On the Organization of Risk Management

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Abstract

The Enterprise Risk Management (ERM) approach advocates coordinated risk management decisions based on firm-wide information. We model how one generates such information within an organization. We identify the characteristics that lead to a (weak) dominance of the centralized ERM compared to the traditional decentralized risk management approach. We subsequently show that the potential costs of the option to coordinate may outweigh the expected benefits of coordination. Risk management as an independent function, the provision of appropriate incentives and the existence of communication obstacles are highlighted as potential (agency) costs of risk management.

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1 Introduction

With what is called the Enterprise Risk Management (ERM)[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 does not have to cope 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. The firm's overall risk is typically not just the sum of the individual risks, which 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] ERM is very different from the "traditional" approach to corporate risk management where departments deal 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 simply "silo"). As Meulbroeck (2002) 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 Integrated Risk Management (IRM), holistic risk management or strategic risk management.

[2] It is actually value destroying to costly hedge risks that do not 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 for 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 upwards. Senior management has the ultimate formal authority, decisions are (partly) based on information reported by several specialists. In practice some firms appoint a Chief Risk Officer (CRO) who is typically a board member with direct access to the CEO or CFO. Liebenberg and Hoyt (2003) even take the appointment of a CRO as a proxy for firms that have implemented the ERM approach.

Knowing the stated benefits arising from ERM we seek to highlight in this paper the associated costs. Considering the crucial role of information collection and processing, we explicitly model the organizational architecture implied. 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 central decision taker, for example the a 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.[3]

Focussing on the implied organizational structure we identify as a first step the conditions for a (weak) dominance of the centralized ERM approach. This is basically the case when one is able to characterize the ERM approach as silo plus an option which is only purchased and executed when in expectations in the money. The subsequent analysis is about identifying and characterizing features that possibly make the option to coordinate costly and lead to a trade-off between ERM and the silo approach, i.e. decentralization. We first discuss a possible option premium, i.e. a fixed amount of cost that is due no matter if coordination effort is actually executed or not. We argue that one can interpret the existence of an option premium in terms

[3]In the appendix we take a third alternative into consideration, which one might consider as a kind of benchmark . This is the option not to implement any kind of explicit risk management, 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.

of the independence of the risk management sphere. In a nutshell, having an independent risk management organization, headed for example by a CRO in a firm will lead to incremental fixes costs that one can interpret as the option premium of risk management coordination. Alternatively, one may imagine that line managers could be also responsible for risk management and that (possible) coordination needs are with, for example the CFO who is anyway in place. We will mostly refer to the central decision maker as the CRO. This is only due to convenience reasons and not a statement of superiority.

We also show, that 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, eliminate the domination of the ERM 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 by keeping 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 ERM approach.

Basically we look at the implications of the extensive information needs[4] of ERM. By explicitly considering that this information is collected and analyzed by opportunistic agents we identify new agency costs associated with risk management. The agents' reports and decisions affect their utility and therefore create incentives to act strategically. One source of associated costs is rents extracted by the agents, another is the fact 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 the fact that hierarchy or centralization performs better than decentralization when

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

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 ERM approach. There is quite a remarkable amount of literature on the benefits of risk management in general and the benefits of ERM in particular. Most of them provide an insightful, but rather intuitive analysis[5]. In contrast, Froot and Stein (1998)and Boyer et al. (2004) are two of the few contributions that derive their results from explicitly modeling the 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,[6] he intuitively identifies the 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 and identify ERM as silo plus the option to coordinate. In the subsequent sections we identify and analyze the characteristics that make the option to coordinate costly. We conclude by providing a summary and a discussion of the robustness and extension of our setup and results.

[5]Numerous contributions by practitioners are out threre. A typical example is KPMG (2001). Froot et al. (1994), Meulbroek (2002) and Laux (2004) among others, provide a more formal approach.

[6]Proposed by Froot et al. (1994) and widely discussed and used in practice.

