Essays on Strategic Interactions, Corporate Structures and Behavioral Accounting

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To my husband Alex.

Abstract

Enhancing the firm value is one of the main goals of business strategies. These strategies often include strategic modifications of corporate structures by using the latest findings both from practice and science. Apart from mergers and acquisitions (M&As) as the obvious corporate restructuring, trends regarding changes in the corporate structures evolve every now and then. However, even if these trends are popular, they are not necessarily well fitting for each firm. To use the full potential of these corporate restructurings, the employees' incentives and strategic decision bases have to be considered in an appropriate manner. This cumulative work focuses on strategic interactions and the choice of a value-enhancing change of the corporate structure dependent on different underlying conditions. It is examined under which conditions the trends regarding changes of corporate structures are as beneficial as they are claimed to be. In two of the three papers, non-monetary utility aspects or other issues from behavioral accounting are part of the analysis.

In particular, the papers analyze

- whether and if so, under which conditions a self-organized team formation as a part of the 'New Work Style' is beneficial for firms under consideration of psychological proximity among employees. Teams can be formed either by the employer or by the employees, the latter one is representing self-organized team formation. If psychological proximity is considered, it can shape the teams' performances and hence, the team formation decision.

- whether the trend of implementing a Center of Excellence (CoE) is as beneficial as it is claimed to be, in particular with regard to expected profits, effort and compliance issues. A CoE is a centralized business unit which adopts and pools processes that are needed by more than one division.

- whether a retention bonus can mitigate the negative effect of a merger announcement on the voluntary turnover rate and thus, the firm value. As the employees' turnover decisions are mainly shaped by their expectations to be retained in the merged firm, the impact of one decision-maker who is biased towards retaining the own employees on their voluntary turnover rate and its interaction with a retention bonus is the main part of the analysis.

Keywords

- Agency-Theory, Team formation, Matching, New work, Social distance, Proximity, Compliance, Centralization, Decentralization, Moral hazard, Earnings manipulation, Consulting, Mergers, Brain Drain, Voluntary Turnover, Biased decision-making, Retention Bonus

Contents

Introduction **1-5**

Essay I **I 1-54**
Self-organized Team Formation with Psychological Proximity among Agents

Essay II **II 1-52**
Center of Excellence: Accounting Trade-offs of Partial Centralization

Essay III **III 1-58**
Brain Drain in Mergers: The Impact of Retention Bonuses and Behavioral Biases on Voluntary Turnover Rates

Introduction

Strategic decision-making and interactions are important aspects of enhancing the firm value. One important subject that is affected elementarily by strategic decisions is the corporate structure as a part of the business strategies. Science and practice work constantly on new opportunities to improve the corporate structure to enhance the firm value. Some of these opportunities are discussed more frequently than others and can evolve into a trend. A classical topic in the corporate structure strategies considers the degree of decentralization or the amount of subsidiaries. A reason for changes in this area are e.g. tightened compliance regulations. They increase the pressure on firm owners to maximize the information precision, e.g. through a partly centralized firm structure and thereby, increased control. However, the corporate structure also includes the intra-organizational structure, e.g. regarding the amount of hierarchy levels as well as the degree of democratization in work processes. The so called "New Work Style" includes approaches to adjust the firm structure, work processes or the firm's principles. Very popular components are the reduction of hierarchy levels and thereby, a higher embedding of the employees in the work and decision processes through e.g. more self-organization. The most obvious change in a corporate structure is a merger or an acquisition (M&A). M&As are well-known for failing or at least not being as value-creating as expected. Thus, the processes before, within and after M&As have to be examined in more detail to make correct decisions from the very beginning.
This cumulative work analyzes selected issues regarding the strategic optimality of changes in the corporate structure. One key aspect that has to be taken into account with regard to the strategically optimal decision-making, is the information asymmetry between the decision-maker or rather employer and the employees. In order to optimize the firm value through the strategically optimal corporate structure decision, the employees' incentives and motives have to be considered as the decision-maker usually delegates the tasks to the employees. Besides monetary incentives, some decisions of the employees may be influenced by non-monetary incentives or even behavioral biases. This behavioral accounting literature received much more attention during the last years and is also an important aspect in two essays in this thesis. In sum, strategic interactions and corporate structure decisions with behavioral accounting impact are in the focus of this work's interest.

