263	6,263	6,263	6,090	6,090	6,090
R-squared	0.9747	0.9747	0.9993	0.9211	0.9211	0.9980
F-stat WID	1.50	3.15	4.52	0.51	1.63	8.88
F-stat WID × Large Firm	.	1.62	8.60	.	1.10	10.50
F-stat WES	7.71	7.30	0.92	1.05	0.85	2.78
F-stat WES × Large Firm	.	0.94	13.32	.	0.06	9.76
Job-Spell	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year	Yes	Yes	Yes	Yes	Yes	Yes

Note: This table excludes family firms and corresponds to Table 6 in the empirical section. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Income, bonus, and value are log-transformed. The explanatory variable "Large Firm Dummy" is a binary indicator that takes the value of 1 if the firm employs more than 100 people, and 0 otherwise.

Table A.12: Volatility Changes the Structure of Compensation

	All Firms				Large Frims			
	(1) Income	(2) Income	(3) Bonus	(4) Bonus	(5) Income	(6) Income	(7) Bonus	(8) Bonus
Value	0.0556***	0.0544***	0.0493**	0.0515**	0.0425***	0.0406***	0.0206	0.0197
	(0.0073)	(0.0073)	(0.0205)	(0.0206)	(0.0096)	(0.0096)	(0.0270)	(0.0271)
Value × Fitted Value Volatility	3.7392		4.4695		4.4634		12.2875	
	(2.7905)		(7.8176)		(4.6433)		(13.0237)	
Value × Fitted Value Volatility (FE)		0.3344**		-0.5912		0.6587***		0.2395
		(0.1703)		(0.4866)		(0.2334)		(0.6558)
Observations	4,179	4,179	4,129	4,129	2,929	2,929	2,902	2,902
Job-Spell FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: This table excludes family firms and corresponds to Table 7 in the empirical section. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Income, bonus, and value are log-transformed. Industry-year fixed effects are based on two-digit NACE industries. The data includes only job spells with at least five observations. Regressions 1 to 4 include firms with fewer than 50 employees. Large firms refer to those that have at least 100 employees in the first year of the sample. Fitted Value Volatility is calculated as the within job spell standard deviation of predicted (log) value from a first-stage regression of (log) value on the WID and WES instruments and job spell and industry-year fixed effects. Fitted Value Volatility (FE) is constructed similarly, but the predicted values include the first-stage fixed effects.

Table A.13: Do Better CEOs Generate Different Return on Shocks?

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	Sales	Sales	Value	Value	Sales	Sales	Value	Value
	Shock (World Import Demand)				Shock (World Export Supply)			
Ability (AKM Fixed Effect)	0.0076	-0.0036	0.0117	0.0018	0.0089*	0.0039	0.0169	0.0332
	(0.0052)	(0.0120)	(0.0124)	(0.0282)	(0.0052)	(0.0129)	(0.0125)	(0.0306)
Shock Quintile 1	-0.0723***	-0.0730***	-0.1830***	-0.1844***	-0.0636***	-0.0652***	-0.2113***	-0.2132***
	(0.0214)	(0.0225)	(0.0512)	(0.0537)	(0.0219)	(0.0231)	(0.0527)	(0.0558)
Shock Quintile 2	-0.0236	-0.0230	-0.0761*	-0.0830**	-0.0008	-0.0028	-0.0465	-0.0498
	(0.0166)	(0.0168)	(0.0395)	(0.0400)	(0.0165)	(0.0167)	(0.0393)	(0.0397)
Shock Quintile 4	0.0070	0.0066	0.0224	0.0156	0.0204	0.0240	0.0788**	0.0888**
	(0.0156)	(0.0160)	(0.0369)	(0.0379)	(0.0156)	(0.0161)	(0.0371)	(0.0382)
Shock Quintile 5	0.0308*	0.0377**	0.1792***	0.1796***	0.0562***	0.0486***	0.1727***	0.1482***
	(0.0170)	(0.0179)	(0.0403)	(0.0425)	(0.0167)	(0.0173)	(0.0396)	(0.0410)
Shock Quintile 1×Ability		0.0132		0.0134		0.0084		-0.0125
		(0.0163)		(0.0389)		(0.0169)		(0.0402)
Shock Quintile 2×Ability		0.0123		0.0400		0.0166		-0.0014
		(0.0165)		(0.0391)		(0.0177)		(0.0419)
Shock Quintile 4×Ability		0.0070		-0.0101		0.0144		0.0128
		(0.0158)		(0.0372)		(0.0165)		(0.0389)
Shock Quintile 5×Ability		0.0225		0.0090		-0.0119		-0.0668*
		(0.0164)		(0.0388)		(0.0164)		(0.0387)
Observations	2,924	2,924	2,858	2,858	2,920	2,920	2,853	2,853
R-squared	0.2055	0.2061	0.1963	0.1969	0.2074	0.2088	0.1955	0.1975
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Job-Spell FE	No	No	No	No	No	No	No	No
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: This table excludes family firms and corresponds to Table 8 in the empirical section. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Income, bonus, and value are log-transformed.