2 The 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, retaining 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 $\theta_i \in \left\{\overline{\theta}, \underline{\theta}\right\}$. However, even when providing effort e there is a positive probability $(1-p)$ that the managers does not learn how to deal with the particular risk and is therefore only able to implement $\theta_i \in \{\underline{\theta}\}$. Without effort provision the output of a department is definitely $\underline{\theta}$. We assume $\overline{\theta} > 0$ and $\underline{\theta} < 0$.

One can interpret the θ_i as the crucial influence factor of a risk-department's probability suffering of 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 should keep in mind that successful learning widens the range of possible department outputs.

It is not at all obvious what the output or contribution of a risk management system is. In agreement with Stulz (1996) we see risk management as an instrument for reducing the expected bankruptcy costs of a firm. Such a reduction can be obtained by reducing the probability of bankruptcy and/or the actual costs in the case of bankruptcy. Risk management may possibly reduce the probability of bankruptcy by hedging. A real possibility of bankruptcy reduces the current firm value by the expected bankruptcy costs (BC). Therefore, risk management directly contributes to firm value by reducing the expected bankruptcy costs.[7] Technically, we assume $BC(\pi)$ with

[7] One can extend this discussion to the more general costs of financial distress. As argued in Froot et al. (1993,1994) a firm may not be able to raise external capital when in financial distress and therefore not being able to pursue profitable opportunities. By reducing the probability of a lack of internal capital, risk management serves value maximation.

$\partial BC/\partial\pi < 0$. So, maximizing π minimizes the expected bankruptcy costs and ultimately maximizes the value of the firm. As shown in (1), we assume that π (as a kind of production function of the risk management sphere) and consequently the expected bankruptcy costs depend collectively on the realizations of the two departments and the parameter γ. For simplicity we assume that an increase of π results in a reduction in the bankruptcy costs by the same amount.

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

$\gamma \in \{\gamma^+, \gamma^-\}$ is a parameter that can be either positive or negative. With probability α the value of γ is $\gamma^+ > 0$ and with probability $(1-\alpha)$ it takes the value $\gamma^- < 0$. We intend to capture two coherencies with γ. This is firstly the interaction of the risks (their correlation) and secondly the relation of the risk management sphere to 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 ERM approach in particular advocates that one has to account for these relations. We do not look at the structure of these interactions[8], but capture the coordination effect through γ and the stated multiplicative production function. It may not be sufficient for positive risk management output to for example hedge or engage in both risks, $\theta_1 = \theta_2 = \overline{\theta}$ because of $\gamma = \gamma^-$. One may reasonably ask what risk the firm actually bears, given that both departments may individually hedge their risk. An example of such a situation is the destruction of a natural hedge, i.e. the risks offset each other. By costly hedging the of risks individually the firm therefore basically carries out a negative net present value investment. This in turn reduces the firm value and therefore makes the firm more likely to default. Another example is the elimination of potential profits. One can imagine that it may be beneficial for a firm to bear particular risks, given their operational strategy and capital structure. Hedging of all risks

[8] See Froot and Stein (1998) for such an analysis.

may then be value destroying.[9] To keep the analysis simple we capture these interactions in an admittedly rather abstract but for our purpose appropriate form, i.e. with the specification of γ.

Organizationally we meet the ERM approach with the possibility that the principal may employ a third agent, called the Chief Risk Officer (CRO). Only the CRO, as the one with access to all areas of the firm, can try to discover the actual occurrence of γ. He has to provide effort e_q and receives with probability q the value of γ. With $(1-q)$ when providing effort and definitely when not providing effort, he does not learn anything about the value of γ. 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 π less the costs of effort.

