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Respondable risk and incentives for CEOs: The role of information-collection and decision-making

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A R T I C L E   I N F O

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A B S T R A C T

This paper examines the incentive provision when the agent can respond to risk by exerting effort to collect information about the underlying state and making corresponding decisions. Such effort is shown to be more valuable in a riskier environment and incentives can increase with “respondable” risk. The relation between incentives and risk is more positive when the agent’s effort is more effective in collecting information or in acting upon it. Using data on chief executive officers (CEOs), I find that incentives for CEOs increase with industry-wide risk, a measure of respondable risk. The positive relation diminishes when the CEO is less able to collect information or is less effective in acting upon it.

1. Introduction

Commonly used principal–agent models assume that risk of the environment is out of the control of the agent, yielding the standard prediction of a negative risk-incentive trade-off. Researchers have been testing the negative trade-off but find, with few exceptions, that the relation between incentives and risk is either insignificant or positive (see Prendergast, 2002 and references therein). Prendergast (2002) offers a compelling explanation of the absence of the posited trade-off of incentives and risk by introducing the agent’s private information of the environment. In a stable environment, he argues, the principal knows what actions to expect from the agent, thus can use input-monitoring. In a risky environment, the principal knows little about the right actions whereas the agent has the information. As a result, it is optimal for the principal to delegate the decision-making to the agent to promote his use of the private information, and at the same time use output-based compensation contracts to align the agent’s interest with the firm’s. Use of output-based pay, that is, a stronger incentive than input-monitoring, is positively related to greater risk in the environment.

Whereas Prendergast (2002) shows that the agent’s information, hence the delegation of decision-making to the agent, is more valuable in a riskier environment, he assumes that the agent possesses the information outright. This paper introduces the element that the agent expends effort to collect information rather than assuming that he is endowed with this information. By supplying information to facilitate decision-making, the agent’s effort is shown to be more valuable in a riskier environment. In a stable...
environment, decision-making is easy and there is little need for collecting information; in a highly uncertain environment, making correct decisions is critical and the agent’s effort becomes important.

To the extent that the agent is able to collect information about the underlying state and make decisions based on that information, I use the phrase, “agents can respond to risk” or “the risk is responsive.” In Section 2, I outline a conceptual framework where the marginal benefit of effort is shown to be higher with greater “responsive” risk. With responsive risk, there are now two forces linking risk to incentives: one is the traditional risk cost effect and the other is the return to effort effect. If the positive effect dominates the risk cost effect, optimal incentives increase with “responsive” risk. Moreover, the relation is more positive when the agent is better at collecting information and acting upon it.

I test these ideas using data on CEOs, whose main responsibility is to make decisions, be they investment, acquisition, or hiring (firing) decisions, in an uncertain environment. The firm under his management is subject to shocks, but the CEO (he) need not be passive. He can exert effort to try to foresee the state of nature and then make decisions. The effort to identify the true state can take many forms: he can network with players in the industry to assess the big picture; he can direct his marketing team to conduct research to assess the state of demand; and he can monitor the regulatory agencies in order to be informed of potential moves. All these efforts help the CEO identify the true state, enabling him to have a more accurate prediction of the state and make the right decisions.

CEOs face firm-wide and industry-wide risks. They are experts on their firms and industries, and have resources to respond to firm-wide and industry-wide risks; both are therefore responsive risk to CEOs. Directly measuring the responsive risk is difficult, I thus use the variability of output to measure them. Variability of the firm’s output is a function of firm-wide risk, industry-wide risk, and the CEOs’ effort, which in turn is a function of pay performance sensitivity (PPS thereafter). This creates an endogeneity problem with PPS regressing on the risk measure. I thus use the variability of the industry’s return instead of the firm’s return to get a measure of the industry-wide risk that the CEO faces; Section 3 will expand on this.

I compute the variance of the industry’s (value-weighted percent) return and further purger from it the market-wide risk to get a measure of industry-wide respondable risk. Uncertainty in demand is a particular kind of respondable risk; I measure it using the variance of the percent change in industry sales.

Using the Execucomp data set from Compustat, I find that incentives for a CEO, measured by the sensitivity of the CEO’s firm-specific wealth to the shareholders’ value (pay performance sensitivity; PPS), is positively associated with the industry-wide respondable risk. This is robust to controlling for firm size, the firm’s growth opportunity, age of the firm, the CEO’s tenure, and a variety of other control variables. Second, the positive relation between incentives and respondable risk diminishes as I broaden the definition of the industry, that is, the CEO is further away from his area of expertise. Third, the positive relation between incentives and respondable risk diminishes when the CEO works in an industry with higher rigidity (measured by higher capital intensity), that is, as the CEO has less discretion in acting on his superior information. And the positive relation between incentives and respondable risk is stronger for CEOs who have greater leeway in utilizing resources to respond to risks.

Besides Prendergast (2002), the closest papers in terms of idea are Zabojnik (1996) and contemporary work by Baker and Jorgensen (2003) and Raith (2008). Baker and Jorgensen (1996) and Baker and Jorgensen (2003) focused on the level of incentives, and distinguished risk where the agent has “pre-decision” information from risk that is beyond the control of the agent. Raith (2008) investigated both the delegation and the level of incentives and focused on risk for which the agent has private information. In modelling the risk on which the agent has information, the common elements among these three papers and this paper are the following: i) the agent exerts effort, ii) he learns something about the state of nature, and iii) he makes a decision based on that information. The difference between this paper and the other three is that here, i), ii), and iii) occur in that order, whereas in the other three, the game starts with ii), and i) and iii) are the same thing, i.e. the agent’s choice of effort is his decision. The other thing that sets this paper apart is that it offers an empirical examination.

My empirical results complement the finding of a positive link between incentives and risk in franchise literature (LaFontaine and Slade, 1998): More risky units are operated by the franchisees, not the parent company. A similar finding surfaces in the sharecropping literature (see Rao, 1971; Allen and Lueck, 1999). An increase in exogenous risk raises the probability of cash rent contracts and reduces that of cropsharing contracts. Kaplan and Strömberg (2004) found that a greater external risk is associated with a more contingent compensation to entrepreneurs (the agent) by venture capitalists (the principal). My study suggests that in examining incentives and risk, one should first assess whether the setting is such that i) the agent can glean information about the underlying state and ii) the agent can act on that information. If both conditions hold, the return to effort is greater and thus the principal likely provides stronger incentives when risk is greater, and a researcher is less likely to find a negative relation between incentives and risk.

This paper has implications on the risk management literature, which examines the use of derivatives in hedging risk in interest rate, foreign exchange rate, or commodity price, for example. One puzzle in this literature is that firms do not appear to hedge their exposure to risk as extensively as theories suggest (Guay and Kothari, 2003). Reinforcing the intuition in Stulz (1996), my study suggests that, if the CEO has a comparative advantage in information, he does not need to fully hedge; he can take positions and benefit from his superior information. As will be shown in the theory section, fully hedging is equivalent to a safe investment rule in my set-up while selective hedging and taking positions are equivalent to an investment rule of acting on collected information.

The remainder of the paper proceeds as follows. In Section 2, I outline a model in order to clarify the relationship between respondable risk and the return to effort. I describe the data in Section 3 and present my findings in Section 4. The paper concludes in Section 5.

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1 Even if the answers to the two questions are negative, that is, the exogenous risk appears to be out of the control of the agent, the researcher still should check if the agent can hedge the risk using derivatives. If the agent can, then a zero relation between incentives and the posited risk should be expected.
2. Theoretical discussion

The purpose of this section is to construct a conceptual framework to guide the empirical analyses.

2.1. Production technology

I model the (static) production technology as

\[ y = \mu I - \frac{1}{2} \gamma^2. \]  \hspace{1cm} (1)

where \( \mu \) denotes the underlying state, with a value of \{0, 1, 2\} representing the poor, mediocre, and good state, respectively; \( I \), investment, is the firm's (and the agent's) choice variable; \( \frac{1}{2} \gamma^2 \) is the (adjustment) cost of investment; and \( y \) denotes output.

The discreet state variable, \( \mu \), which takes the value of 0 with probability \( \frac{2}{3} \), 1 with probability \( 1 - p \), and 2 with \( \frac{2}{3} p \), is used for its computational ease. The symmetric distribution of \( \mu \) entails a constant mean of 1 despite a changing variance — \( \text{var}(\mu) = p \), a mean-preserving property that helps highlight the role of risk. The purpose of introducing \( I \), the investment, and the cost of investment is to allow the agent to act on his information. Later I will first discuss the optimal decision with no knowledge of \( \mu \) prior to decision-making and then look at how the decision changes when a signal about \( \mu \) is obtained.

If all the agent knows prior to the decision-making is the distribution of the state variable, he chooses an investment level such that the expected marginal benefit is equal to the marginal cost:

\[ I^* = E(\mu I) = 1, \text{ and } E(y) = 1 + \frac{1}{2} = \frac{3}{2}, \]  \hspace{1cm} (2)

where \( I^* \) is the optimal investment.