Table A.14: Do More Experienced CEOs Generate Different Return on Shocks?

Firm Fixed Effect

Dependent Variable	(1) Sales	(2) Sales	(3) Value	(4) Value	(5) Sales	(6) Sales	(7) Value	(8) Value
	Shock (World Import Demand)				Shock (World Export Supply)			
Ability (CEO Experience, Total)	0.0078***	-0.0007	0.0238***	0.0009	0.0077***	0.0084**	0.0246***	0.0132
	(0.0015)	(0.0038)	(0.0036)	(0.0087)	(0.0015)	(0.0036)	(0.0035)	(0.0084)
Shock Quintile 1	-0.0807***	-0.0694***	-0.1512***	-0.1096**	-0.0713***	-0.0572***	-0.1552***	-0.1146***
	(0.0180)	(0.0185)	(0.0418)	(0.0430)	(0.0182)	(0.0187)	(0.0426)	(0.0436)
Shock Quintile 2	-0.0300**	-0.0321**	-0.0448	-0.0584*	-0.0083	-0.0087	-0.0418	-0.0526
	(0.0149)	(0.0149)	(0.0345)	(0.0346)	(0.0147)	(0.0148)	(0.0342)	(0.0345)
Shock Quintile 4	-0.0034	-0.0011	0.0205	0.0086	0.0281**	0.0307**	0.0797**	0.0766**
	(0.0144)	(0.0147)	(0.0332)	(0.0340)	(0.0143)	(0.0147)	(0.0330)	(0.0341)
Shock Quintile 5	0.0167	0.0115	0.1580***	0.1592***	0.0540***	0.0641***	0.1508***	0.1574***
	(0.0157)	(0.0168)	(0.0363)	(0.0387)	(0.0154)	(0.0162)	(0.0357)	(0.0375)
Shock Quintile 1×Ability		0.0179***		0.0563***		0.0091*		0.0460***
		(0.0051)		(0.0117)		(0.0049)		(0.0113)
Shock Quintile 2×Ability		0.0131**		0.0142		-0.0014		0.0038
		(0.0053)		(0.0122)		(0.0050)		(0.0116)
Shock Quintile 4×Ability		0.0025		0.0237**		-0.0024		0.0067
		(0.0048)		(0.0110)		(0.0046)		(0.0107)
Shock Quintile 5×Ability		0.0092*		0.0165		-0.0065		0.0025
		(0.0048)		(0.0110)		(0.0046)		(0.0106)
Observations	3,862	3,862	3,775	3,775	3,859	3,859	3,772	3,772
R-squared	0.1922	0.1963	0.1831	0.1894	0.1952	0.1982	0.1827	0.1885
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Job-Spell FE	No	No	No	No	No	No	No	No
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Job Spell Fixed Effect

