# On the Organization of Risk Management

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**Abstract**

The Integrated Risk Management (IRM) approach advocates coordinated risk management decisions based on firm-wide information. We model how one generates such information within an organization. Without informational problems the centralized IRM approach dominates weakly the traditional decentralized risk management approach. However, in some situations it is optimal not to manage risks explicitly at all. The situation changes with the additional consideration of information asymmetries. Providing the agents with appropriate incentives induces costs that may outweigh the expected benefits from coordination. We highlight these agency costs of risk management and consequently provide a rationale for a decentralized approach to manage risks.

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# 1 INTRODUCTION

With the so called Integrated Risk Management (IRM)[1] approach one is primarily interested in a company's overall risk. Particular risks are no longer interesting per se, but in terms of their contribution to the firm-wide risk. Typically one argues in the following way: A firm is not coping with one but several (types of) risks, e.g. hazard risks (a fire is damaging your plant), financial risks (exposure to foreign exchange risk) or operational risk (an employee is acting fraudulently) which together build the firm's risk portfolio. And, as is well known, the portfolio risk is usually not just the sum of the individual risks. This means that there are some risks that offset each other and some that amplify each other. Because only the overall portfolio risk affects the shareholder value it is at first sight quite persuasive that one should only manage the portfolio risk.[2] IRM contrasts highly the "traditional" approach to corporate risk management where departments dealt with individual risks, trying to measure, assess and to independently hedge them in the best way possible (this is henceforth called the "silo-approach" or simple "silo"). As MEULBROECK (2002), p. 69-70 puts it:

> "...risk management is the clear responsibility of senior managers. It cannot be delegated to derivatives experts, nor can management of each individual risk be delegated to separate business units. Although management will no doubt seek counsel from managers of business units or projects, it must ultimately decide which risks are essential to the profitability of the firm, taking into account cross-risk and cross-business effects, and develop a strategy to manage those risks."

[1]Sometimes also called Enterprise(-wide) Risk Management (ERM), holistic risk management or strategic risk management.

[2]It's actually value destroying to costly hedge risks that don't affect firm-wide risk, i.e. they are "natural hedges"against each other. A plain example is that of an European car manufacturer selling and manufacturing parts of its products in the US. The long and short positions in US$ may (almost) offset each other, so that hedging separately e.g. the sales position against fluctuations of the $/€ exchange rate is at least inefficient.

This implies a specific organizational form, namely a decisional hierarchy where information flows up. Senior management has the ultimate formal authority, decisions are (partly) based on information reported by several specialists. In practice many firms appoint a Chief Risk Officer (CRO) who is typically a board member with direct access to the CEO or CFO. LIEBENBERG/HOYT (2003) even take the appointment of a CRO as a proxy for firms that have implemented the IRM approach.

Knowing the stated benefits from IRM we seek to highlight in this paper the associated costs. Considering the crucial role of information collection and processing we therefore compare the silo approach with IRM by explicitly modeling the implied organizational architecture. We interpret the silo approach as a form of decentralization, with departments managing the mitigation of particular risks independently. The individual risk manager does not report explicitly to senior management and there is no CRO who ultimately decides what to do. All decisions are made by the individual risk manager in order to meet the ex-ante known general rule: optimally hedge the risk you are responsible for. In addition, we take a third alternative as a kind of benchmark into consideration. This is the option not to implement something like a risk department in the firm, i.e. there are neither risk managers who are specifically employed to deal with a particular risk, nor a CRO who coordinates the risk management sphere. We henceforth refer to this alternative as "no-info". One should not confuse this issue with no consideration of risks at all. Product and project managers as well as the senior management might make decisions where they at least implicitly account for several types of risks, but there is no organizational risk management sphere.

Focussing on the implied organizational structure and abstracting from informational problems our finding is a weak dominance of the centralized IRM approach. So, compared to silo it is, as suggested by literature and practice, always optimal to implement IRM. One can interpret the IRM approach as silo plus an option which demands the premium only if executed. But, in some special situations no-info can be the best alternative. Introducing contractual problems, i.e. it is not possible to contract on the department-manager's effort directly and nor is it possible for the CRO to verify the received reports, eradicates the domination of the IRM approach. The situation changes because the agents need to be provided with appropriate incentives and are therefore able to generate rents. These agency costs of risk management potentially outweigh the benefits of coordination in a centralized organization. One can reduce these costs with the silo approach because of two effects: First, by leaving less discretion to the management due to ex ante specified risk management rules and second by letting the department managers work relatively independently on projects they like. In addition, there is no CRO with silo, who is also able to generate a rent within the IRM approach. So, opening the black-box of organizational architecture and considering the resultant agency costs leads to new aspects of IRM and questions its proposed general superiority.

Basically we look at the implications of the extensive information needs[3] of IRM. By explicitly considering that this information is collected and analyzed by opportunistic agents we identify new agency costs of risk management. The agents' reports and decisions affect their utility and therefore create incentives to act strategically. One source of associated costs are rents extracted by the agents, another is that risk management decisions may result from distorted information. The informational problem we are investigating is comparable to the one that arises in capital budgeting decisions. STEIN (2002) for example asks how well different organizational structures work in terms of information generation. He identifies that hierarchy or centralization performs better than decentralization when information is "hard". This is in line with our results since one can interpret hard information as better contractual possibilities, which reduces the expected agency costs and therefore strengthens the IRM approach. Quite a remarkable amount of literature exists on the benefits of risk management in general and the benefits of IRM in particular. Most of them provide an insightful, but rather intuitive analysis[4]. In contrast, FROOT/STEIN (1998) and BOYER/BOYER/GARCIA

[3] This is not only information about the risks a company is facing and their interaction, but also information about operational and financing decisions.