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

3 Enterprise Risk Management (ERM) and the option to coordinate

With the ERM approach one wants to benefit from coordinating the risk management decisions. Two things are therefore needed. First, one has to discover the actual value of γ. Second, the agents need to be told which strategy they should implement. One could imagine several ways managing this; however, all of them have at least one thing in common: there must be some centralized information collection. We adopt therefore the installation of a Chief Risk Officer (CRO). He receives reports from the risk department managers concerning their possible strategies and explores the actual occurrence

[9] Microsoft for example holds massive amounts of cash to react to market circumstances, hedging additionally most risks individually might be rather value destroying. Other firms face for example different financing needs depending on market developments. If all goes well they might receive high revenues and it may be worthwhile to invest, if not financing opportunities are worse but so are investment opportunities. Hedging against market development can then actually be value destroying.

of γ. By providing effort e_q he learns the true value of γ with probability q.

There are two situations ($\overline{\theta}\underline{\theta}$,$\gamma^+$ and $\overline{\theta\theta};\gamma^-$) where one could benefit from coordination. The coordination effect of ERM shows up in the discrimination due to γ when the CRO is successful in identifying γ. If he fails to reveal information (with probability $(1-q)$) about γ, the same problems as with silo remain. Our understanding of the ERM process adheres the following sequential timing. First, senior management decides about the employment of the department risk specialists and the CRO. ERM 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 obtain the actual value of γ or not and tells the agents which strategy they should implement.

Proposition 1 *ERM weakly dominates the silo approach if the value of ERM can be stated as the value of the silo approach plus a costless option to coordinate*

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

Proof. see the appendix. ■

We sketch the intuition behind this result in the following. Taking a closer look at the CRO's decision problem we recognize that there are three different situations possible: neither, 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 does not provide effort. If one agent 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 the case of success. So, with probability q one is able to discriminate due to γ, but with $(1-q)$ one realizes the same

output as without investigation, $E[\gamma]\,\overline{\theta}\underline{\theta}$. Therefore, the CRO searches only if (3) is fulfilled.

$$\begin{aligned} q(\alpha\gamma^{+}\underline{\theta\theta} + (1-\alpha)\gamma^{-}\overline{\theta}\underline{\theta}) + (1-q)E[\gamma]\,\overline{\theta}\underline{\theta} - e_q > E[\gamma]\,\overline{\theta}\underline{\theta} \\ \Leftrightarrow q\alpha\gamma^{+}(\underline{\theta\theta} - \overline{\theta}\underline{\theta}) > e_q \end{aligned} \tag{3}$$

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 γ^{-} are not fully offset by the costs of effort. Analogous to the previous situation this is only guaranteed by (4).

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

Note that the left side of (3) and (4) 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 with γ. In addition, one only <u>wants</u> to implement coordination if the expected benefits exceed the required costs (e_q). Summarizing, there are two positive effects arising from ERM (see (2). First, one does not realize $\overline{\theta\theta}$ with γ^{-} but rather $\overline{\theta}\underline{\theta}$, which leads to a positive overall output. And second, one implements $\underline{\theta\theta}$ instead of $\overline{\theta}\underline{\theta}$ with γ^{+}, also leading to a positive output. Coordination is more valuable the higher the unrealized negative impact would be and the greater the implemented output is. This leads to the intuitive result that coordination is more valuable when the difference between the possible realizations ($\overline{\theta}$ and $\underline{\theta}$) is greater.

Comparing (5) and (2) one can clearly see the relation $V(\pi, e)^{ERM} \geq V(\pi, e)^{silo}$. This means that the ERM approach weakly dominates the silo approach. One can envision the ERM 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 γ if it is beneficial (i.e. the expected reduction in the

BC is higher than the increment effort costs), we get the stated dominance of the ERM approach.

4 Coordination as a costly option

Up to this point we have assumed that the principal can observe the effort provided by the agents. In addition, problems of not reporting truthfully did not exist. In this section we expand our analysis and show how communication and contractual costs might alter our previous results. We assume that the agents' effort is unobservable.