Dependent Variable	(1) Sales	(2) Sales	(3) Value	(4) Value	(5) Sales	(6) Sales	(7) Value	(8) Value
	Shock (World Import Demand)				Shock (World Export Supply)			
Ability (CEO Experience)	0.0170***	0.0118*	0.0689***	0.0640***	0.0153***	0.0118**	0.0647***	0.0600***
	(0.0020)	(0.0064)	(0.0053)	(0.0171)	(0.0019)	(0.0057)	(0.0051)	(0.0153)
Shock Quintile 1	-0.0264**	-0.0182	0.0141	0.0508	-0.0396***	-0.0315**	-0.0208	0.0165
	(0.0125)	(0.0136)	(0.0333)	(0.0364)	(0.0126)	(0.0134)	(0.0338)	(0.0359)
Shock Quintile 2	0.0035	-0.0029	0.0269	0.0232	0.0026	0.0016	0.0138	0.0139
	(0.0112)	(0.0114)	(0.0298)	(0.0304)	(0.0116)	(0.0116)	(0.0309)	(0.0309)
Shock Quintile 4	0.0069	0.0096	0.0429	0.0558*	0.0082	0.0105	0.0530*	0.0590*
	(0.0111)	(0.0114)	(0.0295)	(0.0302)	(0.0117)	(0.0118)	(0.0314)	(0.0316)
Shock Quintile 5	0.0094	0.0045	0.0204	0.0348	0.0216*	0.0233*	0.0442	0.0709**
	(0.0122)	(0.0134)	(0.0325)	(0.0358)	(0.0125)	(0.0133)	(0.0334)	(0.0353)
Shock Quintile 1×Ability		0.0094		0.0221		0.0077		0.0240
		(0.0070)		(0.0188)		(0.0063)		(0.0168)
Shock Quintile 2×Ability		-0.0069		0.0003		-0.0008		0.0032
		(0.0078)		(0.0206)		(0.0069)		(0.0184)
Shock Quintile 4×Ability		0.0012		-0.0151		-0.0011		-0.0073
		(0.0073)		(0.0196)		(0.0069)		(0.0184)
Shock Quintile 5×Ability		0.0079		-0.0006		0.0034		-0.0074
		(0.0070)		(0.0187)		(0.0063)		(0.0168)
Observations	3,862	3,862	3,775	3,775	3,859	3,859	3,772	3,772
R-squared	0.2137	0.2160	0.1959	0.1978	0.2166	0.2177	0.1965	0.1988
Firm FE	No	No	No	No	No	No	No	No
Job-Spell FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: This table excludes family firms and corresponds to Table 9 in the empirical section. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Income, bonus, and value are log-transformed.

D Theory

D.1 Globally Engaged Firms Are Larger and More Volatile

Suppose a firm sells goods in both the domestic market (D) and foreign market (F). Then the firm's demand shifter consists of the effects from two markets:

$$\lambda_{it} = (\lambda_i^D + \lambda_i^F)(x_{it}^D + x_{it}^F). \tag{34}$$

The profit function can be written as:

$$\pi_{it} = \frac{p_{it}q_{it}}{\rho} - f = \frac{a_{it}^{\rho-1}\mu_{it}^{1-\rho}(\lambda_i^D + \lambda_i^F)(x_{it}^D + x_{it}^F)}{\rho} - f. \tag{35}$$

It can be simplified as the following firm value function:

$$V_{it} = A_{it}S_i e_{it} + \epsilon_{it}, \tag{36}$$

$$\text{where } S_i = \mu_i^{1-\rho}(\lambda_i^D + \lambda_i^F), \tag{37}$$

$$e_{it} = z_{it}(x_{it}^D + x_{it}^F). \tag{38}$$

Firm size S_i is larger compared to a case where the firm only sells goods in the domestic market. The variance of the interactive shock is also larger due to the existence of demand shock from the foreign market: $var(e_{it}) = var(x_{it}^D) + var(x_{it}^D) + cov(x_{it}^D, x_{it}^F)$.