[4] Numerous contributions of practitioners are out threre. A typical example is KPMG (2001). FROOT/SCHARFSTEIN/STEIN (1994), MEULBROEK (2002) and LAUX (2004) among others, provide a more academic approach.

(2004) are two of the few contributions that derive their results from explicitly modeling coordination of risk management, operational and financial decisions. However, they focus on the benefits of integrating decisions and do not address organizational issues. We rather emphasize the costs of integration by explicitly accounting for organizational requirements. An important exception is TUFANO (1998), who explicitly addresses the costs of risk management. Analyzing the prominent risk management strategy of cash flow hedging[5] he intuitively identifies agency costs of risk management. They stem from the elimination of monitoring by markets if one can fund projects internally. Managers might be able to fund projects that are poor but personally beneficial. Our analysis complements the results of TUFANO (1998) and highlights additional sources of conflict between managers and shareholders within a structured model.

The next section outlines the model. Afterwards we firstly analyze the proposed organizational alternatives by abstracting from informational asymmetries. Considering contractual and informational problems is then the next step in our analysis. We conclude by providing a summary and a discussion of the robustness of our results

# 2 MODEL

A firm faces two different, but not exactly specified kinds of risks. The senior management of the firm can employ specialists (agents) who are able to process information about the risks and how one can handle them (hedging, transferring etc.). The senior management acts on behalf of the shareholders. An agent needs to provide effort $e$, with associated cost of $c(e) = e$ to "learn" about the particular risk he is in charge of. Every agent $i \in \{1, 2\}$ has the same probability ($p_1 = p_2 = p$) of being able to implement the output $\theta_i \in \left\{\overline{\theta}, \underline{\theta}\right\}$. With probability $(1 - p)$ an agent is only able to implement $\theta_i \in \{\underline{\theta}\}$. We assume $\overline{\theta} > 0$ and $\underline{\theta} < 0$. One can interpret the $\theta_i$ as the

[5] Proposed by FROOT/SCHARFSTEIN/STEIN (1994) and widely discussed and used in practice.

crucial influence factor of the risk-department's probability to suffer a loss from the particular risk. This distress probability can be reduced (or even eliminated) when the agent gets to know the characteristics of the risk and how to deal with them and eventually implements $\overline{\theta}$. Summarizing, one can keep in mind that successful learning widens the range of possible department outputs.

It is not obvious at all what the output or contribution of a risk management system is. Going along with STULZ (1996) we see risk management as an instrument to reduce the expected bankruptcy costs of a firm. Such a reduction can be obtained from reducing the probability of bankruptcy and/or the actual costs in the case of bankruptcy. Risk management can possibly reduce the probability of bankruptcy by hedging, but also by shifting exposure from default to non-default states. A real possibility of bankruptcy reduces the current firm value by the expected bankruptcy costs ($BC$). Therefore, risk management directly contributes to the firm value by reducing them.[6] Technically we assume $BC(\pi)$ with $\partial BC/\partial\pi < 0$. So, maximizing $\pi$ minimizes the expected bankruptcy costs and eventually maximizes the value of the firm. As shown in (1), we assume that $\pi$ (as a kind of production function of the rm-sphere) and consequently the expected bankruptcy costs depend collectively on the realizations of the two departments and the parameter $\gamma$. For simplicity we assume that an increase of $\pi$ results in a reduction of the bankruptcy costs by the same amount.

$$\pi = \gamma\theta_1\theta_2 \tag{1}$$

$\gamma \in \{\gamma^+, \gamma^-\}$ is a parameter that can be either positive or negative. With probability $\alpha$ the value of $\gamma$ is $\gamma^+$ and with probability $(1-\alpha)$ it takes the value $\gamma^-$. We intend to capture two coherency with $\gamma$. This is firstly the interaction of the risks (their correlation) and secondly the relation of the

[6] One can extend this discussion to the more generall costs of financial distress. As argued in FROOT/SCHARFSTEIN/STEIN (1993,1994) a firm may not be able to raise external capital when being in financial distress and therefore not being able to pursue profitable opportunities. By reducing the probability of lacking internal capital, risk mangement serves value maximation.

rm-sphere with other characteristics and activities of the firm. It is fairly well known that the overall risk, which a company is facing, depends on its operations. So, one way to avoid risk is not to operate in a specific field. The amount of risk that a firm can bear depends largely on its capital structure. Holding a lot of cash and having a low debt/equity ratio might be a valuable alternative to hedging. The IRM approach in particular advocates that one has to account for these relations. We do not look at the structure of these interactions[7], but capture the coordination effect through $\gamma$ and the stated multiplicative production function. It may not be sufficient for a positive rm-output to hedge both risks, $\theta_1 = \theta_2 = \overline{\theta}$ because of $\gamma = \gamma^-$. This might stem from the destruction of a natural hedge (the risks offset each other) or the elimination of potential profits due to risks that could be borne with the existing capital structure.[8]

Organizationally we meet this structure with the possibility for the principal to employ a third agent, the so called Chief Risk Officer (CRO). Only the CRO, being the one with access to all areas of the firm, can try to disclose the actual occurrence of $\gamma$. He has to provide effort $e_q$ and receives with probability $q$ the value of $\gamma$ and with $(1-q)$ he doesn't learn anything. The costs of effort are equal to $e_q$. Summarizing, the principal (senior management) maximizes the overall value of the risk management system, $V(\pi, e)$ by minimizing the sum of bankruptcy costs $BC(\pi)$ and effort costs. This is equivalent to the maximization of the expected value of $\pi$ less the costs of effort.

We further assume risk neutrality and that the agents are liquidity constrained.

[7]See FROOT/STEIN (1998) for such an analysis.