The agent, however, can do better than investing and waiting for shocks to happen; he can try to assess the state in order to make correct investment decisions. That is, before investment, he can spend time and resources to collect information, and his efforts result in his observing a signal, \( m \in \{0, 1, 2\} \), of the underlying state (the timeline of actions is depicted in Fig. 1).

In particular, I assume that

\[ \text{Prob}(m = \mu | \mu = \mu_i) = \left(1 - \frac{1}{3}\right) \gamma^e + \frac{1}{3}, \hspace{0.5cm} i = 1, 2, 3, \hspace{0.5cm} 0 \leq e \leq 1, \hspace{0.5cm} 0 < \gamma \leq 1, \]  \hspace{1cm} (3)

where \( \text{Prob}(m = \mu | \mu = \mu_i) \) is the agent’s probability of observing the correct signal, \( e \) is the agent’s effort in collecting information, and \( \gamma \) is the effectiveness of effort in information collection. When \( \gamma = 0 \), the agent is still able to observe the correct signal just by chance, with probability \( \frac{1}{3} \). Correspondingly, \( \text{Prob}(m = \mu_i | \mu = \mu) = \frac{1}{3} (1 - \gamma e) \), where \( \mu_i \) is the value of \( \mu \) when it does not take the value of \( \mu_i \).

With the collected information, the agent updates the distribution of the three states using Bayes’ rule. For instance, when the CEO observes a signal of 2, he deduces the likelihood of a good state as

\[ \text{Prob}(\mu = 2 | m = 2) = \frac{p}{2} \left( \frac{2}{3} \gamma^e + \frac{1}{3} \right) + \left(1 - p\right) \frac{1}{3} \left(1 - \gamma e\right) + \frac{p}{2} \frac{1}{3} \left(1 - \gamma e\right). \]  \hspace{1cm} (4)

\(^2\) The literature on investment under uncertainty (e.g., Abel and Eberly, 1994) has no role for the agent's effort in collecting and acting on information about the underlying state.

\(^3\) Take \( \mu = 2 \) as an example. In this set-up, we treat the probability of \( m = 1 \) and \( m = 0 \) as equal. It is possible that when \( \mu = 2 \), if the agent observes the wrong signal, it is more likely that the agent observes \( m = 1 \) than \( m = 0 \). Incorporating this would not affect the basic idea of the model.
The agent then forms his belief on the mean of the posterior distribution and acts on his belief by making corresponding investment decisions: \( l_{m=m} = E(\mu|m_i), m_i \subseteq \{0, 1, 2\} \). Take the case of \( m = 2 \):

\[
l_{m=2} = E(\mu|m = 2) = \frac{p \gamma_e + \frac{1}{3}(1 - \gamma_e)}{\frac{p \gamma_e}{2} + \frac{1}{3}(1 - \gamma_e)}
\]

which has the following properties: \( 1 \leq l_{m=2} \leq 2 \), \( \frac{\partial l_{m=2}}{\partial p} > 0 \), \( \frac{\partial l_{m=2}}{\partial \gamma} > 0 \). Observing a signal of 2, the agent increases his expectation of the likelihood of a good state, and therefore invests relatively more aggressively \( (l_{m=2} \geq 1) \). Yet, the agent is not sure that it is a good state, and therefore invests less aggressively than if he were certain \( (l_{m=2} \leq 2) \). Moreover, a greater effort, by increasing the likelihood of observing the correct signal, makes the agent more confident about his assessment, and emboldens him in setting the investment level \( (\frac{\partial l_{m=2}}{\partial \gamma} > 0) \).

Hence, the CEO will invest relatively aggressively when he observes a signal of 2, and ex-ante this is a wise move since it is truly in a good state that a signal of 2 is likely to be observed (with the expended effort). Higher effort, by raising the probability of investing the right amount at the right time, raises the expected output. I formalize this in the following lemma, formal proof of which is provided in Appendix A.

**Lemma 1.** Given the previous set-up,

\[
E(y) = \frac{1}{2} + \frac{p \gamma_e}{2} + \frac{1}{3}(1 - \gamma_e),
\]

and

\[
\frac{\partial E(y)}{\partial e} > 0.
\]

When an agent’s effort can improve his probability of observing the correct signal, based on which he makes decisions, I say that the risk involved \( (p) \) is respondable. Moreover, the CEO’s effort is more valuable when respondable risk is higher. When things are relatively stable, i.e., the probability of either the poor or good state is low, there is little need to collect information; investing in an average way \( (l = 1) \) would not lose much. When the environment is highly uncertain, i.e., the probability of non-mediocre state is high, figuring out the true state and investing accordingly takes on more importance. This key result is formalized below and proven in Appendix A.

**Proposition 1.** Given the previous set-up,

\[
\frac{\partial^2 E(y)}{\partial e \partial p} > 0.
\]

Two things are necessary for this result. First, it is essential that the agent’s effort is effective in improving the probability of observing the right signal, that is, \( \gamma > 0 \). If \( \gamma = 0 \), from Eq. (3), \( \text{Prob}(m = \mu_i | \mu_i) = \frac{1}{3} \). Take \( m = 2 \) as an example. From Eq. (4), \( \text{Prob}(m = 2 | m = 2) = \frac{p}{2} \), and from Eq. (5), \( l_{m=2} = 1 \), and from Eq. (6), \( E(y) = \frac{1}{2} \). That is, if the agent’s effort in collecting information is not effective in discerning the true state, the signal collected contains no extra information about the true state and the investment decision is the same as the one that is based on the expected value of the state variable, as in Eq. (2); that is, neither \( \frac{\partial E(y)}{\partial e} > 0 \) nor \( \frac{\partial^2 E(y)}{\partial e \partial p} > 0 \). Further, it is shown in Appendix B that the positive relation between return to effort and respondable risk is made stronger if the agent is more effective at collecting information:

\[
\frac{\partial E(y)}{\partial e} > 0.
\]

Second, my set-up of \( y = \mu - \frac{1}{2} \rho^2 \) implicitly assumes that the collected information can be acted upon costlessly by adjusting investment. If investments cannot be adjusted according to his ex-post information and has to be fixed at the ex-ante level of \( l = E(\mu) = 1 \), then the extra information does not materialize into greater profit for the firm (formally, \( E(y) = \frac{1}{2} \)). I use \( \alpha \) to parameterize the degree to which the agent can act on his information: \( l_{m=m} = \alpha E(\mu|m_i), m_i \subseteq \{0, 1, 2\}, 0 < \alpha \leq 1 \). I show in Appendix B that the positive relation between return to effort and respondable risk is stronger when the agent is more able to act on his information:

\[
\frac{\partial E(y)}{\partial e} > 0.
\]
2.2. Incentives and respondable risk

In the previous subsection, it is shown that the firm’s expected output is highly non-linear in the agent’s effort, so even if I make the most convenient assumptions regarding the agent’s utility function and the form of compensation contract, it is difficult to get a closed form solution to the optimal contract. In Appendix C, I set up the principal–agent problem and numerically solve the optimal contract. Shown in Fig. 2, for a given agent utility function, the pay performance sensitivity (how pay varies with performance) indeed increases with $p$, the underlying uncertainty in the environment.

While the equations (in Appendix C) are complicated, the intuition is straightforward: The optimal pay performance sensitivity, $\beta$, is set such that $MB_\beta = MC_\beta$, where the marginal benefit is a better incentive provision and the marginal cost is a higher risk cost imposed on a risk-averse agent. How $\beta$ changes with risk thus depends on how $MB_\beta$ and $MC_\beta$ change with risk. In the commonly used agency models (think of $y = e + \mu$), $MB_\beta$ has no relation to risk and $MC_\beta$ increases with risk, resulting in $\beta$ decreasing with risk. But here, as I demonstrated in Proposition 1, the central feature is that the return to effort increases with “respondable” risk. As a result, the final relation between incentives and respondable risk depends on two opposite forces: the return to effort effect and the risk cost effect. If the former dominates the latter, incentives, $\beta$, will increase with respondable risk.

2.2.1. Variance of output as a function of $p$ and $e$

In the commonly used agency model (think of $y = e + \mu$ again) where there is no interaction between the agent’s effort and the state of the world, variability of output comes solely from that of the random shock. For the production technology outlined above where the agent forms a belief of the state and acts on it, the variance of output changes with both respondable risk ($p$) and effort ($e$) — as shown in Appendix A. In Fig. 3, for a given $e$, I show how the variance of output changes with $p$.

The variance of output is a nonlinear function of $e$. As $e$ increases, the agent becomes more confident in making investment decisions (\(\frac{\partial \ln \sigma_e}{\partial e} > 0\)), the support of output becomes wider, and output becomes more variable. There exists, however, a counterforce that reduces the variability of output: A greater effort improves the accuracy of prediction. Fig. 4 plots the variance of output as a function of the agent’s effort for the case of $p = \frac{2}{3}$. Indeed, the relation between the two is non-linear: the variance of the output initially increases and then decreases with the agent’s effort.