D.2 How Does Volatility Affect the Level of CEO Compensation?

The expected compensation given a realization of the interactive shock is:

$$E[c_{ijt}|e_{it}] = \bar{w}_{ijt} + \left(\frac{\theta_{ij}^2}{2}\right)\left(\frac{S_i^2 e_{it}^2}{g_j} + \eta\sigma_i^2\right). \tag{39}$$

Treat the interactive shock as a random variable and take expectation of this equation give unconditional expected compensation:

$$E[c_{ijt}] = \bar{w}_{ijt} + \left(\frac{\theta_{ij}^2}{2}\right)\left(\frac{S_i^2 E(e_{it}^2)}{g_j} + \eta\sigma_i^2\right) = \bar{w}_{ijt} + \left(\frac{\theta_{ij}^2}{2}\right)\left(\frac{S_i^2(\delta_i^2+1)}{g_j} + \eta\sigma_i^2\right), \tag{40}$$

where $\theta_{ij} = \frac{1}{1+g_j\frac{\sigma_i^2}{\delta_i^2+1}\frac{\eta}{S_i^2}}$.

The percentage ownership is increasing in the volatility of the interactive shock and decreas-

ing in the volatility of the additive shock ($\frac{\partial \theta_{ij}}{\partial \delta_i^2} > 0, \frac{\partial \theta_{ij}}{\partial \delta_i^2} < 0$). The derivative of the expected compensation with respect to the volatility of the interactive shock is:

$$\frac{\partial E[c_{ijt}]}{\partial \delta_i^2} = \theta_{ij} \left(\frac{S_i^2(\delta_i^2+1)}{g_j} + \eta \sigma_i^2 \right) \frac{\partial \theta_{ij}}{\partial \delta_i^2} + \frac{\theta_{ij}^2}{2} \frac{S_i^2}{g_j} > 0. \tag{41}$$

This implies that expected compensation is positively correlated with the volatility of interactive shock.

On the other hand, the derivative of the expected compensation with respect to the volatility of the additive shock is:

$$\frac{\partial E[c_{ijt}]}{\partial \sigma_i^2} = \theta_{ij} \left(\frac{S_i^2(\delta_i^2+1)}{g_j} + \eta \sigma_i^2 \right) \frac{\partial \theta_{ij}}{\partial \sigma_i^2} + \frac{\eta}{2} \theta_{ij}^2. \tag{42}$$

According to the optimal percentage ownership equation, $\frac{g_j}{S_i^2} = \left(\frac{1}{\theta_{ij}} - 1 \right) \frac{\delta_i^2+1}{\sigma_i^2 \eta}$. Thus, $\frac{\partial \theta_{ij}}{\partial \sigma_i^2} = -\frac{\frac{g_j}{S_i^2} \frac{\eta}{(\delta_i^2+1)}}{\left(1+\frac{g_j}{S_i^2} \frac{\sigma_i^2 \eta}{\delta_i^2+1}\right)^2} = -\frac{\theta_{ij}(1-\theta_{ij})}{\sigma_i^2}$. Substituting these two equations into equation (42) yields $\frac{\partial E[c_{ijt}]}{\partial \sigma_i^2} = -\frac{\eta}{2}\theta_{ij}^2$. Since the absolute risk aversion parameter (η) and percentage ownership (θ) are positive, $\frac{\partial E[c_{ijt}]}{\partial \sigma_i^2} < 0$. Average compensation decreases with the variance of the additive shock.