4.1 Fixed option premium

As has been pointed out before, the statement that ERM weakly dominates silo (Proposition 1) only holds if there is no fixed cost of coordination. Recall that with (2) the CRO only invests effort to coordinate if this is (in expectation) beneficial. While it may seem artificial that there are no fixed costs involved, one may consider the following quote from the IBMs Global CFO Study in 2008 of IBM:

> CFOs are uniquely positioned to determine and guide the overall enterprise risk profile. In publicly traded companies, they are the only C-suite members called upon quarterly to provide an aggregate picture of the enterprise.

One may well imagine that the CFO and not a, with the introduction of ERM, newly appointed CRO may take the central decision takers position in the ERM system. This goes well along with the situation envisioned with Proposition 1: coordination efforts are only conditionally undertaken. In addition, one can imagine that a CFO may be in a better position judging the overall situation of a firm (as indicated by γ) compared to a risk specialist like the CRO. On the other hand, he will surely be less able to judge the situation with the risk management sphere and in contrast to an independent CRO

occupied with other business of the firm and possibly biassed.[10] The overall effect, of appointing a CRO or having the CFO to coordinate, on γ is rather ambiguous and depends on the characteristics like size, nature of business etc. However, it seems clearly more likely to interpret the option to coordinate as costless if the is no independent CRO but the decisions are taken by already existent institutions, for example the CFO.

While it might be intuitively convincing to have like a fixed (wage) cost with the appointment of a CRO we can also derive this endogenously. Imagine that the CRO is an agent that needs to be given incentives to make the right effort decision, conditional on the reports of the department mangers. Because one can not write contracts on these reports (see also the discussion below) we need to contract on π. This is the only variable that the CRO can influence and that is unambiguously linked with the value of the risk management system. Additionally, one may not perfectly infer from the realized output which decision has been made. This may stem for example 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 π is positive or negative. An equivalent way to model the resulting situation is to allow a positive chance to identify γ without effort provision of the CRO. One then would also not be able to infer from the resulting output on the CRO's decision.

We show in the appendix that the CRO is able to generate a positive wage in every state and consequently receives some fixed amount of remuneration if we can only contract on π Therefore ERM becomes a costly option and does not dominate the silo approach any more.

4.2 Agency costs of risk management

A department risk manager might prefer to minimize the exposure of his own department. We assume that he receives a private benefit (B) when $\overline{\theta}$

[10] For example, the Global Association of Risk Professionals (GARP) argues is this spirit: "Vital to ensuring the CRO's inclusion at the governance level is... [that she] stays on point with the risk function, meaning she does not get bogged down in other board business!" (The CRO of tomorrow, 2009)

is carried out. For (at least) the following reasons this seems natural to us. First, the manager cares about his future. As head of a department that may often have to realize $\underline{\theta}$ due to firm wide considerations, he bears the risk of being branded as "low type" on the (internal and external) job market because of imperfect information. If it is not perfectly transparent that he only obeyed orders, his career may be negatively affected by the judgement of "outsiders" (relating at least partly on his departmental performance), defined as not being actively involved in the structure of the RM-system of the particular firm. Tufano (1998) 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 does not need to answer questions about the poor performance of his department. Second, one can imagine that working on one's own project is somewhat more satisfying than collecting information and not being able to implement or use it. Working on one's own ideas as a private benefit is quite a recognized effect in the literature.[11] In addition, one can imagine that it is more likely that a manager prefers pursuing "pet projects" to not implementing any project.

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

We assume that the principal is able to verify the output of every risk department ex post, but not ex ante, if the information reported by the agent is true or not (soft information). Let us 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 has 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 fulfill all of the stated requirements one has to pay wages conditional on $R_i, \hat{\theta}_i$

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

and the realized department output θ_i, i.e. $w_i = w_i(R_i, \hat{\theta}_i, \theta_i) = w(R, \hat{\theta}, \theta)$.