2.3. Guidance to the empirical work and hypotheses to be tested

The theoretical discussion does not predict a universally positive relation between incentives and risk, but a finding of a positive relation between incentives and risk is definitely supportive of a positive relation between the return to effort and respondable risk. So our first testable hypothesis is

$$\frac{\partial \beta}{\partial p} > 0.$$
where $\beta$ is pay performance sensitivity and $p$ is the risk of the environment ($p = \text{var}(\mu)$) that is respondable ($\gamma_e \geq 0$), or respondable risk. The discussion does predict that the positive relation between return to effort and respondable risk is made stronger when the agent is more effective in i) collecting information ($\gamma$) and ii) acting upon his information ($\alpha$), so my second and third testable hypotheses are

$$\frac{\partial \beta}{\partial \gamma} > 0 \quad \text{and} \quad \frac{\partial \beta}{\partial p} > 0.$$ 

I empirically examine the relation between incentives and responsible risk using data on CEOs. The CEO is an expert on his firm and his industry so he is able to collect information and form a judgment of the underlying state ($\gamma \neq 0$) and can use his decision-making power to act on it ($\alpha \neq 0$). While there is a grain of truth in claiming that having vision is an innate ability, it is defensible that for a CEO with an innate ability in predicting the future, he can still improve his ability to foresee the future by making greater efforts.\textsuperscript{4}

\textsuperscript{4} Although my paper differs from most papers on executive compensation in assuming that the data are generated by my production technology rather than a model of $y = \varepsilon + \varepsilon$, I am still pursuing an optimal contracting framework.
3. Data and construction of variables

The equation to be estimated relates the intensity of CEO incentives to responsible risk. Data on incentives come from the Executive Compensation database (Execucomp) 2001 in Compustat of Standard & Poor, data on stock return risk from the CRSP database, and data on demand uncertainty from the Compustat database. Execucomp 2001 spans 1992 to 2001 and covers more than 2500 publicly traded firms, both active (firms in the current S&P 1500 and firms that have been removed from the index but are still traded) and inactive (companies that were once part of the S&P 1500 and are no longer traded). The final number of firm-year observations is 17,233. Since among senior executives the CEO exerts the most influence on the firm, I focus on incentive provisions for CEOs.

3.1. Incentive measures

Incentives are provided to a CEO in various forms. In recognizing good performance, a raise in salary, a bonus award, a grant of (restricted) stocks and options, and an increase in value of his holdings of the firm’s stock and options all provide incentives. Performance measures come mainly in two forms, accounting- and stock-based measures. Stock price is more forward-looking compared with an accounting measure, and starting in the 1980s, firms have placed more emphasis on maximizing shareholders’ value as their goal (Holmstrom and Kaplan, 2001). I therefore focus on the change in shareholders’ value as the performance measure.

Following Jensen and Murphy (1990), I measure incentives using pay-performance sensitivity, which is the change in a CEO’s firm-specific wealth with a $1000 change in shareholders’ value. Change in a CEO’s firm-specific wealth, as discussed previously, includes salary adjustments, bonus, a grant of stocks and stock options, other flow compensation, and a change in the value of holdings of stocks and stock options. As Hall and Liebman (1998) showed and I confirmed in my sample as well, sensitivity from salary adjustments, bonus, and the size of stock or option grant is swamped by sensitivity generated by changes in value of the CEO’s holdings of stocks and options. Therefore, I focus on the latter.

The change in value of a CEO’s stock holdings is computed as the CEO’s stock holding value at the beginning of the year multiplied by the current year’s stock percent return. If information on the strike price and the maturity date of each currently held option is available, one can compute the change in value of options using the Black–Scholes formula. Obtaining this information, as Hall and Liebman (1998) explained, is complicated and involves making many assumptions. This costly data collection motivates me to compute the change in value of a CEO’s option holdings by subtracting the beginning of the year option value from the end of the year option value. Proxy statements of publicly traded firms, from which Execucomp collects compensation data, keep track of “in the money” options only, for which it reports only the intrinsic value, not the Black–Scholes value. Intrinsic value, the difference between the spot price and the strike price, ignores the time value of an option. Thus, the computed change in value of stock options is equal to the end of the year intrinsic value of “in the money” options minus the beginning of the year intrinsic value of “in the money” options plus the realized value from option exercising minus the value of new option grants.

This measure of change in the value of stock options has two drawbacks. First, the intrinsic value of an option disregards the time value of an option. Second, as Aggarwal and Samwick (1999) pointed out, change in “in the money” options introduces measurement errors of opposite directions. An increase in price not only changes the value of already “in the money” options, it also makes options that are just “under the water” back in the water. Change in “in the money” options thus biases the true change upward. Meanwhile, change in the value of “under the water” options also provides incentives but is not captured by the measure; change in “in the money” options thus biases the true change downward. The lower the proportion of “under the water” options, the smaller either bias is.

Change in shareholders’ wealth is the firm’s market value at the beginning of the year multiplied by the current year’s stock percent return. Having all the necessary elements, I thus compute the pay-performance sensitivity of CEO c at firm j in year t:

\[
PPS_{cjt}^\text{computed} = \frac{(\Delta \text{ Value of CEO's holdings of stock and stock options})_{cjt}}{(\Delta \text{shareholders' value})_{jt}} \times 1000.
\]

Table 1 contains summary statistics for compensation and incentive measures. For the average (median) CEO during the period of 1992–2001, salary is $547,000 ($496,000), bonus is $561,000 ($291,000), the stock option grant value is $1,981,000 ($444,000), pay-performance sensitivity is 44.4 (13.8) per $1000 change in shareholders’ value, sensitivity from pure stock ownership is 34.1 (3.5), and sensitivity from stock options is 13.4 (4.8). The data thus suggest that both stock and option holdings provide incentives. The median pay-performance sensitivity (13.8 per $1000 change in shareholders’ value) implies that, for a firm

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3 First, CEOs often hold options that were granted before they become CEOs, and gathering information on the initial conditions is difficult. Second, proxy statements report option gains from exercising as a total dollar value, so it is impossible to determine exactly which options were sold in a given year. The two adjustments are made because options are granted and exercised during the year, which causes changes in value of the option holdings that are not attributable to changes in the stock price.

7 Computing pay-performance sensitivity, which uses two data points, rather than estimating pay performance sensitivity, which draws a line across all data points, enables me to keep the variation of pay-performance sensitivity across time within a firm, which allows me to use CEO fixed effects.

8 I dropped those observations for which one of the following applies: i) computed sensitivity from stock option holdings is negative; ii) computed pay-performance sensitivity is greater than 1; iii) market-to-book value is negative; or iv) industry-wide responsible risk is greater than 1.
Table 1
Summary statistics.

<table>
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<th>Obs.</th>
<th>Mean</th>
<th>Median</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salary</td>
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<td>547</td>
<td>496</td>
<td>296</td>
</tr>
<tr>
<td>Bonus</td>
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<td>561</td>
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<td>1058</td>
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<td>Value of stock option grants</td>
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<td>8667</td>
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<td>Pay-performance sensitivity</td>
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<td>44.4</td>
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<td>3.9</td>
<td>71.4</td>
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<td>11.1</td>
<td>4.7</td>
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<td>5–6 digit NAICS Industry-wide responsible risk</td>
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<tr>
<td>4-digit NAICS Industry risk</td>
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<td>Market value ($MM)</td>
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<td>Firm age</td>
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<td>Tenure</td>
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</tr>
<tr>
<td>Capital expenditure variability</td>
<td>19,580</td>
<td>128</td>
<td>0.24</td>
<td>5968</td>
</tr>
<tr>
<td>Variability in capital expenditure and acquisition</td>
<td>18,805</td>
<td>3545</td>
<td>0.62</td>
<td>143,449</td>
</tr>
<tr>
<td>Variability in employment</td>
<td>20,579</td>
<td>8.33</td>
<td>0.016</td>
<td>385</td>
</tr>
</tbody>
</table>

Pay-performance sensitivity is the change in the value of the CEO's holdings of stock and stock option value divided by the change in the firm's value multiplied by 1000, where the change in value of stock holdings is computed as the CEO's beginning of period value of stocks multiplied by the current year stock percent return; the change in value of stock option holdings is computed as the difference in value of the year-end intrinsic value (current stock price minus strike price) of the in-the-money stock option holdings plus the value from exercising stock options, minus the value of new option grants; and change in the firm's value is the firm's beginning of period value multiplied by the firm's stock return of the current year. Incentives from stock options are the change in value of the CEO's holdings of stock options divided by the change in the firm's value. Value of stock option grants is the Black–Scholes value. NAICS represents North America Industry Classification System 1997. Industry-wide responsible risk at a given digit level is the variance of the residuals from regressing the preceding 48 months of value-weighted stock percent return of all firms in that digit industry on market-wide value-weighted stock percent return. Industry demand uncertainty is the variance of the preceding 48 months of percent change in total sales in that industry. Capital intensity is calculated as the net value of plant and equipment (Compustat item 8) divided by number of employees (Compustat item 29). Industry-level capital intensity is the median value of capital intensity of firms (fetched from the universe of Compustat) in that industry. Variability in capital expenditure, capital expenditure plus acquisition, and employment, is calculated as variance of the current and preceding 4 years of annual percent change in capital expenditure (Compustat item 128), sum of capital expenditure and acquisition (Compustat item 129), and employment (Compustat item 29). Market value refers to market value of the firm's equity; the shares outstanding multiplied by the closing price. The market value and market-to-book ratio variables are once-lagged to minimize endogeneity. Firm age is the number of years the firm is listed on the stock exchanges. Tenure is the number of years the executive has been with the firm as a CEO. The sample period is 1992–2001. Except otherwise noted (MM is millions), all nominal variables are expressed in thousands of 1995 dollars.