In detail, this cumulative work analytically examines three options to change the corporate structure under consideration of different incentives and motives or even behavioral aspects of the employees. First, this work considers more democratization of work processes in a setting in which teams can be formed either by the employer or by the employees themselves. The employees' utility and thereby effort and team formation decisions can be influenced by both, a monetary utility and a non-monetary utility through a compensation payment and psychological proximity between the employees. Afterwards, this work compares the approach of a fully decentralized firm structure with a partly centralized firm structure in the environment of incentives for earnings management and thus, the risk for compliance infringements. Last, the consequences of a merger announcement on the firm value through the employees' voluntary turnover rate are analyzed. Here, the employees' expected utility and thus, staying decision can be influenced by a retention bonus and a biased staffing decision-maker. The following gives a comprehensive overview of the motivation and the results of the essays.

Essay I:

To enhance the firm value, one important issue to consider is team performance. As a team consists of at least two employees, the teammates' social interactions and relationships can have an impact on their performance. Several studies show that e.g. team member proximity affects team performance.[1] Due to improved information and communication technologies, the consideration of psychological proximity between teammates based on their social distance is more relevant than physical proximity to improve our understanding of team performance. The challenge is to find a mean to make use of potential psychological proximity benefits in order to maximize the team performance if individual social distances are not observable for the employer but have an impact on the employees' effort decisions. This paper examines the trend of self-organized team formation as a 'New Work Style' method in order to analyze whether it is the right mean to benefit from the employees' private information about their proximity factors. The 'New Work Style' is actually a trend in improving corporate structures and work processes by implementing more democratization, e.g. through more self-organization. This paper focuses on self-organization by leaving the team formation decision to the employees. The intention is that they can use potential information advantages regarding their psychological proximity towards each other in order to increase the team performance if they have to form the teams on their own.

This paper examines analytically under which conditions a self-organized team

[1] See Cha, M., Park, J.-G., Lee, J., 2014. Effects of team member psychological proximity on teamwork performance. Team Performance Management: An International Journal 20 (1/2), 81-96.

formation is beneficial for firms if psychological proximity among employees is considered by using a one-period principal-agent model. Therefore, we develop a process of endogenous team formation by the employees and compare the expected profits and team constellations with an exogenous team formation by the employer. The results show that self-organized team formation is strictly preferable over exogenous team formation from the firm's view if and only if the employees' proximity priorities are sufficiently high. With the employees' proximity priorities being sufficiently high, heterogeneous teams in terms of ability receive a positive ex ante probability of occurrence which is impossible under the other examined scenarios and especially without proximity consideration. While the employer only has expectations about the teammates' proximity factors and thus, would always form teams based on the employees' abilities, the employees can decide based on the observed proximity factors which results in different team constellations and hence, expected profits. Overall, the trend of self-organization through self-organized team formation as a part of organizational changes can in fact enhance the firm's profit but only if the employees priorities for interpersonal relations, here proximity, have a sufficiently high impact on the employees' utilities.

Essay 2:

Decentralization is seen as a firm structure that is very often beneficial and can make use of information advantages in order to increase the firm value. A new trend that combines decentralization with centralization is the implementation of a Center of Excellence (CoE) as a special form of a Shared Service Center which is a centralized business unit that pools processes that are needed by more than one division.[2] The main purpose for implementing such a CoE is the increased pressure regarding compliance regulations. A CoE should increase control and thereby, decrease compliance infringements through enhanced centralization. The question is whether a CoE is the right mean to improve compliance and under which conditions a CoE can also be a useful approach to enhance the firm value.