[8]Every firm wide constellation can be interpreted according to the combination of $\gamma$ and the two risk department outputs. If, for example, both departments implement $\underline{\theta}$ but the operational strategy of the firm as well as its capital structure is best supported by hedging the, lets say, uncorrected risks, then $\gamma$ will be negative ($\gamma^-$ ) and henceforth the overall RM output $\pi = \gamma^- \underline{\theta\theta} < 0$ will also be negative.

# 3 Without contractual and information costs

## 3.1 No explicit RM-system (no-info)

We firstly take a look at the risk output when neither specialists nor a CRO has been appointed. This doesn't mean that there is no risk consideration at all but that risk management is not an individual function in the firm. The expected output takes the following form:

$$E[\pi]^{ni} = (\alpha\gamma^{+} + (1-\alpha)\gamma^{-})\underline{\theta\theta} = E[\gamma]\,\underline{\theta\theta}$$

Because of $\underline{\theta\theta} > 0$ we need $\gamma$ to be positive in expectation ($E[\gamma] > 0$) for a positive output. Putting it differently, there is a lower bound for $\alpha$ to get a positive expected output and consequently relatively low bankruptcy costs.

*Assumption 1*: We focus on positive expected outputs ($E[\pi] > 0$) and assume therefore $E[\gamma] > 0$. This serves only for clarity and does not alter the generality of our results.

## 3.2 The Silo-RMS (silo)

This traditional approach to manage corporate risks is, as mentioned before best characterized as a decentralized department structure. One has to consider, that there is no CRO and that the agents are employed by the senior management of the firm. Each risk is organized as an (relatively) independent performance center. In our setting this means that there will be two employed agents, each in charge of one risk which they manage independently. There is neither explicit communication among the agents nor with the principal. Therefore, we need a general rule about the treatment of risks that the department managers have to obey. We assume that they have to deal "optimally" with the individual risk. This means that they are told to search for information and to implement the alternative being the best from the individual risk point of view. Putting it technically, each agent searches for $\overline{\theta}$ and implements it if possible. By abstracting from information costs we basically treat the effort provided by the agents as observable. Therefore we do not explicitly model wages in this section but rather refer to expected effort costs. Basically we implicitly assume that agents are willing to participate when compensated for their effort and that there is no incentive problem.

As stated, the value of the risk management system $V(\pi, e)$ is maximized by minimizing the sum of bankruptcy costs $BC(\pi)$ and effort costs. This is equivalent to the maximization of $E[\pi]$ less the costs of effort.

$$V(\pi, e)^{silo} = E[\gamma] \overbrace{(p^2\overline{\theta\theta} + 2p(1-p)\overline{\theta}\underline{\theta} + (1-p)^2\underline{\theta\theta})}^{\equiv E[\theta\theta]^{silo}} - 2e \tag{2}$$

To get a potential benefit from the silo approach we need $E[\theta\theta]^{silo} > \underline{\theta\theta}$ because otherwise there would be no reason to employ costly agents, $V(\pi, e)^{silo}$ is always smaller than $E[\pi]^{ni}$.

**Lemma 1** *We assume $p > \widehat{p}$ which implies $E[\theta\theta]^{silo} > \underline{\theta\theta}$. In addition, we assume $\overline{\theta} > \mid \underline{\theta} \mid$ which relaxes the requirement that $p$ is above the critical threshold $\widehat{p}$.*
***Proof.*** *see the appendix.* ■

**Lemma 2** *The silo approach is only optimal compared to no-info if and only if (3) is fulfilled*

$$\begin{aligned} E[\gamma] E[\theta\theta]^{silo} - 2e &> E[\gamma]\underline{\theta\theta} \\ \Longleftrightarrow E[\theta\theta]^{silo} - \underline{\theta\theta} &> \frac{2e}{E[\gamma]} \end{aligned} \tag{3}$$

We see that lowering the bankruptcy costs ($E[\theta\theta]^{silo} > \underline{\theta\theta}$) is not sufficient for the advantageousness of silo. The reduction of the expected bankruptcy costs has to be above some threshold, namely the induced expected effort costs.

With silo, there are three combinations of department outputs possible, i.e. $\theta_i\theta_i = \{\overline{\theta\theta}, \overline{\theta}\underline{\theta}, \underline{\theta\theta}\}$ .There is no coordination problem when neither agent learns anything ($\underline{\theta\theta}$). With $\gamma^+$ the output is optimal and there is no possibility to meet $\gamma^-$ in a better way. If only one agent can obtain the high output

($\overline{\theta}\underline{\theta}$) it is only optimal to implement this combination with $\gamma^-$. With a positive gama it would be value enhancing when both managers realize the low output. Implementing $\overline{\theta}$ in both departments is in contrast only optimal with $\gamma^+$. So, under the silo-max rule the problem is that with two constellations ($\overline{\theta}\underline{\theta}$,$\gamma^+$ and $\overline{\theta\theta}; \gamma^-$) there would be the possibility to realize a better output ($\underline{\theta\theta}, \overline{\theta}\underline{\theta}$ respectively) but one is not able to differentiate with this approach in respect to $\gamma$. This leads us to the IRM approach, discussed in the next section.

## 3.3 The Integrated Risk Management approach (IRM)

With the IRM approach one wants to benefit from coordinating the risk management decisions. Two things are therefore needed. Firstly, one has to discover the actual value of $\gamma$ and secondly the agents need to be told what concrete strategy they should implement. One could imagine several ways to manage this, however all of them have at least one thing in common: there must be some centralized information collection. We here adopt, as stated in the introduction, the widely used installation of a Chief Risk Officer (CRO). He receives reports from the risk department managers concerning their possible strategies and explores the actual occurrence of $\gamma$. By providing effort $e_q$ he learns the true value of $\gamma$ with probability $q$.