Pay-performance sensitivity has a standard deviation of 79.2 and skewness of 3.45.

3.2. Risk measures

To test the impact of responsible risk on incentives, I need a measure of risk of the environment (\(\text{var}(\mu)\)) that is the agent can collect information on (\(\gamma \neq 0\)) and act on (\(\alpha \neq 0\)).9 Examples of these are risk in technology development, risk in consumers' acceptance of an introduced good or service, and risk in regulatory policies, to name a few. Directly measuring them is very difficult. One way to capture these various forms of \(\text{var}(\mu)\) is to use \(\text{var}(\gamma)\); it is shown in Section 2.2 that \(\text{var}(\gamma)\) is a positive function of \(\text{var}(\mu)\). That is, a firm in a volatile environment will have volatile return. In using \(\text{var}(\gamma)\) to measure \(\rho\), the theoretical framework in Section 2 provides a guidance on how to implement it. From Section 2, one gets

\[
y_{jt} = f(p_{jt}, p_{jt}, \gamma_{jt}, \epsilon_{jt}).
\]

where \(j\) refers to the firm, \(i\) refers to the industry, \(y_{jt}\) is the company's return, where \(\mu_{jt}\) are the shocks affecting the company only, \(\mu_{it}\) are the shocks affecting the industry, \(\gamma_{jt}\) is the effectiveness of effort that varies by industry, and \(\epsilon_{jt}\) is the CEO's effort. Under certain regularity conditions, one then has \(\text{var}(y_{jt}) = g(p_{jt}, p_{jt}, \gamma_{jt}, \epsilon_{jt})\), where \(p_{jt}\) is the \(\text{var}(\mu_{jt})\) and \(p_{jt}\) is the \(\text{var}(\mu_{jt})\). That is, the variability of a company's return is also a function of the CEO's actions, \(\epsilon_{jt}\), which is a positive function of the dependent variable, \(\text{PPS}_{jt}\). Thus, while \(\text{var}(y_{jt})\) captures nicely both \(\text{var}(\mu_{jt})\) and \(\text{var}(\mu_{jt})\), there is a severe endogeneity problem in regressing \(\text{PPS}_{jt}\) on \(\text{var}(y_{jt})\).

9 The magnitudes of the summary statistics are comparable to other studies on CEO compensation, including Hall and Liebman (1998), Aggarwal and Samwick (1999), and Jin (2002).

10 There are various kinds of risk that a CEO faces. For some risks, a CEO cannot respond, either because he cannot discern the state through effort in collecting information (\(\gamma = 0\)) or because he has no resources to draw upon even after discerning the state (\(\alpha = 0\)). For these kinds of risk, if there is a market for trading the risk, he can hedge or buy insurance. Risk in interest rates and exchange rates are examples of these.
One way to get around this problem and still use $\text{var}(y)$ to capture $\text{var}(\mu)$ is to realize that
\[
\sum_j y_{jt} = \sum_j f(\mu_j, \beta_j, \gamma_j e_{jt}).
\]

Dividing both sides by the number of firms in industry $i$ and under certain regularity conditions, one gets
\[
y_{it} = h \left( \frac{\sum_j \mu_j}{n}, \beta_t, \gamma_t, \frac{\sum_j e_{jt}}{n} \right),
\]
where $n$ is the number of firms in industry $i$. The item $\frac{\sum_j e_{jt}}{n}$ approaches a constant that does not vary with individual firm or industry as $n$ gets “large.” The item $\frac{\sum_j \mu_j}{n}$ approaches $e_\alpha$, an average effort level in industry $i$, a term that does not vary with individual firm as $n$ gets “large.” So the variance of average industry return becomes
\[
\text{var}(\bar{y}_{it}) = I(\text{var}(\bar{\mu}_t), \gamma_t e_\alpha) = I(p_{it}, \gamma_t e_\alpha).
\]

Notice that $\text{var}(\bar{y}_{it})$ captures $p$ across industry. Also note that it also captures the $\gamma$ across industry. Since $p$ and $\gamma$ are integral parts of the responsible risk, I use variability of industry return to capture the responsible risk in a regression of $\text{PPS}_{jt}$. And most importantly, $\text{var}(\bar{y}_{it})$ is not a function of $e_{jt}$, thus regressing $\text{PPS}_{jt}$ on $\text{var}(\bar{y}_{it})$ is free of the endogeneity concern.\(^{11}\)

Industry-wide risk qualifies for the necessary condition that $\gamma \neq 0$ and $\alpha \neq 0$ for two reasons. First, CEOs are experts on their firms and industries ($\gamma \neq 0$), and they can engage in information-collecting effort. Second, CEOs are delegated the decision-making power ($\alpha \neq 0$); they can hire or fire people, borrow money, undertake mergers and acquisitions, and make investment decisions.

There is potentially a measurement error problem in using $\text{var}(\bar{y}_{it})$ to capture $p_{it}$ and $\gamma_t$ across industry — it is possible that $e_\alpha$, i.e., the average effort of CEOs in industry $i$ responds to the shocks common to industry, $\mu_t$, and thus $\text{var}(\bar{y}_{it})$ over-estimates the true $p_{it}$ and $\gamma_t$. To shed light on this issue, it is worthwhile to go back to Section 2.2 where it is shown (also in Fig. 4) that the relation between effort and risk of the output is non-linear — initially $\text{var}(y)$ increases with $e$ and later on it decreases with $e$.\(^{12}\) Therefore, the impact of $e$ on $\text{var}(y)$ indeed might cause measurement error in the explanatory variable. But this should work against the researcher from finding any significant result, yet, as I show in Section 4, I do find significant relation between PPS and the risk variable.

One more adjustment needs to be made before $\text{var}(\bar{y}_{it})$ can be used to measure $p_{it}$ and $\gamma_t$. While I argue that many kinds of risks are responsible, there is probably part of the risk that is not, and $\text{var}(\bar{y}_{it})$ contains both. If one believes that market-wide risk proxies for pure-noise risk because market-wide shocks are too general for CEOs to apply their expertise, then one crude way to purge the pure-noise risk is to use a market model to separate industry-wide responsible risk from pure-noise risk. The steps of achieving this are provided in Appendix D. The result of this procedure, industry-wide responsible risk, is my first measure of responsible risk.

Firms in the Execucomp belong to 566 distinct NAICS (Northern American Industry Classification System) industries.\(^{13}\) Since firms in Execucomp are a subset of those in Compustat, I fetch all the firms in the Compustat universe that belong to the 566 NAICS industries. With these, I compute the market-value weighted industry return and use the preceding 48 months of return data to compute the variance.\(^{14}\) For the preceding 48 months, the mean (median) of the industry-wide responsible risk is 0.0043 (0.0027). For example, during the sample period, the computer chip industry’s return variance is 0.0061 and the natural gas distribution industry’s variance is 0.00066. I also explore the industry-wide responsible risk at different aggregation levels. The broadest unit of an NAICS industry is two-digit and the most refined is six-digit.\(^{15}\) Table 1 shows the expected diversification effect: As industry aggregation moves from the five- or six-digit level to the two-digit level, i.e., as the industry’s span increases, industry-wide responsible risk falls.

One other way to capture $\text{var}(\mu)$ is to measure a certain aspect of risks that a CEO faces. A particular kind of industry-wide risk is risk in demand for an industry’s products or services, computed as the variance in percentage change in total sales of firms in that industry (see Hambrick and Abrahamson, 1995).\(^{16}\) This measure is severely skewed, with mean (median) of 18.72 (0.01) and standard deviation of 1579. I thus take the log of it in regressions below.