This paper compares a fully decentralized firm structure with a partially centralized firm structure with a CoE in a one-period principal-agent setting. With a CoE, the CoE adopts the service process and consulting activity that are usually exerted by the division and an externally hired consultant. The aim is to analyze the conditions for a CoE being beneficial regarding expected profits, efforts, earnings

[2] See KPMG, 2013. Shared Services für Controlling-Prozesse: Ergebnis einer empirischen Erhebung zu Status quo und Perspektiven. See the References of Essay II for the URL.

manipulation (compliance infringements), and added values through consulting. We show that it is not always beneficial to implement a CoE. It critically depends on the firm's objectives and human resources: If a firm wants to improve its compliance performance and highly fears reputational damages, a CoE is the right mean to lower the troublesome earnings manipulation. However, a CoE reduces the effort for the main (still decentralized) process. In addition, the advantageousness of a CoE regarding the service process effort as well as the expected profits depend on certain conditions: A CoE is only beneficial regarding the expected profits if the CoE's ability exceeds a critical value which can be lower than the division manager's expected ability. Considering the named trade-off of the paper, more centralization is beneficial since it results in less manipulated reports and thereby more precise accounting information. On the contrary, decentralization results in better effort incentives for the main process.

Essay 3:

The classical change of an existing corporate structure is a merger or an acquisition (M&A). The main issue of M&As is that they often turn out to be less efficient than expected before and sometimes even fail.[3] One frequently observed phenomenon regarding M&As is that already a forthcoming merger increases the employees' voluntary turnover rates.[4] This is an issue as the expected firm value of the merged firm crucially depends on the business continuity which in turn depends on the firm specific knowledge of the experienced and talented employees. The employees' staying decision mainly depends on their expectations whether they are going to be retained in the merged firm. As they know that there is a position scarcity, they are uncertain about their job future. Their expectations are also shaped by their employer's staffing preferences. A common phenomenon is that people tend to favour the people they know, hence, decision-makers can tend to favour the employees they know and are biased towards their true productivity.[5] These differing expectations can also influence the employees' staying decisions. Additionally, the staying decision can potentially be influenced by monetary incentives, as e.g. by the trend of paying a one-time retention bonus directly after the merger announcement.

[3] See Tetenbaum, T. J., 1999. Beating the odds of merger & acquisition failure: Seven key practices that improve the chance for expected integration and synergies. Organizational Dynamics 28 (2), 22-36.

[4] See Light, D. A., 2001. Who goes, who stays? Harvard Business Review 79 (1), 35-41 and Walsh, J. P., 1988. Top management turnover following mergers and acquisitions. Strategic Management Journal 9 (2), 173-183.

[5] See Kidd in Light, D. A., 2001. Who goes, who stays? Harvard Business Review 79 (1), 35-41.

In order to examine which factors mainly influence the employees' turnover rate, the third essay analyzes analytically whether a so called retention bonus is suitable in order to decrease the voluntary turnover rate after a merger announcement in a one-period model. In addition, we analyze the impact of a staffing decision-maker that is positively biased towards his own employees on the voluntary turnover rates. The results show that implementing a retention bonus successfully decreases the voluntary turnover rate and generates higher benefits from merging, with and without a biased decision-maker. Concerning the behavioral aspect of this essay, a positively biased decision-maker usually enhances her employees' ex ante probability to be retained and thereby, decreases their voluntary turnover rate. The opposite results for the employees that stem from the other merging firm with a rational decision-maker. However, considered together, the bias and the retention bonus interact and switch the effects of the bias on the voluntary turnover rates, i.e. the turnover rate of the biased decision-maker's employees exceeds the one of the rational decision-maker's employees. This effect can mainly be explained by the biased decision-maker's decision to pay a relatively low retention bonus.

In sum, the essays provide the following results:

1. Self-organized team formation is the right mean to make use of the employees' information advantages regarding their proximity towards their teammates, as long as they announce their preferred teammate based on the proximity factors due to sufficiently high proximity priorities. Otherwise, the employer should decide to form the teams herself.

2. A CoE is not unambiguously beneficial: On the one hand, a CoE successfully improves the compliance performance through less earnings manipulation but on the other hand, the main process effort is reduced. The service process effort and the expected profit are not unambiguously higher than in a fully decentralized firm structure. In sum, the implementation of a CoE is predominately recommended for firms with a low ability variance among their employees and a high penalty on detected earnings manipulation.