As we know from the previous section there are two situations ($\overline{\theta}\underline{\theta}$,$\gamma^+$ and $\overline{\theta\theta}; \gamma^-$) where one could benefit from coordination. The coordination effect of IRM shows up in the discrimination due to $\gamma$ when the CRO is successful in identifying $\gamma$. If he fails to reveal information (with probability $(1-q)$) about $\gamma$, the same problems as with silo remain. Our understanding of the IRM process inhabits the following sequential timing. First, senior management decides about the employment of the department risk specialists and the CRO. IRM is implemented if all of them are hired. Then the department mangers investigate simultaneously the particular risk they are in charge of and each of them learns with probability $p$ how to realize $\overline{\theta}$. Afterwards, the CRO decides conditional on their reports to trying to obtain the actual value of $\gamma$ or not and tells the agents which strategy they should implement.

Taking a closer look at the CRO's decision problem we recognize that there are three different situations possible: no, one or both agents report the possibility of realizing the high output. Coordination is not necessary when neither agents learns something (i.e. each can only implement $\underline{\theta}$) and therefore the CRO doesn't provide effort. If one agents is able to implement $\overline{\theta}$, but not the other, the CRO has the following alternatives. He provides effort $e_q$ and realizes $\pi = \alpha\gamma^+\underline{\theta\theta} + (1-\alpha)\gamma^-\overline{\theta}\underline{\theta}$ in case of success. So, with probability $q$ one is able to discriminate due to $\gamma$, but with $(1-q)$ one realizes the same output as without investigation, $E[\gamma]\overline{\theta}\underline{\theta}$. Therefore, the CRO searches only if (4) is fulfilled.

$$q(\alpha\gamma^+\underline{\theta\theta} + (1-\alpha)\gamma^-\overline{\theta}\underline{\theta}) + (1-q)E[\gamma]\overline{\theta}\underline{\theta} - e_q > E[\gamma]\overline{\theta}\underline{\theta}$$
$$\Leftrightarrow q\alpha\gamma^+(\underline{\theta\theta} - \overline{\theta}\underline{\theta}) > e_q \tag{4}$$

With positive reports from both agents the CRO faces a similar problem. Providing $e_q$ is only optimal when the possible coordination benefits (i.e. the reduction of the bankruptcy costs) in case of $\gamma^-$ are not fully offset by the costs of effort. Analogous to the previous situation this is only guaranteed with (5).

$$q(\alpha\gamma^+\overline{\theta\theta} + (1-\alpha)\gamma^-\overline{\theta}\underline{\theta}) + (1-q)E[\gamma]\overline{\theta\theta} - e_q > E[\gamma]\overline{\theta\theta}$$
$$\Leftrightarrow q(1-\alpha)\gamma^-(\overline{\theta}\underline{\theta} - \overline{\theta\theta}) > e_q \tag{5}$$

Note that the left side of (4) and (5) is always positive. So, there are positive coordination effects, but one is only <u>able</u> realize them when the CRO is able (with probability $q$) to discriminate in accordance to $\gamma$. In addition, one only <u>wants</u> to implement coordination if the expected benefits exceed the required costs ($e_q$).

When deciding ex ante about the implementation of IRM the senior management has to compute the expected value of the IRM approach, $V(\pi, e)^{IRM}$ and compare it with the value of the two alternatives.

**Lemma 3** *One can expect the following value of the risk management system when implementing IRM:*

$$\begin{aligned} V(\pi, e)^{IRM} &= E[\gamma] \cdot E[\theta\theta]^{silo} - 2e \\ &+2p(1-p)\max\left\{0; q\alpha\gamma^{+}(\underline{\theta\theta} - \overline{\theta}\underline{\theta}) - e_q\right\} \\ &+p^2 \max\left\{0; q(1-\alpha)\gamma^{-}(\overline{\theta}\underline{\theta} - \overline{\theta\theta}) - e_q\right\} \end{aligned} \quad (6)$$

**Proof.** see the appendix. ■

Comparing (2) and (6) it is straight forward to see the relation $V(\pi, e)^{IRM} \geq V(\pi, e)^{silo}$. This means that the IRM approach weakly dominates the silo approach. One can envision the IRM approach as silo plus an option for which one only has to pay when exerted. So, considering that one only uses the option to search for $\gamma$ if its beneficial (i.e. the expected reduction of the BC is higher than the increment effort costs), we get the stated dominance of the IRM approach.

In detail, there are two positive effects from IRM identifiable (see (6). Firstly, one doesn't realize $\overline{\theta\theta}$ with $\gamma^-$ but $\overline{\theta}\underline{\theta}$ which leads to a positive overall output. And secondly, one implements $\underline{\theta\theta}$ instead of $\overline{\theta}\underline{\theta}$ with $\gamma^+$, leading also to a positive output. Coordination is more valuable the higher the not realized negative impact would be and as greater the implemented output is. This leads to the natural result, that coordination is more valuable when the difference between the possible realizations ($\overline{\theta}$ and $\underline{\theta}$) is greater. The required information processing effort ($e_q$) reduces the potential benefit of IRM.

**Lemma 4** *Consider $\Delta IRM$ as the additional effect of IRM compared to silo on the risk management system (see (6)). IRM dominates no-info if and only if:*

$$E[\theta\theta]^{silo} - \underline{\theta\theta} > \frac{2e - \Delta IRM}{E[\gamma]} \quad (7)$$

**Proof.** see the appendix. ■

**Proposition 5** *The IRM approach weakly dominates the silo approach. However, it might be optimal not to implement a risk management system at all.*

# 4 Asymmetric Information

Up to this point we assumed that the principal can observe the effort provided by the agents. In addition, problems of reporting truthfully didn't exist. In this section we expand our analysis and show how communication and contractual costs might alter our previous results. We assume firstly, that the agents's effort is unobservable. Therefore, one obviously can't write contracts on effort provision. We secondly assume that each department's output isn't observable and verifiable in absolute terms, but one can identify if its negative or positive (put another way: if hedging activities were pursued or not). The same is true for the overall output of the risk management sphere.