Proposition 2 *(i)The optimal incentive contract for a risk manager with the ERM approach is:*

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

(ii) The overall (expected) wage-costs for the risk department managers with ERM is: $E[w]^{ERM} = 2(e - pB + (1+p)\beta B)$

Proof. see the appendix. ■

We sketch the setup of the proof in the following. The optimal wage contract for every agent has to meet all of the following constraints:

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

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

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

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

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

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

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

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

Effort provision. Every agent should exert effort e. Therefore an agents needs to be given incentives to do so, i.e. (PC) and (IC) need to be met, with β 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 included in the wage contract. But because high output

($\overline{\theta}$) is only achievable 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 has learned something. It must always be optimal for the agent to report truthfully. We capture this with the constraints (TT1) and (TT2). *Implementing.* Lastly, the agent needs to obey the principal's decision and implement the strategy /he is given. The last three of the above constraints provide the agent with the incentive to do so. We label them "implementing incentive constraints" (IIC).

One should recognize the crucial role of β 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 receive full compensation with $\beta = 1$ for their effort and an additional (fixed) payment amounting to the private benefit B. However, the expected wage costs of ERM are the same with $\beta = 0$ as with silo (see also the appendix). This is due to the fact that a department manager is not able to extract any extra payment when reporting L but not having learned anything, because he will surely be told to implement $\overline{\theta}$ if possible. Consequently he realizes the private benefit B whenever possible.

4.3 Communication and transferability of information

There have been no communication problems, in the sense that the agent were not able to report or receive the reports unbiased. The CRO received the reports of the agents without any loss of information. However, distortions in communication might, for example, occur due to for example the nature of information. While some risks may be easy to report (like the estimated probability of a fire and the potential damage) in formation on others may be "soft information", that is hard to document and can not be easily transferred. One might for example think of experienced characteristics of a borrower that may not show up in the "hard facts". Additionally, reports may, due to the ability of the CRO to evaluate what is possibly very different and specialized information, impose limits and leave discretion in interpreting and understanding them. Therefore, information send and information

received may differ. It may happen, that the CRO does not grasp the whole report and reads NL instead of Lor that the CRO interprets a report too broad and reads L instead of NL.

Taking a closer look at the situation that the CRO does read NL instead of L (refer to mNL) we can identify three possible situations. $\{NL; mNL\}$, $\{mNL; mNL\}$. and $\{L; mNL\}$. With all of them, there is now a trade-off between ERM and silo even without any fixed cost of coordination or opportunistic risk managers. The optimal organizational structure depends on α, i.e. the distribution of γ and the probability that the CRO does read mNL, ERM is no longer (weakly) dominant. With a high enough chance that CRO does read L instead of NL (refer to mL) and in the case of $\{L; mL\}$, silo is even superior to ERM. This is the case because the "coordinator" may call the wrong department, namely the one that actually isn't able to do so to implement the high output. ERM and silo are equivalent in the other two cases ($\{NL; mL\}$and$\{mL; mL\}$).

Overall, ERM does not dominate silo with the existence of communication obstacles and may even be the source of an inferior risk management output.

5 Summary and outlook

In this paper we investigate different approaches to organizing corporate risk management. By basically abstracting from informational and contractual problems we are able to show that the proposed superiority of the ERM approach holds. This stems from the fact that centralized information processing only takes place when it is 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 ERM and possibly outweigh the benefits of coordination. 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 might also value not being constantly questioned and forced to implement or to omit projects he investigated.

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 separation of decision and processing duties implicitly proposed by ERM is only optimal if information can be transferred without (significant) frictions. This might be due to higher incentive payments. However, the main results are also achieved 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. that is hard to document, operational risk) or due to the ability of the CRO to evaluate what is possibly very different and specialized information.

We feel that quite some questions concerning the corporate governance of risk management may be investigated within our setup. One may, for example look at asymmetric departments (different values of p and θ), the effect of volatility in outputs, different organizational regimes (for example only one agent) or the effect of catastrophic risk (expected values vs. extreme cases). Additionally, our setup can be easily adopted to possible extensions. This includes, that the investigation of γ depends on available reports, collusion among risk managers and with the CRO and a deeper hierarchy with for example business unit/projects – risk department – CRO. Also, the relation to empirical would be very interesting and may answer questions like: How do firms deal with the obstacles of ERM in practice? What are the characteristics of firms that actually employ an ERM approach and do they match with the predictions of our analysis?