\(^{11}\) Papers that use aggregation to get around the endogeneity problem include Allen and Lueck (1999) which uses variability of regional crop yields to measure the risk that a farmer faces and Lafontaine and Bhattacharyya (1995) which proposes using the proportion of discontinued outlets in the franchising sector in the industry (see Hambrick and Abrahamson, 1995).\(^{16}\) This measure is severely skewed, with mean (median) of 18.72 (0.01) and standard deviation of 1579. I thus take the log of it in regressions below.
Control variables for the pay-performance sensitivity regressions, borrowed from previous literature, include a size variable, a market-to-book ratio, the firm's age, the CEO's tenure, and year fixed effects. An empirical regularity is that the pay-performance sensitivity for a CEO declines with the firm's size. I use lag of the market value as the size measure. The median (mean) market value is $1.0 ($4.9) billion. The market-to-book ratio is a proxy for growth opportunities, which affects the marginal value of the agent's effort (see Gaver and Gaver, 1993; Bushman et al., 1996). The market-to-book ratio is calculated as the market value of the firm's equity divided by its book value, which has a mean (median) of 2.63 (1.80). In a young firm, the CEO's pay-performance sensitivity, especially the ownership percentage, is likely to be high since CEOs may well be founders and therefore own a large portion of the stock. I use the number of years listed on the exchanges to proxy for the age of the firm. The mean firm age is 21 and the median is 16. To capture a CEO's accumulation of stock and options over time, I include the CEO's tenure, which has a mean (median) of 7.34 (5.00) years. The growing use of stock options in executive compensation during the 1990s is well documented in Murphy (1999) and Hall and Liebman (1998); I therefore include year dummies.

4. Empirical analysis of PPS and respondable risk

4.1. Basic results: PPS and industry-wide respondable risk

Before presenting regression results, I examine some anecdotal and graphical evidence. Comparing semi-conductor with natural gas distribution industries, for example, I find that firms in the semi-conductor industry tie their CEOs' wealth more closely with their shareholders' wealth (pay-performance sensitivity is $26 per $1000 in the former compared with $3.6 in the latter), are characterized by higher industry-wide respondable risk (0.009 compared with 0.0009 as shown above), and are slightly bigger firms (a median market value of $1 billion compared with $0.7 billion). More broadly, Fig. 5, plotting the median log of pay-performance sensitivity against the median log of industry-wide respondable risk for the 566 industries, reveals a clear positive relation between pay-performance sensitivity and industry-wide respondable risk.

Formally, I estimate an equation of the following specification:

$$PPS_{ijit} = \beta_1 \times \text{industry	extoquoteright s respondable risk}_{it} + \theta_2 \times X_{ijit} + \alpha_t + \epsilon_{ijit}.$$  

where $PPS$ denotes computed pay-performance sensitivity, $cjit$ refers to executive $c$ at firm $j$ in industry $i$ in the year $t$, the risk measure is industry-wide respondable risk, $X_{ijit}$ are control variables that include size, lagged firm market-to-book ratio, firm age, CEO's tenure, and $\alpha_t$ represents year dummies. The coefficient $\beta$ captures how pay-performance sensitivity varies with respondable risk. In all regressions, standard errors are adjusted for heteroskedasticity and clustered at the CEO level to accommodate possible within-cluster correlation. Lag of market value is highly skewed toward the right, so I use the log.

Columns 1–4 of Table 2 provide regression results using industry-wide respondable risk that is computed from industry stock return. Column 1, using OLS, shows that pay-performance sensitivity is positively associated with industry-wide respondable risk. Moreover, the magnitude is economically significant. Based on this estimate, moving the industry-wide respondable risk from the
25th percentile (0.0016) to the 75th percentile (0.0056) causes an increase in pay-performance sensitivity of 714 * 0.004 = 2.9. Evaluated at the median value of pay-performance sensitivity of 13.8, \(^{17}\) this is a 2.9/13.8 ≈ 21% increase.

Pay-performance sensitivity is highly skewed towards the right, violating the symmetry assumption required for OLS. I therefore apply the log to it and the result is in column 2 of Table 2. The log of pay-performance sensitivity is positively correlated with industry-wide responsible risk. A Box-Cox test shows that using log(PPS) provides a better “fit” than using PPS. Estimated coefficients suggest that moving the industry-wide responsible risk from the 25th percentile (0.0016) to the 75th percentile (0.0056) causes a 19.9 * 0.004 ≈ 8% increase in pay-performance sensitivity, lower than but comparable to the 21% previously.

The industry-wide responsible risk variable is also highly skewed towards the right, so I also use log of the risk variable. A Box-Cox test shows again that using ln(PPS) provides a better “fit” than using PPS; column 3 provides regression results using log(PPS) on log(risk). The estimated coefficient suggests that moving the industry-wide responsible risk from the 25th percentile (0.0016) to the 75th percentile (0.0056) causes a (ln(0.0056) − ln(0.0016)) * 0.28 = 35% increase in pay-performance sensitivity. The magnitude of the relation is greater in this specification than in the linear or semi-log specification.

While taking the log is one solution I also try a median regression, the results of which are shown in column 4. The positive relation between pay-performance sensitivity and industry-wide responsible risk remains. The estimated coefficient in the median regression implies that moving the industry-wide responsible risk from the 25th percentile to the 75th percentile causes a 414 * 0.004/13.8 ≈ 12% increase in pay-performance sensitivity. The result from a robust regression is very close.

Columns 5–7 of Table 2 report results with industry-wide demand uncertainty as the risk measure. Specifications in these three columns are identical to those in columns 1–3, except that the risk variable is now the log of the demand industry risk rather than the industry return risk. In all three cases, the coefficient is positive, implying that a higher demand uncertainty is associated with a greater pay-performance sensitivity. These estimated effects of demand uncertainty are statistically significant in two out of three cases — columns 5 and 6. The real-world magnitude implied by the coefficients is substantial. According to estimates using log of pay-performance sensitivity (in column 5), moving the demand uncertainty from the 25th percentile (0.0037) to the 75th percentile (0.0352) is associated with an increase in pay-performance sensitivity of 0.08 * (ln(0.0352) − ln(0.0037)) = 18%; according to estimates using a median regression (in column 6), the increase is 0.43 * (ln(0.0352) − ln(0.0037))/13.8 ≈ 7%.

The other coefficients in the model appear plausible estimated. Take column 1 as an example. The lag of market-to-book value is positively associated with pay-performance sensitivity. CEOs in younger firms appear to have a greater pay-performance sensitivity. Being in a CEO position for a longer period is associated with a greater pay-performance sensitivity.

Table 3 investigates the sensitivity of the coefficient on industry-wide responsible risk to a range of alternative specifications. I take the specification in column 2 of Table 2 as a baseline; the industry-wide responsible risk coefficient from that regression is reported in the top row of Table 3. Each row of the table represents a different specification.

Omitted variables may be a concern in the regressions given the relatively limited set of covariates available. It may be that firms in volatile industries are more cash-constrained and thus use stock options more heavily which, through accumulation over

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\(^{17}\) A PPS of 13.8 means that the CEO’s firm-specific wealth changes by $13.8 per $1000 change in the shareholders’ value.
time, translates into more options held by CEOs. To construct a measure of cash-constraints, I follow the variable suggested by Kaplan and Zingales (1997): cash flow (the sum of earnings before extraordinary items and depreciation) divided by the beginning of the year capital (net property, plant, and equipment, Compustat item 8). The industry-wide respondable risk coefficient, shown on rows 2 and 3 of Table 3, is similar to, although slightly smaller than, the baseline coefficient.

A possible interpretation of the positive coefficient on industry-wide respondable risk is that industry-wide respondable risk is positively correlated with industry-wide return, which is positively correlated with the incentive strength because a CEO’s effort is more valuable in an industry with a higher return. To address this concern, I include a lagged industry-wide return as a control variable. Results in row four show that the coefficient on industry-wide respondable risk barely changes from the baseline coefficient. In a similar vein, younger industries may have higher volatility and greater pay-performance sensitivity. Including the industry age as an additional control has little impact on my estimated coefficient.

A selection story can potentially explain the positive coefficient on industry-wide respondable risk: More capable or more risk-loving CEOs self-select into firms in industries with more uncertainty. If one believes that those unobserved characteristics tend to be time-invariant, including CEO fixed effects can help address the issue. The disadvantage, however, is that the cross-sectional variation – and the main variation – in industry-wide respondable risk, is not exploited. Including CEO fixed effects does greatly reduce the magnitude of the coefficient in the specification of log(PPS) on risk. In the specification of ln(PPS) on ln(industry-wide respondable risk), however, the positive relation between CEO pay-performance sensitivity and industry-wide respondable risk, although reduced a bit, is still statistically significant.

CEO pay-performance sensitivity, the focus of analysis thus far, is the result of both the firm’s compensation policy and the CEO’s own actions — exercising stock options and trading of stocks. To isolate the firm’s practice from the CEO’s trading, I investigate the firm’s compensation decision solely. In particular, I examine the percentage of incentive pay in the CEO’s flow compensation: the value of stock and stock option grants divided by the CEO’s compensation received from the firm. Since the value of stock options increases with the volatility of the underlying stock, this may cause a mechanical positive relation between the rate of incentive pay and the volatility in the firm’s industry. To circumvent this issue, I apply to all option grants a common yearly volatility rate of 0.3, a yearly risk-free rate of 0.05, and a holding period of five years before exercising. The median CEO has over one third of his compensation in the form of stock and stock options. Since stock option grants are zero in over a quarter of firm years, I use a Tobit model. The rate of incentive pay is found to be positively associated with industry-wide respondable risk.