We further assume that a department manager prefers minimize the exposure of his own department. He receives a private benefit ($B$) when $\overline{\theta}$ is carried out. For (at least) the following two reasons this seems natural to us. Firstly, the manager cares about his future. As head of a department that maybe constantly suffer from losses he bears the risk of being branded as "low type" on the (internal and external) job market because of imperfect information. If its not perfectly transparent that he only obeyed orders, his career can be negatively affected by the judgement of "outsiders" (relating at least partly on his department performance), defined as not being actively involved in the structure of the RM-system of the particular firm. Tufano (1998), p. 74-75 provides anecdotanal evidence that in practice many projects are intended to manage "career or employment risk". The implementation of $\overline{\theta}$ also means independence for the manager. He probably doesn't need to answer questions about the poor performance of his department. Secondly, one can imagine that working on one's project is somewhat more satisfying than collecting information and not being able to implement or use it. Working on own ideas as private benefit is quite a recognized effect in the literature.[9] In addition, one can imagine that it is more likely that a manager prefers pursuing "pet projects" compared to not implementing any project.

[9] See for example Záboiník (2002) in a comparable context.

**Silo-approach.** Every agent is told to maximize the output of the risk-department he is in charge of. The principal can only verify if the output is negative or positive after the agent had to choose his effort provision. Due to limited liability one can't punish an agent harder than with "no-wage". So, a contract can be written conditional on (the sign of) $\theta_i$ :

$$wage^{silo} = \left\{ \begin{array}{ll} w_1 & \text{if } \theta_i = \overline{\theta} \\ w_2 & \text{if } \theta_i = \underline{\theta} \end{array} \right\}$$

Because one wants to punish in the case of $\underline{\theta}$ as hard as possible we optimally set $w_2 = 0$. Assuming that the "outside option" of every agent is zero, $w_1$ and $B$ need to cover the cost of effort provided by the agent in expectation. We need the following constraint to be met. It represents both, the participation and the incentive constraint of every single agent.

$$\begin{aligned} p \cdot (w_1 + B) - e \geq 0 \rightarrow w_1 &= \frac{e}{p} - B \\ \rightarrow E\left[w\right]^{silo} = 2(pw_1 + (1-p)w_2) &= 2(e - pB) \end{aligned} \tag{8}$$

We assume that the private benefit doesn't outweigh the expected cost of effort and receive therefore a positive wage in case of success. This is not crucial for our analysis and also helps meeting the limited liability constraint. Employing two agents results therefore in overall costs of $2(e - pB)$.

**IRM-approach**. We now demand from the department managers not only to provide effort, but also to report what and if they learned something to the CRO. And eventually they need to execute the CRO's decision. So, by assuming that implementation is without additional effort possible one can ask if the what wage contract assures effort execution and truthtelling and the right implementation by the agents.

*Assumption 3:* The principal is able to verify the output of every risk department (it's sign, to be more precise) ex post, but not ex ante if the reported information by the agent is true or not (soft information).

Lets take a closer look at the concrete situation. We mark the report of agent i with $R_i \in \{L, NL\}$. $L$ means that the agent learned something and can possibly implement $\theta_i \in \left\{\overline{\theta}, \underline{\theta}\right\}$. Reporting $NL$ states that the agent is only able to realize $\theta_i \in \{\underline{\theta}\}$. The briefing every agent receives from the CRO is labelled with $\hat{\theta}_i \in \left\{\overline{\theta}, \underline{\theta}\right\}$. To possibly fulfill all of the stated requirements one has to pay wages conditional on $R_i, \hat{\theta}_i$ and the realized department output $\theta_i$. The optimal wage contract for every agent has to meet all of the following constraints:

$$w(R, \hat{\theta}, \theta) \geq 0 \qquad \forall R, \hat{\theta}, \theta \tag{LL}$$

$$p\left[(1-\beta)(w(L, \overline{\theta}, \overline{\theta}) + B) + \beta w(L, \underline{\theta}, \underline{\theta})\right] + (1-p) w(NL, \underline{\theta}, \underline{\theta}) \geq e \tag{PC}$$

$$p\left[(1-\beta)(w(L, \overline{\theta}, \overline{\theta}) + B) + \beta w(L, \underline{\theta}, \underline{\theta}) - w(NL, \underline{\theta}, \underline{\theta})\right] - e \geq 0 \tag{IC}$$

$$w(L, \overline{\theta}, \overline{\theta}) \geq w(NL, \underline{\theta}, \overline{\theta}) \tag{TT1}$$

$$w(NL, \underline{\theta}, \underline{\theta}) \geq \beta w(L, \underline{\theta}, \underline{\theta}) \tag{TT2}$$

$$w(L, \overline{\theta}, \overline{\theta}) + B \geq w(L, \overline{\theta}, \underline{\theta}) \tag{IIC1}$$

$$w(L, \underline{\theta}, \underline{\theta}) \geq w(L, \underline{\theta}, \overline{\theta}) + B \tag{IIC2}$$

$$w(NL, \underline{\theta}, \underline{\theta}) \geq w(NL, \underline{\theta}, \overline{\theta}) + B - e \tag{IIC3}$$

*Effort provision.* Every agent should exert effort $e$. Therefore he needs to be given incentives to do so, i.e. (PC) and (IC) need to be met, with $\beta$ as the probability of being told to implement $\underline{\theta}$ , given the report $L$. One should be aware that the agent's effort provision is not verifiable and therefore not comprised in the wage contract. But because the high output $(\overline{\theta})$ is only receivable with effort executed ($p$ is otherwise zero), one is able to implement a forcing contract. With the limited liability constraint (LL) we only need to meet the (IC) since it implies that (PC) is also satisfied. *Truthtelling.* We need the agent to report if he learned something. It must be always optimal for the agent to report truthfully. We capture this with the constraints (TT1) and (TT2). *Implementing.* Lastly, the agent needs to obey the principals decision and implement the strategy he is told. The last three of the above constraints provide the agent with the incentive to do so. We label them "implementing incentive constraints" (ICC).