3. A retention bonus is always a recommendable mean to enhance the expected firm value of a merged firm by reducing the voluntary turnover rates, independent of whether a biased decision-maker is considered. Although the biased decision-maker's employees have a higher ex ante probability to be retained, their retention bonus is lower and their voluntary turnover rate is higher than the one of the rational decision-maker's employees if a retention bonus is paid.

Essay I

Self-organized Team Formation with Psychological Proximity among Agents*

Abstract

Several studies show that team member proximity affects team performance. We concentrate on psychological proximity as improved Information and Communication Technology (ICT) possibilities make physical proximity negligible. In order to determine how to make use of possible psychological proximity benefits, we examine self-organized team formation as one strategy to use the employees' private information about their proximity. We aim at analyzing analytically whether and if so, under which conditions a self-organized team formation is beneficial for the firms in the presence of proximity among employees. We show that without taking proximity into account, self-organized team formation does not add any value and the employer decides to form homogeneous teams by herself. In contrast, if the proximity priorities are sufficiently high, self-organized team formation is strictly preferable from the firm's view and heterogeneous teams can occur.

* This chapter is joint work with Carsten Sören Ruhnke (Leibniz Universität Hannover).

1 Introduction

Several studies show that team member proximity positively affects team performance. The study by Cha et al. (2014) shows that the relationship between team member distance and team performance can be seen as a crucial factor for firms' team project results and that psychological team member proximity improves team performance. Hoegl et al. (2007) underline that team member proximity is an important factor for team performance. These results propose that it could be beneficial to consider teammates' proximity in order to improve team performance. We differentiate between two forms of proximity: physical and psychological proximity. For a long time, research only focused on physical distance and found that increasing proximity enhances the communication frequency and quality which leads to higher team performance. More recent studies do not find a significant effect: Besides the fact that psychological proximity has not been taken into account that far, the improved Information and Communication Technologies (ICT) are claimed to make an analysis of physical proximity obsolete (Wilson et al., 2008; Chong et al., 2012). Thus, we focus on psychological proximity in the following. Psychological proximity contains at least three dimensions, the spatial, temporal and social distance (Cha et al., 2014). In contrast to the physical distance, these dimensions base on the individual's perceptions rather than on facts like the measurable distance between two agents.[1] Cha et al. (2014) found that social distance has the most significant impact on team performance among these three dimensions. Thus, we consider psychological proximity as a function of the team members' social distance and disregard the spatial and temporal distance dimension. Several researchers already focused on social distance and its determination. We consider social distance as the perceived closeness that an individual feels towards another individual, e.g. due to interpersonal (dis-)similarities in attributes and personal characteristics (Heider, 1958; Miller et al., 1998; Tesser, 1988; Liviatan et al., 2008; Boguñá et al., 2004).[2] The literature shows that similar others are perceived as socially closer to oneself than dissimilar ones (Heider, 1958; Miller et al.,

[1] According to Cha et al. (2014), the spatial distance is the perceived areal distance between the individuals; the temporal distance is the time difference between an event and the individual. Social distance measures the perceptions of the relationship's importance (Stephan et al., 2010; Lim et al., 2012). For more details, see e.g. Cha et al. (2014), Lim et al. (2012), Liberman et al. (2007) and Stephan et al. (2010).

[2] There exist other forms of proximity that are discussed in the literature. One form that is analyzed by several authors is the cognitive proximity due to (dis-)similarities in the professional knowledge base (Heringa et al., 2014). Note that this form of proximity is clearly different from what we focus on in the following. By using the term "proximity" in the rest of the paper, we refer to psychological proximity.

1998; Tesser, 1988).[3] The social distance perception can arise from the cooperation in previous projects or from a first impression if the employees have not met before. In line with the previous explanations, a low (high) social distance comes along with a high (low) psychological proximity.