I perform a range of other sensitivity checks. Although Compustat reports one (the major) NAICS industry per firm, firms can have segments operating in different industries. One expects that the computed industry-wide respondable risk is closer to the true industry-wide respondable risk for a firm with fewer segments, and the coefficient on industry-specific risk should be stronger. I thus do a robustness check on the sample of firms that have less than the median number (4) of segments. The positive relation between pay-performance sensitivity and industry-specific risk, as expected, is greater than the baseline coefficient for the whole sample. Finally, a major portion of the data years coincides with the “boom” of the U.S. economy in the 1990s, and the issue of whether this result is specific to a period of expansion should be considered. A regression using only the period 2000–2001 yields a coefficient similar to, although somewhat smaller than, the baseline coefficient.

4.2. The positive relation between PPS and risk as a function of γ

While finding a positive association of pay-performance sensitivity and respondable risk is suggestive of a positive link between return to effort and respondable risk, a more accurate test of this model, as discussed earlier, is to examine whether the link between pay-performance sensitivity and respondable risk becomes less positive as the risk becomes less respondable, that is, when the agent is less able to collect information to assess the true state. In the next subsection, I examine the case when the agent is less able to act on his collected information.

Table 3

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Coefficient (standard error)</th>
<th>Sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>19.9 (4.2)</td>
<td>10,468</td>
</tr>
<tr>
<td>Include control for cash constraint</td>
<td>22.6 (4.3)</td>
<td>9547</td>
</tr>
<tr>
<td>Include control for ln(cash constraint) in ln(pps) regression</td>
<td>19.2 (4.1)</td>
<td>9547</td>
</tr>
<tr>
<td>Include control for industry return</td>
<td>15.1 (3.9)</td>
<td>10,468</td>
</tr>
<tr>
<td>Include control for industry age</td>
<td>14.2 (3.5)</td>
<td>10,468</td>
</tr>
<tr>
<td>Include CEO fixed effects</td>
<td>1.2 (2.4)</td>
<td>10,468</td>
</tr>
<tr>
<td>Include CEO fixed effects and use ln(responsible risk)</td>
<td>0.13 (0.03)</td>
<td>10,468</td>
</tr>
<tr>
<td>Dependent variable is percent of incentive pay</td>
<td>1.33 (0.56)</td>
<td>11,959</td>
</tr>
<tr>
<td>Sub-sample of firms with less than or equal to 4 segments</td>
<td>22.6 (5.9)</td>
<td>5149</td>
</tr>
<tr>
<td>Sub-sample of period 2000–2001</td>
<td>13.9 (5.1)</td>
<td>2441</td>
</tr>
</tbody>
</table>

This table reports results from specifications that are variations on the one reported in column 2 of Table 2. The top row of the current table is the result from the baseline specification that is presented in Table 2. Except where noted, all specifications are estimated using an annual, CEO-level panel of data for the years 1992–2001. Standard errors (in parentheses) are adjusted for clustering at the CEO level and heteroskedasticity. Cash constraint is defined as cash flow (the sum of earnings before ordinary items and depreciation, sum of Compustat item 18 and 14) divided by beginning of year capital (net property, plant, and equipment, Compustat item 8). Industry age is the maximum of the firms’ age in that industry. Percent of incentive pay in flow compensation is measured as (stock option grant value + restricted stock grant value)/flow compensation, where flow compensation includes salary, bonus, grant of restricted stock, grant of stock options, long term incentive pay, and other annual compensation. Data on segments are from Compustat.
In the preceding analysis, I use industry-wide respondable risk to proxy for the respondable risk based on the reasoning that a CEO, before making his decisions, is able to collect information and forecast the future state. It follows that as the industry definition becomes broader, that is, as it moves from a 5–6 digit NAICS code to a 4-, 3-, and 2-digit code, the industry is further away from the CEO’s expertise and he is less able to collect relevant information to help predict the future state.

Moving from 5–6 to 2-digit, the level of industry respondable risk declines. This makes it difficult to compare the coefficients on the risk variables across the specifications; I therefore run a regression using the natural log of industry respondable risk and the log of pay-performance sensitivity. Table 4 displays the regression results. Control variables are identical to those in Eq. (8). A pooled regression is run with standard errors clustered at CEO levels and heteroskedasticity adjusted.

Across columns 1–4, a pattern emerges: The coefficient on the industry respondable risk steadily falls as the industry span gradually increases. In the case of the industry-wide respondable risk at the 2-digit level, the coefficient turns negative, implying that the positive return to effort effect is dominated by the risk cost effect as CEOs are in a relatively poor position to assess the state of world that is far from their familiar “territory.” This finding, however, should be interpreted with caution, as there are only 23 distinct 2-digit industries.

4.3. The relation between PPS and risk as a function of \( \alpha \) at the industry level

Agents have different levels of effectiveness in acting upon their information. For example, Rao (1971) provided evidence that farmers cannot costlessly switch land for other crops into land for rice, nor can he costlessly switch land for rice into land for other crops; farmers have little discretion in using their superior information, even if they have it.

In the preceding analysis, I use industry-wide respondable risk to proxy for respondable risk based on the reason that a CEO is able to make decisions based on his collected information. Yet, there is a great deal of variation across industries in a CEO’s ability to act on his information. Hambrick and Abrahamson (1995) argue that capital intensity in an industry, by inducing strategic rigidity and committing CEOs to long-term courses of action, reduces CEOs’ discretion in that industry. Following them, I measure capital intensity by net value of plant and equipment divided by the number of employees. I first fetch the information for each firm in that industry and then use the median value as the industry-level capital intensity. Thus, I estimate the following equation:

\[
P_{\text{PPS},ijt} = \alpha + \beta_1 \text{industry}_t \times \text{risk}_{ijt} + \beta_2 \text{industry}_t \times \text{risk}_{ijt} \times \ln(\text{capital}_t) + \beta_3 \ln(\text{capital}_t) + \alpha X_{ijt} + u_{ijt},
\]

and to the extent that high capital intensity hinders a CEO’s ability to act on his information, I expect to find \( \beta_2 < 0 \).

Table 5 provides the regression results. Columns 1, 2, and 3 employ OLS, median, and robust regression methods, respectively. Columns 4–6 are identical to columns 1–3 except that the log of capital intensity is used. Capital intensity has a mean of 121, median of 31, and standard deviation of 262. Across all specifications, the coefficient on industry-wide respondable risk is positive and statistically significant. The coefficient on capital intensity is generally negative, implying that a more capital intensive industry is associated with lower pay-performance sensitivity. The coefficient on the interaction term has the expected negative sign, implying that a more capital intensive industry is associated with a weaker positive correlation between pay-performance sensitivity and industry-wide respondable risk. While the estimated coefficient is statistically insignificant in columns 1–3, it turns significant in columns 4–6 where the log of capital intensity is used.

The economic magnitude implied by the coefficient on the interaction term is substantial. Based on Eq. (9), one has

\[
\frac{\partial (\text{PPS})}{\partial \text{industry}_t \times \text{risk}_{ijt}} = \beta_1 + \beta_2 \ln(\text{capital}_t) = 1412 - 284.3 \ln(\text{capital}_t);
\]

an increase in capital intensity from the 25th percentile (16.34) to the 75th percentile (55.28) is associated with a reduction of

\[
\frac{\partial (\text{PPS})}{\partial \text{industry}_t \times \text{risk}_{ijt}} \text{ from } 1412 - 284.3 \ln(16.34) = 618 \text{ to } 1412 - 284.3 \ln(55.28) = 271, \text{ a 56% drop.}
\]

| Table 4 |
| The relation between pay-performance sensitivity and industry-wide respondable risk as industry becomes more broadly defined. |

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>ln(pay-performance sensitivity)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5–6 digit</td>
</tr>
<tr>
<td>ln(industry-wide respondable risk)</td>
<td>0.28</td>
</tr>
<tr>
<td>(0.04)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>ln(market value)</td>
<td>−0.25</td>
</tr>
<tr>
<td>(0.02)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>Sample size</td>
<td>10,468</td>
</tr>
<tr>
<td>Number of CEOs</td>
<td>2915</td>
</tr>
<tr>
<td>Adj. R²</td>
<td>0.389</td>
</tr>
</tbody>
</table>

This table reports the results of pay-performance sensitivity regressing on risk as the definition of industry moves from NAICS (North America Industry Classification System 1997) 5–6 digit (most finely defined) to 2-digit (most broadly defined). Industry-wide respondable risk is the variance of the residual that results from regressing industry value-weighted percent return on market percent return. Covariates included are firm age, market-to-book value of equity, CEO’s tenure, and year-fixed effects. The market value and market-to-book ratio variables are once-lagged to minimize endogeneity. The regressions use annual CEO-level data for the period 1992–2001. Standard errors (in parentheses) are adjusted for clustering at the CEO level and heteroskedasticity.
4.4. The relation between PPS and risk as a function of $\alpha$ at the CEO level