We solve the problem by firstly checking which of the truthtelling and implementing constraint are binding. Afterward we use our findings for solving the (IC) and obtain the optimal wage structure. It is instructional to begin with the last chronological step, the implementation. Having learned something and being told to implement $\overline{\theta}$ is self-enforcing because the agent receives the private Benefit $B$. (IIC1) is therefore fulfilled. Implementing $\overline{\theta}$ when having reported that this isn't possible (see (IIC3)) represents the next case we need to consider. Because we assumed (see the above paragraph about silo in this section) that the private benefit doesn't outweigh the expected cost of effort this is also not a binding constraint. If the agent learned something he must be compensated in the case of not being allowed to implement $\overline{\theta}$ and therefore not to realize the private benefit $B$. So, if an agents reports the possibility of implementing $\overline{\theta}$ and is told not to do so he must receive a wage of at least $B$. This means that (IIC2) is the only binding implementation constraint: With $w(L, \underline{\theta}, \overline{\theta}) = 0$ we need $w(L, \underline{\theta}, \underline{\theta}) = B$. There isn't a problem with truthful reporting if the agent was successful and has $\overline{\theta}$ identified. Obviously he is better of reporting the truth since he is able to generate $w(NL, \underline{\theta}, \underline{\theta})$ without effort provision and implementing $\overline{\theta}$ doesn't raise his expected wage (see (TT1). The second truthtelling constraint is binding. With $w(L, \underline{\theta}, \underline{\theta}) = B$ (needed for implementing) we assure that the agent has no incentives to report $L$ if he hasn't found something. Therefore, must the expected wage from truthtelling at least be $\beta w(L, \underline{\theta}, \underline{\theta})$, which equals the expected payoff from pretending to have learned something. Note, that with probability $(1 - \beta)$ a manager gets no payment since he isn't able to implement $\overline{\theta}$.

We receive the necessary wage in case that the agents learns something, reports truthfully and executes the order to implement $\overline{\theta}$ by plugging the results so far in (IC):

$$p\left[(1-\beta)(w(L,\overline{\theta},\overline{\theta})+B)+\beta B-\beta B\right]-e\geq 0$$
$$\rightarrow w(L,\overline{\theta},\overline{\theta})=\frac{e}{p(1-\beta)}-B \qquad (9)$$

This leaves the agent with the following optimal wage contract:

$$wage^{IRM}=\left\{\begin{array}{l} w(L,\overline{\theta},\overline{\theta})=\frac{e}{p(1-\beta)}-B \\ w(NL,\underline{\theta},\underline{\theta})=\beta B \\ w(L,\underline{\theta},\underline{\theta})=B \\ w(\cdot)=0 \end{array}\right\}$$

We are now able to compute the overall (expected) wage-costs for the risk department managers with IRM:

$$\begin{aligned} E\left[w\right]^{IRM} &= 2\left[p\left[(1-\beta)w(L,\overline{\theta},\overline{\theta})+\beta w(L,\underline{\theta},\underline{\theta})\right]+(1-p)w(NL,\underline{\theta},\underline{\theta})\right] \\ &= 2\left[p\left[(1-\beta)\left(\frac{e}{p(1-\beta)}-B\right)+\beta B\right]+(1-p)\beta B\right] \\ &= 2(e-pB+(1+p)\beta B) \qquad (10) \end{aligned}$$

Comparing (8) with (10) we see that the department managers' wage costs are under IRM strictly greater than with the silo approach: $E\left[w\right]^{IRM} > E\left[w\right]^{silo}$. One should recognize the crucial role of $\beta$ as the probability with which an agent expects to be told to implement $\underline{\theta}$ if he has reported the possibility of implementing $\overline{\theta}$. The agents get with $\beta = 1$ full compensation for their effort and an additional (fix) payment amounting to the private benefit $B$. However, the expected wage costs of IRM are with $\beta = 0$ the same as with silo. This is due to the fact that a department manager isn't able to extract any extra payment when reporting $L$ but not having learned something, because he surely will be told to implement $\overline{\theta}$ if possible. Consequently he realizes the private benefit $B$ whenever possible.

In contrast to the silo approach one has to employ a third agent with

IRM, the CRO. He needs to be given incentives to make the right effort decision, conditional on the reports of the department mangers. Because one can't write contracts on these reports (they are soft information, see assumption 3) we need to contract on $\pi$. This is the only variable the CRO can influence and that is unambiguously linked with the value of the risk management system. As stated, one can not perfectly infer from the realized output which decision has been made. This stems from the assumption that one is only able to verify if the actual output is below or above some threshold, to be more precise if $\pi$ is positive or negative (see assumption 3). One should consider that this assumption is quite natural and leads to constellations that are in line with comparable literature. An equivalent way to model the resulting situation is to allow for a positive chance to identify $\gamma$ without effort provision of the CRO. We then would also not be able to interfere from the resulting output on the CRO's decision. Our approach follows from consistency and simplicity reasons.