D.3 Preventing Dismissal and Increasing Effort in Lower Interactive Shocks

Suppose the CEO is afraid of being fired and will have utility loss if the firm's value is lower than a threshold $\bar{v}$. The value of loss is the cost of firing L times the probability of being fired $P(V \leq \bar{v})$. The expected utility now becomes

$$E\left[u\left(c(A) - g(A) - LP(V \leq \bar{v})\right)\right], \tag{43}$$

where the probability of being fired is

$$\begin{aligned} P(V \leq \bar{v}) &= P(SAe + \varepsilon \leq \bar{v}) \\ &= P\left(\frac{\varepsilon - 0}{\sigma} \leq \frac{\bar{v} - SAe}{\sigma} \right) \\ &= \Phi\left(\frac{\bar{v} - SAe}{\sigma} \right) \\ &= \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\frac{\bar{v}-SAe}{\sigma}} e^{-\frac{t^2}{2}} dt. \end{aligned}$$

The derivative of expected utility w.r.t. effort A gives:

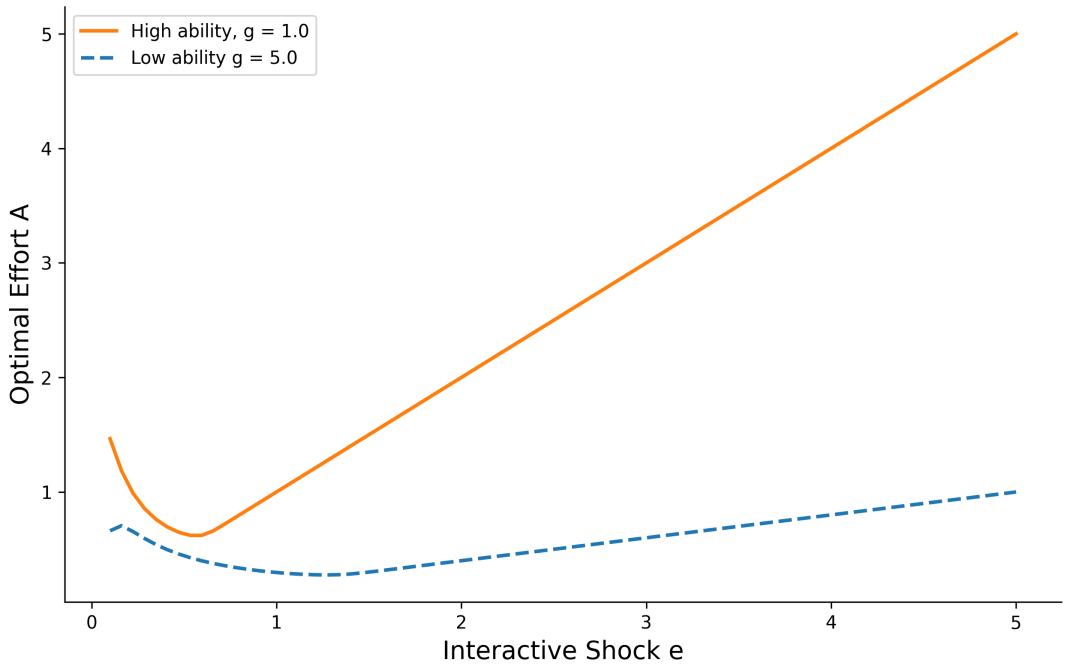
$$\theta Se - gA - L\Phi'\left(\frac{\bar{v} - SAe}{\sigma}\right)\left(-\frac{Se}{\sigma}\right) = 0. \tag{44}$$

Since $\Phi'\left(\frac{\bar{v}-SAe}{\sigma}\right) = \frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{\bar{v}-SAe}{\sigma}\right)^2}$, the optimal effort is pinned down by the following equation:

$$A = \frac{\theta Se}{g} + \frac{LSe}{g\sigma\sqrt{2\pi}}e^{-\frac{(\bar{v}-SAe)^2}{2\sigma^2}}. \tag{45}$$

The optimal effort A needs to be solved numerically. Under some parameters, a higher-ability CEO exerts more effort in a negative shock, as shown in the following figure:

Figure A.2: Higher-Ability CEO Exerts More Effort in a Negative Shock



Notes: $\theta = 0.1, S = 10.0, L = 10, \sigma = 1, \bar{v} = 0.0$