CEOs vary in their ability to deploy the company’s resources to respond to risks. While an independent board of directors is a balance and check for the CEO’s power, in time of greater uncertainty, when decisive and swift actions are needed, a CEO, if also presiding over the board of directors, is more likely to better respond to the demands from the environment, that is, $\alpha$ is greater. I thus introduce the interaction of the risk variable and the CEO-level discretion variable and estimate the below equation:

$$\ln \text{PPS}_{jt} = \alpha_c + \beta_1 \cdot \text{industry}_{jt} \cdot \text{risk} + \beta_2 \cdot \text{CEO}_{jt} \cdot \text{Chairman}_{jt} + \beta_3 \cdot \text{industry}_{jt} \cdot \text{risk} \cdot \text{CEO}_{jt} \cdot \text{Chairman}_{jt} + \alpha_x \cdot X_{jt} + u_{jt}. \quad (10)$$

Execcomp data provide the latest title of the reported executives. Therefore, for a CEO who has served and but later left the company, that CEO’s title information when he was serving is missing. I thus focus on the current CEO’s, whose title captures whether he is also the chairman of the board of directors, or the co-chairman, or neither. The variable CEO-Chairman takes the

| Table 5 |
| The relation between pay-performance sensitivity and industry-wide responsible risk as a function of industry-level managerial discretion. |

<table>
<thead>
<tr>
<th>Dep. var.: PPS</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimation method</td>
<td>OLS</td>
<td>Median</td>
<td>Robust</td>
<td>OLS</td>
<td>Median</td>
<td>Robust</td>
</tr>
<tr>
<td>Industry-wide responsible risk</td>
<td>566</td>
<td>385</td>
<td>164</td>
<td>1412</td>
<td>1238</td>
<td>497</td>
</tr>
<tr>
<td>Industry-level capital intensity</td>
<td>(214)</td>
<td>(32)</td>
<td>(24)</td>
<td>(660)</td>
<td>(104)</td>
<td>(75)</td>
</tr>
<tr>
<td>Industry-wide responsible risk * Industry-level capital intensity</td>
<td>–0.015</td>
<td>–0.006</td>
<td>–0.0051</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>ln(industry-level capital intensity)</td>
<td>–1.14</td>
<td>–0.10</td>
<td>–0.136</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>ln(industry-wide responsible risk * ln(industry capital intensity))</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Sample size</td>
<td>10,494</td>
<td>10,494</td>
<td>10,493</td>
<td>10,460</td>
<td>10,460</td>
<td>10,459</td>
</tr>
<tr>
<td>No. of CEOs</td>
<td>2919</td>
<td>–</td>
<td>–</td>
<td>2915</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Adj. $R^2$</td>
<td>0.21</td>
<td>0.13</td>
<td>–</td>
<td>0.21</td>
<td>0.13</td>
<td>–</td>
</tr>
</tbody>
</table>

Columns 1–3 use industry-level capital intensity and its interaction with industry-wide responsible risk. Robust regression employs a fitting criterion that is not as vulnerable as least squares to data with heavy tails or large outliers (see Huber, 1964). Capital intensity is calculated as the net value of plant and equipment (Compustat item 8) divided by number of employees (Compustat item 29). Industry-level capital intensity is the median value of capital intensity of firms (fetched from the universe of Compustat) in that industry. Covariates included are firm age, market-to-book value of the firm’s equity, the CEO’s tenure, and year-fixed effects. The regressions use annual CEO-level data for the period 1992–2001. The industry-level capital intensity, market value, and market-to-book ratio variables are once-lagged to minimize endogeneity. The $R^2$ in columns 2 and 4 are Pseudo $R^2$ for median regression. Standard errors (in parentheses) are adjusted for clustering at the CEO level and heteroskedasticity.

| Table 6 |
| The relation between pay-performance sensitivity and industry-wide responsible risk as a function of CEO-level managerial discretion. |

<table>
<thead>
<tr>
<th>Dep. Var.: ln(PPS)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimation method</td>
<td>OLS</td>
<td>Median</td>
<td>Robust</td>
<td>OLS</td>
<td>Median</td>
<td>Robust</td>
</tr>
<tr>
<td>Industry-wide responsible risk</td>
<td>15.5</td>
<td>8.0</td>
<td>12.6</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Industry-level capital intensity</td>
<td>(7.3)</td>
<td>(5.5)</td>
<td>(4.9)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>CEO-level discretion</td>
<td>0.17</td>
<td>0.03</td>
<td>0.10</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Industry-wide responsible risk * CEO-level discretion</td>
<td>(0.10)</td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>ln(industry-wide responsible risk)</td>
<td>4.4</td>
<td>22.8</td>
<td>15.2</td>
<td>0.19</td>
<td>0.12</td>
<td>0.13</td>
</tr>
<tr>
<td>ln(industry-wide responsible risk) * CEO-level discretion</td>
<td>(10.7)</td>
<td>(6.7)</td>
<td>(6.0)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>CEO-level discretion</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.07</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>ln(industry-wide responsible risk) * CEO-level discretion</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Sample size</td>
<td>6943</td>
<td>6943</td>
<td>6942</td>
<td>6943</td>
<td>6943</td>
<td>6942</td>
</tr>
<tr>
<td>No. of CEOs</td>
<td>1846</td>
<td>–</td>
<td>–</td>
<td>1846</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Adj. $R^2$</td>
<td>0.38</td>
<td>0.28</td>
<td>–</td>
<td>0.39</td>
<td>0.28</td>
<td>–</td>
</tr>
</tbody>
</table>

Robust regression employs a fitting criterion that is not as vulnerable as least squares to data with heavy tails or large outliers (see Huber, 1964). CEO-level discretion takes the value of 1 if the CEO is also the chairman of the board of directors, 0.5 if the CEO is the co-chairman, and 0 if the CEO is neither. Covariates included are firm age, market-to-book value of the firm’s equity, the CEO’s tenure, and year-fixed effects. The regressions use annual CEO-level data for the period 1992–2001. The title for the CEO is only available for the present CEO, hence the smaller sample than that in Table 2. The $R^2$ in columns 2 and 4 are Pseudo $R^2$ for median regression. Standard errors (in parentheses) for the OLS estimates are adjusted for clustering at the CEO level and heteroskedasticity.
value of 1 if the CEO is the chairman, 0.5 if he is the co-chairman, and 0 if he is neither. Among the 2509 CEOs that have the title information, 63% are also the chairman of the board, 2% are co-chairman, and 35% are neither.

The results are in Table 6.1 use OLS, median, and robust regressions. Across the specifications, there are two main results. First, being a CEO and chairman is associated with greater pay for performance. Second, the coefficient on the interaction of risk and discretion is overall positive and significant, suggesting that a CEO and chairman, having greater discretion, is given greater pay-performance sensitivity in a riskier environment. One potential explanation is that the fact that the CEO is also the chairman gives the CEO greater ease in setting higher pay for himself—a rent-seeking explanation. The positive coefficient on the interaction term suggests that the rent-seeking is not the single force. Although in the OLS specification, the coefficient does not reach statistical significance (where they do in the other two specifications), the economic magnitude of the estimated coefficient is high. From column 4, one gets that

$$\frac{\partial \ln(PPS)}{\partial \ln(industry \_risk)} = \beta_1 + \beta_2 * CEO\_Chairman_{ct} = .19 + .08*CEO\_Chairman_{ct}.$$ 

This means that if one moves a firm from the 25th percentile of the ln(risk) (−6.4) to the 75th percentile (−5.2), its CEO’s PPS increases by 0.19*(−5.2 + 6.4) = 22.8%, but the PPS of a CEO and chairman would increase by (0.19 + 0.08)*(−5.2 + 6.4) = 32.4%. Being a CEO with greater discretion makes his PPS more responsive to risk.

5. Concluding remarks

The central idea of this paper is that, in many instances, the agent is not powerless in facing risk: He can exert effort and mobilize resources to try to identify the true state and then make appropriate decisions, and the effort is more valuable when there is a greater need for such effort—when responsible risk is greater. The relation between incentives and “responsible” risk thus depends on the strength of two opposing forces—a return to effort effect and a risk cost effect.

I find evidence that incentives for CEOs increase with industry-wide responsible risk, a measure of responsible risk. Moreover, the positive relation between incentives and industry-wide responsible risk diminishes, i) as I broaden the definition of the industry, that is, as the CEO has less expertise in collecting information; ii) as the CEO works in an industry with greater capital intensity, that is, as he faces more rigidity and has less discretion in acting on his information; and iii) as the CEO has less control on utilizing the company’s resources.

The implication of this study is that when examining the relation between incentives and risk in any setting, one needs to think first about the relation between the risk involved and the agent’s effort. Is the risk variable exogenous to the agent’s effort? Can the agent do anything to respond to the shocks from the environment by collecting information and acting on the information? A researcher is less likely to find a negative relation between incentives and risk when the agent can respond to the risk.