This leads to the following wage scheme for the CRO:

$$wage^{CRO} = w(\pi) = \left\{ \begin{array}{c} w^{+} \text{ if } \pi > 0 \\ w^{-} \text{ if } \pi < 0 \end{array} \right\}$$

The participation and the incentive constraint are given by (11) respectively (IC), whereas $\lambda$ names the probability of receiving $\pi > 0$.

$$\lambda \cdot w^{+} + (1 - \lambda) \cdot w^{-} \geq e_q \tag{11}$$

It is optimal, as usual with limited liability, to set $w^{-} = 0$. So, the CRO is willing to participate if the expected wage ($\lambda w^{+}$) at least offsets his effort costs ($e_q$). One also needs to provide appropriate incentives for the CRO. Taking a closer look at the situation the CRO is facing we derive in the following the incentive constraint.

From section 3.3 we know that the CRO possibly faces three different situations: he might get no, one or two positive reports from the agents, i.e. that they are able to implement the high department output, $\overline{\theta}$. Receiving no positive output , he hasn't any decisional discretion, both agents realize $\underline{\theta}$

anyway. With at least one possibility of implementing $\overline{\theta}$ the CRO faces the decision problems shown in (4) and (5).

Having received one positive report the CRO should make his effort decision due to (4): $q \cdot \alpha\gamma^{+}(\underline{\theta\theta} - \overline{\theta}\underline{\theta}) > e_q$. But, the CRO is only interested in a positive wage and therefore if the output ($\pi$) is positive or not. Providing effort, this will be for sure the case with probability $q$. Not being successful in identifying the true value of $\gamma$ leaves the CRO with the same opportunities as without effort provision. So, the alternative is not to provide any effort and tell the department managers to implement (i) $\underline{\theta\theta}$ or (ii) $\overline{\theta}\underline{\theta}$. The probability of receiving a positive output (i.e. that $\gamma$ is positive or negative) is therefore $\alpha$ respectively $(1-\alpha)$. To provide appropriate incentives for the CRO one therefore needs to meet the following incentive constraint:

$$qw^{+} + (1-q)\max\{\alpha, (1-\alpha)\} - e_q \geq \max\{\alpha, (1-\alpha)\}\, w^{+} \qquad \text{(IC)}$$
$$\rightarrow w^{+} = \frac{e_q}{q(1-\max\{\alpha, (1-\alpha)\})}$$

While the optimal decision base changes with two positive reports ((5): $q \cdot (1-\alpha)\gamma^{-}(\overline{\theta}\underline{\theta} - \overline{\theta\theta}) > e_q$), what the CRO takes into consideration remains basically the same. Executing effort yields exactly the left hand side of (IC) and free riding the same opportunity. The only difference is that it is possible to implement $\overline{\theta\theta}$ with two positive reports. But it only matters for the CRO if $\pi$ is positive or negative and not it's actual amount. Therefore both alternatives ($\overline{\theta\theta}, \underline{\theta\theta}$) getting a positive output when $\gamma = \gamma^{+}$ (again, this is the case with $\alpha$) are virtually equivalent for him.

**Proposition 6** *The CRO is able to generate a positive wage in every state and consequently receives some fixed amount of remuneration. Therefore IRM becomes a costly option and doesn't dominate the silo approach any more. In addition, the CRO extracts a rent and the department managers need to be compensated higher than with silo.*

# 5 Conclusion

In this paper we investigate different approaches to organize corporate risk management. Abstracting from informational problems we are able to show that the proposed superiority of the RM approach holds. This stems from the fact that centralized information processing takes only place when it's optimal to do so. However,lifting the assumption of verifiable information yields a rationale for the decentralized silo approach. The agency costs of risk management are expected to be much higher with IRM and possibly outweigh the benefits of coordination. A decentralized risk management organization with ex-ante specified fixed decision rules provides the managers with less discretion and therefore fewer opportunities to act strategically. A manager also might value not being constantly questioned and forced to implement or to omit projects he investigated. Nevertheless, one should note that in some special cases it is even optimal not to actively manage risks at all.

The key point of our analysis is that we explicitly account for the different organizational structures underlying the two approaches we investigate. It is vital to see that bundling the right to take decisions with information acquisition and processing can be valuable. Putting it differently, the implicitly with IRM proposed separation of decision and processing duties is only optimal if information can be transferred without (significant) frictions. This might be, as in our approach, due to higher wages. However, the main results do not rely on our modelling approach but can for example also be received by considering that even if the agents always want to report their information truthfully they simply might not be able to do so. Such communication problems may arise due the nature of the information (e.g. hardly documentable operational risk) or due to the ability of the CRO to evaluate possibly very different and specialized information.

# 6 Appendix

**Proof.** of Lemma 1. For $E\left[\theta\theta\right]^{silo} > \underline{\theta\theta}$ we need the following equation to be met. This implies a lower bound of $p$, i.e. it needs to be higher than a critical $\widehat{p}$.

$$p^2\overline{\theta\theta} + 2p(1-p)\bar{\theta}\underline{\theta} + (1-p)^2\underline{\theta\theta} > \underline{\theta\theta}$$
$$\rightarrow \widehat{p} = \frac{-2(\bar{\theta}\underline{\theta} - \underline{\theta\theta})}{(\overline{\theta\theta} - 2\bar{\theta}\underline{\theta} + \underline{\theta\theta})}$$

Obviously we need a lower $p$ when $\overline{\theta\theta}$ is higher and the other way around. This means that $p$ and $\overline{\theta\theta}$ behave like substitutes. If there is nothing to discover it naturally doesn't make sense to invest effort; this proves with the requirement of $p > 1$ what is impossible. We therefore can relax the requirement about $p$ by assuming that $\bar{\theta} > \underline{\theta}$. ■