The consideration of psychological proximity between teammates is indispensable to improve our understanding of team performance, as has been shown in the previous paragraph. The question is how to make use of possible psychological proximity benefits in order to maximize the team performance and hence, the firm's expected profit, if individual social distances are not observable but have an impact on the employees' effort decisions. In our paper, we aim at examining self-organized team formation as a "New Work Style" method in order to analyze whether it is the right mean to benefit from the employees' private information about their proximities. The term "New Work Style" receives more and more attention both in science and in practice. "New Work" includes various possibilities to restructure a firm, its principles and its work processes. However, its focus is on autonomous team work and the democratization of work processes (Schermuly, 2019; Scholl, 2020). Thus, we concentrate on the "New Work" elements of implementing lower hierarchies and more self-organization of the employees. In our paper, we focus on self-organization by leaving the team formation decision to the employees. This means that the employees' private information about their social distance and thus, psychological proximity can be used in order to improve the team performance by adapting the team compositions. In this self-organized team formation scenario, employees are expected to select the team members from which they expect the highest utility.[4] They try to find a team member with low social distance and high ability (dependent on their utility function) as low (high) social distance facilitates (complicates) communication and thereby, the overall effort (Boschma et al., 2014; Breschi and Lissoni, 2009; Kessler, 2000; Sethi, 2000; Sethi and Nicholson, 2001; Allen, 1970). Compared to this self-organized team formation, an exogenous team formation by the employer happens without detailed information about the employees' proximities. Thus, the employer has to determine the teams by using expectations about these factors. Our goal is to analyze whether and if so, under which conditions a self-organized team formation is beneficial for firms if psychological proximity among employees is considered.

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[3] One literature strand refers to "homophily" as the "attraction between individuals with shared characteristics" (Kim and Aldrich, 2006, p. 85). These similarities can refer to personal characteristics but also to beliefs and attitudes (Hinds et al., 2000).

[4] Experimental studies like e.g. Glaman et al. (2002) already examined a similar setting in which the participants have been asked to describe their preferred coworker in terms of similarity.

As already mentioned, "New Work Style" methods receive more and more attention, e.g. by implementing lower hierarchies and more self-organization of the employees. This is also known as the (social-)structural empowerment-approach. According to Liden and Arad (1996), the approach considers power that has been transferred to formerly powerless participants within the organization. This could mean leaving the team formation decision that the superior previously decided about to the employees. Spreitzer (2008) refers to Liden and Arad (1996) by determining that the main goal of the approach is power allocation to lower hierarchy levels in order to share the decision-making power between different levels.[5] Lower hierarchies usually go hand in hand with more self-organization within the organization and thus, within the considered teams. Schermuly (2019) notes the trend of more democratized work processes and structures within the organization as "New Work" measures used by firms. Especially leaving the team formation process to the employees can be seen as a democratization of organizational structures and work processes. A famous example for a successful implementation of low hierarchical structures is the Dutch nursing firm Buurtzorg. They achieve an enormous success by dissociating from hierarchies. The employees have to self-allocate all tasks and exercises and there is no team leader or superior who benefits with a bonus from the performance of his team (Buurtzorg, 2022).[6] The goal for the employees is to work with more motivation and perform better since they receive more (self-)responsibilities, trust and thereby, job satisfaction.[7] Additionally, they can make use of potential information advantages, as e.g. their social distance preferences regarding their potential teammates are not known to the employer. Thus, the impact of their interpersonal relations on their decisions should be taken into account.[8]

In order to define our understanding of psychological proximity more precisely and to underline why employees can receive a private benefit from high psychological proximity towards their teammate, we extend our previous definition of psychological proximity. Rotemberg (1994) states that people can derive utility from the presence of another person if they like that person's company.[9] This is clearly different from

[5] Spreitzer (2008) uses the social-structural and psychological empowerment. Low hierarchical structures always refer to the structural empowerment-approach.

[6] Other well-known firms that have implemented self-organization are Spotify, Zalando SE, Deutsche Bahn AG and Daimler AG (Schumacher and Wimmer, 2019; Fischer et al., 2019; Bock and Schilling, 2019).

[7] See Frega (2021) for a current overview in organizational research about democratization in the workplace and employee involvement as well as the psychological background.