6 Appendix

No explicit RM-system (no-info) We first take a look at the risk output when neither specialists nor a CRO have been appointed. This does not mean that there is no risk consideration at all but that risk management has no explicit organizational 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 $\underline{\theta\theta} > 0$, we need γ to be positive in expectation ($E[\gamma] > 0$) of a positive output. Putting it differently, there is a lower bound for α to produce a positive expected output and consequently relatively low bankruptcy costs.

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.

The Silo-RMS (silo) This traditional approach to managing corporate risks is 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 two agents will be employed, each in charge of one risk which they manage independently. There is no 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 that is 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 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.

$$V(\pi,e)^{silo} = E[\gamma]\overbrace{(p^2\overline{\theta\theta}+2p(1-p)\overline{\theta}\underline{\theta}+(1-p)^2\underline{\theta\theta})}^{\equiv E[\theta\theta]^{silo}} - 2e \tag{5}$$

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 as $V(\pi,e)^{silo}$ is always smaller than $E[\pi]^{ni}$. For $E[\theta\theta]^{silo} > \underline{\theta\theta}$ 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 $\widehat{p}$.

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

Obviously we need a lower $\widehat{p}$ 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 does not make sense to invest effort; this proves with the requirement of $\widehat{p} > 1$ which is impossible to meet. We therefore can relax the requirement about p by assuming that $\overline{\theta} > \underline{\theta}$.

We assume $p > \widehat{p}$ and $\overline{\theta} > \mid \underline{\theta} \mid$.

The silo approach is only optimal compared with no-info if and only if (6) is fulfilled

$$\begin{gathered} E[\gamma]\,E[\theta\theta]^{silo} - 2e > E[\gamma]\,\underline{\theta\theta} \\ \iff E[\theta\theta]^{silo} - \underline{\theta\theta} > \frac{2e}{E[\gamma]} \end{gathered} \tag{6}$$

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

With silo, three combinations of department outputs are possible, i.e. $\theta_i\theta_i \in \left\{\overline{\theta\theta}, \overline{\theta}\underline{\theta}, \underline{\theta\theta}\right\}$ .There is no coordination problem when neither agent learns anything ($\underline{\theta\theta}$). With γ^+ the output is optimal and there is no possibility of meeting γ^- 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 γ^-. With γ^+ it would be value enhancing if both managers realize the low output. Implementing $\overline{\theta}$ in both departments is in contrast only optimal with γ^+. So, under the silo-max rule the problem is that with two constellations ($\overline{\theta}\underline{\theta}$,$\gamma^+$ and $\overline{\theta\theta};\gamma^-$) it would be the possible to realize a better output ($\underline{\theta\theta}, \overline{\theta}\underline{\theta}$ respectively) but one is not able to differentiate with this approach with respect to γ. This leads us to the ERM approach, discussed in the next section.

Consider ΔERM as the additional effect of ERM compared with silo on the risk management system (see (2)). ERM dominates no-info if and only if:

$$E\left[\theta\theta\right]^{silo} - \underline{\theta\theta} > \frac{2e - \Delta ERM}{E\left[\gamma\right]} \tag{7}$$

(7) stems hereby from the following considerations:

$$\begin{aligned}
&+\alpha\gamma^+(2p(1-p)q\cdot(\underline{\theta\theta}-\overline{\theta}\underline{\theta})+p^2q(1-\alpha)\gamma^-\cdot(\overline{\theta}\underline{\theta}-\overline{\theta\theta})-(1-p)^2\cdot e_q \\
&>\alpha\gamma^+\cdot\underline{\theta\theta}+(1-\alpha)\gamma^-\cdot\underline{\theta\theta} \\
&\Leftrightarrow (E\left[\theta\theta\right]^{silo}-\underline{\theta\theta})(\alpha(\gamma^+-\gamma^-)+\gamma^-)>2e+(1-p)^2\cdot e_q \\
&-\alpha\gamma^+(2p(1-p)q_1\cdot(\underline{\theta\theta}-\overline{\theta}\underline{\theta})-p^2q(1-\alpha)\gamma^-\cdot(\overline{\theta}\underline{\theta}-\overline{\theta\theta}) \\
&\Leftrightarrow (E\left[\theta\theta\right]^{silo}-\underline{\theta\theta}) \\
&>\frac{2e+\overbrace{(1-p)^2\cdot e_q-\alpha\gamma^+(2p(1-p)q\cdot(\underline{\theta\theta}-\overline{\theta}\underline{\theta})-p^2q(1-\alpha)\gamma^-\cdot(\overline{\theta}\underline{\theta}-\overline{\theta\theta})}^{\equiv\Delta ERM}}{(\alpha(\gamma^+-\gamma^-)+\gamma^-)} \\
&\rightarrow (E\left[\theta\theta\right]^{silo}-\underline{\theta\theta})>\frac{2e-\Delta ERM}{E\left[\gamma\right]}
\end{aligned}$$

CRO as agent Wage scheme for the CRO with the assumption that one is only able to verify if the actual output is below or above some threshold, to be more precise if π is positive or negative

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

The participation and the incentive constraint are given by (8) respectively (IC), whereas λ names the probability of receiving $\pi > 0$.

$$\lambda \cdot w^+ + (1-\lambda) \cdot w^- \geq e_q \tag{8}$$

It is optimal, as usual with limited liability, to set $w^- = 0$. As a result, the CRO is willing to participate if the expected wage (λw^+) 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 the incentive constraint in the following section.

From the text 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 departmental output, $\overline{\theta}$. If he receives no positive output, he has no decisional discretion, as both agents realize $\underline{\theta}$ anyway. With at least one possibility of implementing $\overline{\theta}$ the CRO faces the decision problems shown in (3) and (4).

Having received one positive report the CRO should make his effort decision according to (3): $q \cdot \alpha\gamma^+(\underline{\theta\theta} - \overline{\theta}\underline{\theta}) > e_q$. But the CRO is only interested in a positive wage and therefore in whether the output (π) is positive or not. If he provides effort, this will certainly be the case with probability q. Not being successful in identifying the true value of γ 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 γ is positive or negative) is therefore α or 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 ((4): $q \cdot (1-\alpha)\gamma^{-}(\overline{\theta}\underline{\theta} - \overline{\theta\theta}) > e_q$), what the CRO takes into consideration remains 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 π is positive or negative and not it is actual amount. Therefore both alternatives $(\overline{\theta\theta}, \underline{\theta\theta})$ producing a positive output when $\gamma = \gamma^{+}$ (again, this is the case with probability α) are virtually equivalent to him.

Proof. of Proposition 1. We firstly work out the expected output with the ERM approach

$$
\begin{aligned}
V(\pi, e)^{ERM} = \alpha\gamma^{+} & \overbrace{\left(\begin{array}{c} p^2 q\overline{\theta\theta} + p^2(1-q)\,\overline{\theta\theta} + 2p(1-p)\underline{\theta\theta}q \\ +2p(1-p)(1-q)\overline{\theta}\underline{\theta} + (1-p)^2\underline{\theta\theta} \end{array} \right)}^{=E[\theta\theta]^{silo}} \\
& + (1-\alpha)\gamma^{-} \cdot \underbrace{\left(\begin{array}{c} p^2 q\overline{\theta}\underline{\theta} + p^2(1-q)\,\overline{\theta\theta} \\ +2p(1-p)q\overline{\theta}\underline{\theta} + 2p(1-p)(1-q)\overline{\theta}\underline{\theta} + (1-p)^2\underline{\theta\theta} \end{array} \right)}_{>E[\theta\theta]^{silo}} \\
& -2e - (1-(1-p)^2 e_q
\end{aligned}
\tag{9}
$$

Taking the silo output as reference point and rearranging equation (9) leads

to:.