Acknowledgements

I thank Marianne Bertrand, Tobias Moskowitz, Canice Prendergast, and Abbie Smith for their guidance and support. For useful comments, I thank Bo Becker, Kent Daniel, Janice Eberly, Daniel Ferreira, Michael Gibbs, Stephen Shore, Jagadeesh Sivadasan, Frederic Warzynski, and seminar participants at the Chicago GSB, Kellogg Zell Center, Toronto, UJIC, UW (Seattle), and especially several anonymous referees. Research support from the Oscar Mayer Foundation is gratefully acknowledged. All errors are my own.

Appendix A. Proof of Lemma 1 and Proposition 1

Denote $l_{m=2}$ as $I_2$, $l_{m=1}$ as $I_1$, and $l_{m=0}$ as $I_0$. Using the Bayes’ rule, it is derived that $I_2 = \frac{pe + \frac{1}{2} - ye}{pe + \frac{1}{2} - ye} I_1 = 1$, and $I_0 = \frac{\frac{1}{2} - ye}{\frac{1}{2} - ye}$. Then the principal’s expected output (before paying the agent) is

$$E[y] = \frac{p}{2} \left[ \frac{2}{3} ye + \frac{1}{3} \right] \left[ \frac{2}{3} l_2 - \frac{1}{2} l_1^2 \right] + \frac{1}{3} \left( 1 - ye \right) \left( 2l_1 - \frac{1}{2} l_1^2 \right) + \frac{1}{3} \left( 1 - ye \right) \left( 2l_0 - \frac{1}{2} l_0^2 \right)$$

$$+ \left[ 1 - p \right] \left[ \frac{1}{3} \left( 1 - ye \right) \left( 1 - l_2 - \frac{1}{2} l_1^2 \right) + \frac{2}{3} ye + \frac{1}{3} \right] \left( l_1 - \frac{1}{2} l_1^2 \right) + \frac{1}{3} \left( 1 - ye \right) \left( l_0 - \frac{1}{2} l_0^2 \right)$$

$$+ \frac{p}{2} \left[ \frac{1}{3} \left( 1 - ye \right) \left( -\frac{1}{2} l_1^2 \right) + \frac{1}{3} \left( 1 - ye \right) \left( -\frac{1}{2} l_0^2 \right) + \frac{2}{3} ye + \frac{1}{3} \right] \left( -\frac{1}{2} l_0^2 \right).$$

18 This includes cases where a CEO’s title is purely CEO, or CEO and president and its variants.
The first item is for the state of 2. Ex ante, with a probability of \( \frac{2}{3} \), the state of 2 obtains. Then, with a probability \( \frac{2}{3} \gamma + \frac{1}{3} \), the agent observes (correctly) the signal of 2 and invests accordingly, resulting in a profit, \( 2l_{2} - \frac{1}{2}d \). All others follow.

Simplifying,

\[ E[y] = \frac{1}{2} + \frac{p}{2} \gamma e + \frac{1}{3} \left( \frac{1}{2} - \gamma e \right) = \frac{1}{2} + \frac{1}{2} \frac{p}{2} \gamma e + \frac{1}{3} \left( \frac{1}{2} - \gamma e \right). \]

From the previous equation, it is derived that

\[ \frac{\partial E[y]}{\partial e} = \frac{p}{4} \gamma e \left[ \frac{p}{2} \gamma e + \frac{1}{3} \left( \frac{1}{2} - \gamma e \right) \right] \geq 0, \]

which finishes the proof for Lemma 1. It is further derived that

\[ \frac{\partial^2 E[y]}{\partial ep} = \frac{p}{4} \gamma e^2 \left[ \frac{p}{2} \gamma e + \frac{1}{3} \left( \frac{1}{2} - \gamma e \right) \right] p^2 e \geq 0, \]

which finishes the proof for Proposition 1. One can also calculate the variance of output — \( \text{var}(y) \). Formally,

\[ \text{var}(y) = \frac{p}{2} \left( \frac{1}{3} \gamma e \left[ 2l_{2} - \frac{1}{2} d \right]^2 + \frac{1}{3} \left( \frac{1}{2} - \gamma e \right) \left[ 2l_{1} - \frac{1}{2} d \right]^2 + \frac{1}{3} \left( \frac{1}{2} - \gamma e \right) \left( 2l_{0} - \frac{1}{2} d \right)^2 \right) \]

\[ + \left( 1 - p \right) \frac{1}{3} \left( \frac{1}{2} - \gamma e \right) \left[ l_{2} - \frac{1}{2} d \right]^2 + \frac{1}{3} \gamma e \left[ l_{1} - \frac{1}{2} d \right]^2 + \frac{1}{3} \left( \frac{1}{2} - \gamma e \right) \left( l_{0} - \frac{1}{2} d \right)^2 \]

\[ + \frac{p}{2} \left( \frac{1}{3} \gamma e \left[ - \frac{1}{2} d \right]^2 + \frac{1}{3} \left( \frac{1}{2} - \gamma e \right) \left( - \frac{1}{2} d \right)^2 + \frac{2}{3} \gamma e + \frac{1}{3} \left( \frac{1}{2} - \gamma e \right) \right) \right) \left( - \left( \text{Ey} \right) \right). \]

**Appendix B. Positive relation between return to effort and risk as a function of \( \gamma \) and \( \alpha \)**

First, from the equation on \( \frac{\partial^2 E[y]}{\partial ep} \), it is derived that

\[ \frac{\partial^3 E[y]}{\partial ep^2} = \frac{p}{12} \gamma e^3 \left[ \frac{p}{2} \gamma e + \frac{1}{3} \left( \frac{1}{2} - \gamma e \right) \right] \]

\[ \geq 0. \] Second, when \( I_{m} = m \alpha = d \gamma e(m) \), it is derived that \( E[y] = (2 \alpha - \alpha^2) \left[ \frac{1}{2} + \frac{p}{2} \gamma e + \frac{1}{3} \left( \frac{1}{2} - \gamma e \right) \right] \). It is evident that \( \frac{\partial^3 E[y]}{\partial ep^2} = 2 \left( \frac{p}{4} \gamma e^2 + \frac{1}{8} p \gamma e \left( \frac{1}{2} - \gamma e \right) + \frac{1}{3} \left( \frac{1}{2} - \gamma e \right) \left( \frac{1}{3} - \gamma e \right) \right) \]

\[ \geq 0. \] for \( 0 \leq \alpha \leq 1. \]

**Appendix C. Optimal contracting**

I assume that the agent has a utility function \( Eu(w, e) = Ew - \frac{1}{2} \text{var}(w) - \frac{1}{2} e^2 \), where \( Eu \) is expected utility, \( w \) represents the compensation, \( e \) is the agent’s effort in collecting information, and \( d \) captures the convexity of the cost of effort function. A linear compensation scheme, \( w = \alpha + \beta y \), is assumed for simplicity. The agent’s maximization problem is then \( \max \left\{ \alpha + \beta y - \frac{1}{2} \beta^2 \text{var}(y) - \frac{1}{2} e^2 \right\} \). The first order condition on \( e \) yields \( \frac{\partial E[y]}{\partial e} = \frac{1}{2} \beta y + \frac{1}{2} \left( \beta \frac{\partial \text{var}(y)}{\partial e} \right) = \frac{1}{2} e \beta \), and \( e = e(\beta, p, d) \) is obtained through implicit theorem. The principal maximizes her surplus under the agent’s incentive compatibility and participation constraints: \( \max_{\alpha, \beta} \left\{ Ey - (\alpha + \beta y) \right\} \) subject to an IR constraint: \( \alpha + \beta y - \frac{1}{2} \beta^2 \text{var}(y) - \frac{1}{2} e^2 \geq u \) and an IC constraint: \( e = e(\beta, p, q) \). In principle, I could solve for the optimal contract as a function of the exogenous variables: \( \beta = \beta(p, d) \) where \( p \) is “responsible” risk. Unfortunately, I am unable to get a closed-form solution because both the objective function and the constraints are highly nonlinear in \( \beta \) and \( e \). In Fig. 2, I show how \( \beta \) varies with \( p \) for \( \gamma = 1 \) and \( d = 4. \)
Appendix D. Purging pure-noise risk (un-respondable risk) from industry-wide risk

Following the Campbell, et al. (2001) procedure, I regress $\tilde{R}_i$ on the $\tilde{R}_m$: $\tilde{R}_i = \beta_{im} \tilde{R}_m + \tilde{e}_i$, where $\tilde{R}_m$ is the excess return (percent return minus the treasury bill rate from the same period) of the value-weighted market portfolio at year $t$, $\tilde{R}_i$ represents the excess percent return of the value-weighted industry $i$ portfolio at year $t$, $\beta_{im}$ is the coefficient on $\tilde{R}_m$, and $\tilde{e}_i$ is the residual. By construction, $\tilde{e}_i$ is orthogonal to $\tilde{R}_m$. Thus, industry-wide respondable risk, the part of the industry-wide risk that is filtered out of the market-wide risk, is industry-wide respondable risk $\tilde{r}_{it} = \text{var}(\tilde{e}_i)$.

References