**Proof.** of Lemma 3.

We firstly work out the expected output with the IRM approach

$$V(\pi,e)^{IRM} = \alpha\gamma^{+}\overbrace{\begin{pmatrix} p^2q\overline{\theta\theta} + p^2\left(1-q\right)\overline{\theta\theta} + 2p(1-p)\underline{\theta\theta}q \\ +2p(1-p)(1-q)\bar{\theta}\underline{\theta} + (1-p)^2\underline{\theta\theta} \end{pmatrix}}^{=E[\theta\theta]^{silo}} \tag{12}$$
$$+ (1-\alpha)\gamma^{-}\cdot\underbrace{\begin{pmatrix} p^2q\bar{\theta}\underline{\theta} + p^2\left(1-q\right)\overline{\theta\theta} \\ +2p(1-p)q\bar{\theta}\underline{\theta} + 2p(1-p)(1-q)\bar{\theta}\underline{\theta} + (1-p)^2\underline{\theta\theta} \end{pmatrix}}_{>E[\theta\theta]^{silo}}$$
$$-2e - (1-(1-p)^2 e_q$$

Taking the silo output as reference point and rearranging equation (12) leads to:.

$$
\begin{aligned}
V(\pi,e)^{IRM} &= \alpha\gamma^{+}(2p(1-p)\underline{\theta\theta}q - 2p(1-p)\overline{\theta}\underline{\theta}q + (1-\alpha)\gamma^{-}\cdot(p^2q\overline{\theta}\underline{\theta} - p^2q\overline{\theta\theta}) \\
&+ \alpha\gamma^{+}\overbrace{\begin{pmatrix} p^2q\overline{\theta\theta} + p^2\left(1-q\right)\overline{\theta\theta} + 2p(1-p)\overline{\theta}\underline{\theta}q \\ +2p(1-p)(1-q)\overline{\theta}\underline{\theta} + 2p(1-p)\overline{\theta}\underline{\theta} + (1-p)^2\underline{\theta\theta} \end{pmatrix}}^{=E[\theta\theta]^{silo}} \\
&+ (1-\alpha)\gamma^{-}\cdot\underbrace{\begin{pmatrix} p^2q\overline{\theta\theta} + p^2\left(1-q\right)\overline{\theta\theta} + 2p(1-p)q\overline{\theta}\underline{\theta} \\ +2p(1-p)(1-q)\overline{\theta}\underline{\theta} + 2p(1-p)\overline{\theta}\underline{\theta} + (1-p)^2\underline{\theta\theta} \end{pmatrix}}_{=E[\theta\theta]^{silo}} \\
&- 2e - p(2-p)^2\cdot e_q \\
&= \left(\alpha\gamma^{+} + (1-\alpha)\gamma^{-}\right)\cdot E\left[\theta\theta\right]^{silo} - 2e \\
&+ \alpha\gamma^{+}(2p(1-p)q\cdot(\underline{\theta\theta} - \overline{\theta}\underline{\theta}) + p^2q(1-\alpha)\gamma^{-}\cdot(\overline{\theta}\underline{\theta} - \overline{\theta\theta}) - (1-p)^2\cdot e_q
\end{aligned}
$$

Considering the "option-character" of IRM provided by (4) and (5) yields:

$$
\begin{aligned}
V(\pi,e)^{IRM} \quad = \quad & E\left[\gamma\right]\cdot E\left[\theta\theta\right]^{silo} - 2e \\
& +2p(1-p)\max\left\{0; q\alpha\gamma^{+}(\underline{\theta\theta} - \overline{\theta}\underline{\theta}) - e_q\right\} \\
& +p^2\max\left\{0; q(1-\alpha)\gamma^{-}(\overline{\theta}\underline{\theta} - \overline{\theta\theta}) - e_q\right\}
\end{aligned}
\tag{13}
$$

■

**Proof.** of Lemma 4.

$$\alpha\gamma^{+}\cdot E\left[\theta\theta\right]^{silo}+(1-\alpha)\gamma^{-}\cdot E\left[\theta\theta\right]^{silo}-2e$$
$$+\,\alpha\gamma^{+}(2p(1-p)q\cdot(\underline{\theta\theta}-\overline{\theta}\underline{\theta})$$
$$+\,p^{2}q(1-\alpha)\gamma^{-}\cdot(\overline{\theta}\underline{\theta}-\overline{\theta\theta})-(1-p)^{2}\cdot e_{q}$$
$$>\alpha\gamma^{+}\cdot\underline{\theta\theta}+(1-\alpha)\gamma^{-}\cdot\underline{\theta\theta}$$
$$\Leftrightarrow(E\left[\theta\theta\right]^{silo}-\underline{\theta\theta})(\alpha(\gamma^{+}-\gamma^{-})+\gamma^{-})$$
$$>2e+(1-p)^{2}\cdot e_{q}$$
$$-\,\alpha\gamma^{+}(2p(1-p)q_{1}\cdot(\underline{\theta\theta}-\overline{\theta}\underline{\theta})$$
$$-\,p^{2}q(1-\alpha)\gamma^{-}\cdot(\overline{\theta}\underline{\theta}-\overline{\theta\theta})$$
$$\Leftrightarrow(E\left[\theta\theta\right]^{silo}-\underline{\theta\theta})$$
$$>\frac{2e+\overbrace{(1-p)^{2}\cdot e_{q}-\alpha\gamma^{+}(2p(1-p)q\cdot(\underline{\theta\theta}-\overline{\theta}\underline{\theta})-p^{2}q(1-\alpha)\gamma^{-}\cdot(\overline{\theta}\underline{\theta}-\overline{\theta\theta})}^{\equiv\Delta IRM}}{(\alpha(\gamma^{+}-\gamma^{-})+\gamma^{-})}$$
$$\rightarrow(E\left[\theta\theta\right]^{silo}-\underline{\theta\theta})>\frac{2e-\Delta IRM}{E\left[\gamma\right]}$$

■

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