[8] Mayo (1946) was one of the first authors to highlight the importance of social preferences in the context of economic decision problems.

[9] Rotemberg (1994) does not explicitly name proximity in this context, but he differentiates these words from altruism.

altruism, as altruism means that "one's utility is increasing in the other's utility" (Rotemberg, 1994, p. 700). Sally (2001) varies the model of Rotemberg (1994) by implementing sympathy instead of altruism into game theoretic models. His paper is one of few articles that make psychological distance a subject of discussion in economic modelling and similar to our definition, he considers sympathy as a reciprocal behavior. However, in contrast to the work of Sally (2001), our model aims at viewing proximity as a self-serving social factor without altruistic components. Nevertheless, the modelling of sympathy in the work of Sally (2001) is one of very few ways we know of that can be compared to our way of modelling proximity.

The main finding of our paper is that self-organized team formation is strictly preferable over exogenous team formation from the firm's view if and only if the employees' proximity priorities are sufficiently high. With the employees' proximity priorities being sufficiently high, heterogeneous teams in terms of ability receive a positive ex ante probability of occurrence. This is impossible if the teams are solely formed based on the employees' abilities, in case of exogenous team formation and especially without proximity consideration. We obtain these results by analyzing the effect that proximity among employees has on the way of forming teams and the team performance in a one-period principal-agent model.[10] Therefore, we develop a process of endogenous (self-organized) team formation by the employees if the employer waives her right of forming the teams by herself. The comparison with the scenario of exogenous team formation by the employer enables us to state conditions under which the endogenous team formation might be preferred by firms. The analysis of a benchmark scenario without proximity consideration gives us the chance to clearly identify the effects of proximity. Additionally, we do not limit our analysis to positive effects of an increasing proximity among the agents but also discuss the implications of a negative proximity effect on the agents' productivity. To the best of our knowledge, this is the first time that the process of team formation and the effects of proximity have been jointly studied in a theoretical model.

The rest of the paper is organized as follows: Section 2 gives an overview of relevant literature and states our contribution to it. The model setup as well as the distribution of information and the procedure of exogenous and endogenous team formation are explained in section 3. Section 4 presents the first-best and second-best solutions for the benchmark case without proximity consideration and examines the advantageousness of endogenous and exogenous team formation. The analogous analysis is conducted for agents whose utility is influenced by proximity

[10] We denote the principal (she) as employer and the agents (he) as employees.

in section 5 with a strictly positive impact of proximity on the agents' productivity. Section 6 discusses the same proximity setting with a negative proximity impact on the agents' productivity. Section 7 concludes.

2 Contribution to Literature

There exists a wide range of literature that deals with principal-agent models depicting the aspects of teamwork and the incentivization of the team members. However, many authors do not incorporate the team formation process into their work and take the teams as given. Some of the first authors to consider aspects of teamwork in the context of the principal-agent theory were Holmström (1982) and Mookherjee (1984). They identify key problems in teams like free riding and the competition among team members as well as the moral hazard problem in case the principal only observes the team output. Other authors followed their lead. Among them are Che and Yoo (2001), who analyze teamwork not only in a single period but in a repetitive setting. They show that implicit incentives arise among the team members due to monitoring each other. In addition, they consider the difference between joint and relative performance evaluation and highlight the implications on the team incentives and performance. Arya et al. (1997) deal with a similar problem as Che and Yoo (2001), but they explicitly allow side contracting between the agents in the team, which enforces the mutual monitoring. Both papers show that implicit incentives play an important role for the performance of teams, especially in multi-period settings.

Bartling (2011) and Dur and Sol (2010) only consider explicit contracting in the context of teams, but they include social factors in their models. Bartling (2011) incorporates other-regarding preferences of the agents and shows the impact on the incentive contracts, especially on the conditions for the optimality of joint or relative performance measures. Dur and Sol (2010) introduce social interaction between agents and co-worker altruism, which increases with social interaction. They show that the principal can implement the optimal level of social interaction with the right incentive scheme. Not focusing so much on the aspect of teamwork, Rotemberg (1994) develops a model to show under which circumstances altruism exists between colleagues at the work place. He analyzes which compensation scheme leads to stronger or weaker altruism among agents.