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

Considering the "option-character" of ERM provided by (3) and (4) yields:

$$
\begin{aligned}
V(\pi,e)^{IRM} \;=\; & E\left[\gamma\right]\cdot E\left[\theta\theta\right]^{silo} - 2e \\
& + 2p(1-p)\max\left\{0; q\alpha\gamma^{+}(\underline{\theta\theta} - \overline{\theta}\underline{\theta}) - e_q\right\} \qquad (10) \\
& + p^2\max\left\{0; q(1-\alpha)\gamma^{-}(\overline{\theta}\underline{\theta} - \overline{\theta\theta}) - e_q\right\}
\end{aligned}
$$

■

Proof. of Proposition 2.

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 has chosen his effort provision. Due to limited liability one can not punish an agent more severely than with "no-wage". So, a contract can be written conditional on (the sign of) θ_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 severely 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.

$$p \cdot (w_1 + B) - e \geq 0 \rightarrow w_1 = \frac{e}{p} - B$$
$$\rightarrow E\left[w\right]^{silo} = 2(pw_1 + (1-p)w_2) = 2(e - pB) \tag{11}$$

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

ERM approach. We solve the problem by firstly checking which of the truthtelling and implementing constraints are binding. We also set $w(R, \hat{\theta}, \theta) = 0$ for $\hat{\theta} \neq \theta$. Afterwards we use our findings to solve the (IC) and obtain the optimal wage structure. It is instructive 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 $\overline{\theta}$ after after it has been reported that this is not 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 does not outweigh the expected cost of effort this is also not a binding constraint. If the agent learns 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 agent 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 is no problem with truthful reporting if the agent has been successful and has $\overline{\theta}$ identified. Obviously he is better off reporting the truth since he is able to generate $w(NL, \underline{\theta}, \underline{\theta})$ and implementing $\overline{\theta}$ does not raise his expected wage (see TT1). The second truthtelling constraint is binding. With $w(L, \underline{\theta}, \underline{\theta}) = B$ (needed for implementation) we ensure that the agent has no incentives to report L if he hasn't found something. Therefore, the expected wage from truthtelling must be at least $\beta w(L, \underline{\theta}, \underline{\theta})$, which equals the expected payoff from pretending to have learned something. Note, that with probability $(1 - \beta)$ a manager gets no payment since /he is not able to im-

plement $\overline{\theta}$.

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

$$\begin{aligned} p\left[(1-\beta)(w(L,\overline{\theta},\overline{\theta})+B)+\beta B-\beta B\right]-e &\geq 0 \\ \rightarrow w(L,\overline{\theta},\overline{\theta}) &= \frac{e}{p(1-\beta)}-B \end{aligned} \tag{12}$$

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

$$\begin{aligned} E[w]^{ERM} &= 2\left[p\left[(1-\beta)w(L,\overline{\theta},\overline{\theta})+\beta w(L,\underline{\theta},\underline{\theta})\right]+(1-p)w(NL,\underline{\theta},\underline{\theta})\right] \\ &= 2\left[p\left[(1-\beta)\left(\frac{e}{p(1-\beta)}-B\right)+\beta B\right]+(1-p)\beta B\right] \\ &= 2(e-pB+(1+p)\beta B) \end{aligned} \tag{13}$$

Comparing (11) with (13) we see that the department managers' wage costs under ERM are strictly greater than with the silo approach: $E[w]^{ERM} > E[w]^{silo}$. One should recognize the crucial role of β 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 receive full compensation with $\beta = 1$ for their effort and an additional (fixed) payment amounting to the private benefit B. However, the expected wage costs of ERM are the same with $\beta = 0$ as with silo. This is due to the fact that a department manager is not able to extract any extra payment when reporting L but not having learned anything, because he will surely be told to implement $\overline{\theta}$ if possible. Consequently he realizes the private benefit B whenever possible. ■

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