Before being able to work in teams, these teams need to be formed. Several authors develop models that depict the process of team formation or incorporate this aspect into their models of teamwork. As opposed to our study, most of the models that deal with team formation do not particularly focus on social factors. Our model aims at filling this gap. Franco et al. (2011) develop a model in which the principal chooses the teams from agents with different types. They consider different production functions and show their impact on the ideal team composition. Similar to our work, their model deals with four agents to be split up into two teams and considers agents of different types. However, we add the scenario of endogenous team formation by the agents. Also, in contrast to Franco et al. (2011), our model incorporates a social factor. Hssaine and Banerjee (2019) consider an endogenous team formation by agents of different types. Thereby, the principal knows about the types of the agents, whereas the agents do not. The principal makes use of her information advantage and chooses the signals, so that the agents form the teams according to her preferences. The model focuses primarily on the design of the optimal signaling scheme of the principal. Also, in contrast to our model, Hssaine and Banerjee (2019) do not consider social factors and assume that the principal has an information advantage. Other authors considering endogenous team formation by the agents are Fahn and Hakenes (2019). They do so without incorporating a principal into their model. Due to inconsistent time preferences, the agents have a self-enforcement problem, which can be solved by forming teams. The self-enforcement in teams is obtained through relational contracts. We do not consider a similar problem of self-enforcement and do not model implicit incentives. However, the model of Fahn and Hakenes (2019) is a relevant reference concerning the team formation process.

Few authors consider social factors in the context of team formation. Among them is Corgnet (2010), who assumes that the agents know neither about their own abilities nor about the abilities of the others. In this context, the model deals with overconfident agents. He shows that learning biases in a multi-period setting can help to form efficient teams. We do not incorporate overconfidence as a social factor in our model and only model one period so that learning biases are not considered. In addition, we have a principal and explicit incentives for the agents, which is opposed to the work of Corgnet (2010). Hakenes and Katolnik (2018) consider an endogenous team formation with endogenous team size and overconfident agents without a principal. They show how free riding affects the decision problem and how overconfidence of agents helps to mitigate problems with implementing the optimal solution. Generally, the model is similar to our work, as we also examine endogenous team formation by the agents, but we consider the team formation impact on the principal's goals and our pool of agents is limited.

Besides the papers above, there are several authors analyzing the effects of social factors in the principal-agent setting without a focus on team incentives or team formation. Numerous authors deal with the effects of inequity aversion. While Fehr and Schmidt (1999) show how to model inequity-averse agents, Rey-Biel (2008) uses their findings to analyze how to incentivize two inequity-averse agents. Itoh (2004) works on a similar topic, as he combines the aspects of inequity-aversion with the well-known problem of moral hazard in the principal-agent setting. Dur and Tichem (2015) analyze the effects of altruism between a manager and an employee, whereas Bénabou and Tirole (2003) focus on cohesiveness in their principal-agent model, which also serves as a relevant reference for our model.

Regarding the literature concerning social distance and proximity, the analytical paper of Sally (2001) is one of few articles that examine physical and psychological distance in an economic model. Most literature with regard to social distance and proximity stems from the organization theory. Several papers connect the psychological proximity theory with the Construal Level Theory (CLT), as Weisner (2015) and Trope and Liberman (2010). As in our main model, facilitated knowledge spillovers due to less effort costs in case of low social and physical distances are part of many papers, e.g. Breschi and Lissoni (2009) and Balland (2012). Team performance increases if proximity increases as the frequency and quality of communication increases, see e.g. Allen (1970), Kessler (2000), Sethi (2000) and Sethi and Nicholson (2001). Besides the three proximity dimensions mentioned before, the proximity categories of Boschma (2005) mainly shape this body of literature.[11] Overall, Cha et al. (2014) serves as a base for our paper as they consider the relationship between psychological proximity and team work quality and thereby, team performance.

In sum, our model contributes to the theoretical team formation literature and incorporates proximity in this context for the first time. It adds to the existing literature in the fields of agency models with multiple agents and behavioral accounting.

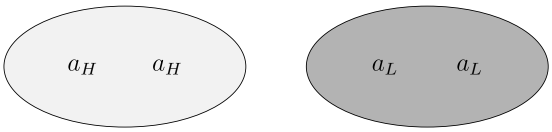
[11] The categories of Boschma (2005) refer to the conditions of knowledge transfer. He examines the categories of geographical (physical distance), cognitive (absorptive capacities), organisational (coordination possibilities), social (social relations between agents, e.g. friendship) and institutional (laws, language and cultural norms) proximity. Our paper focuses on the social proximity category.

3 Model Setup

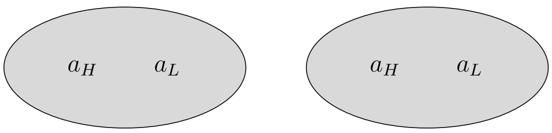
Our model deals with four risk neutral agents $i \in \{1, 2, 3, 4\}$ who work for a risk neutral principal over one period. The principal has two tasks to be completed by two agents each.[12] A task cannot be performed by only one agent. Therefore, the agents need to (be) split up into two teams of equal size. They can either be divided into the teams by the principal (exogenous team formation) or they form the teams by themselves (endogenous team formation) if the principal decides to waive her right of forming the teams by herself. The following describes the joint team output of agent i and j:

$$X_{ij} = (e_{ij} + e_{ji})\ a_i\ a_j + \varepsilon_X, \tag{1}$$

with $i, j \in \{1, 2, 3, 4\}$, i $\neq j$ and $\varepsilon_X \sim \mathcal{N}(0,\, \sigma_X^2)$. Let $a_i \in \{a_L, a_H\}$ denote agent i's ability, with $a_H > a_L > 1$. The agents mutually know their own abilities and the principal can observe these abilities in detail before contract offering. Among the four agents there are two agents of each ability type which is common knowledge. This means that there are two options to form the teams. If each team consists of one agent with high ability a_H and one with low ability a_L, we call this heterogeneous teams or negative assortative matching. In case that the agents with equal abilities form a team, we speak of homogeneous teams or positive assortative matching.[13] Figures 1a and 1b illustrate these team constellations.



(a) Homogeneous teams or positive assortative matching.



(b) Heterogeneous teams or negative assortative matching.

Figure 1: Possible team constellations based on the agents' abilities.

The factor $(e_{ij} + e_{ji}) \geq 0$ represents the effect from teamwork and depends on the effort levels $e_{ij} \geq 0$ of agent i and $e_{ji} \geq 0$ of agent j if agent i and j constitute

[12] Franco et al. (2011) also considers a setting in which four agents have to be split up into two teams.

[13] The wording "assortative matching" with direction "positive" or "negative" is also used by Franco et al. (2011) and Shimer and Smith (2000).

the team.[14] This effort can be seen as a communication effort within the team, i.e. the higher the effort the better the knowledge transfer. In case of $(e_{ij} + e_{ji}) = 0$, there is no effort and the expected team output is zero. The individual effort choices e_{ij} and e_{ji} are private information and cannot be contracted upon. Denote $E(\Pi) \equiv E(\Pi_{ij,mn})$ the principal's expected profit if agent i and j constitute one team and agent m and n the other team.[15] The principal seeks to maximize her expected profit function

$$E(\Pi) = E\left(X_{ij} + X_{mn} - \sum_{l=1}^{4} w_l\right), \tag{2}$$

with $i, j, m, n \in \{1, 2, 3, 4\}$, being pairwise disjoint and dependent on the team composition. Note that the outputs of the two teams are given by X_{ij} and X_{mn} and are calculated according to equation (1). The parameter w_i describes the compensation payment of agent i. The compensation contract of the agents is based on the team output. In order to keep the model simple, a linear compensation contract, consisting of a fixed payment and a variable part, is used. The linear compensation contract of agent i is given by

$$w_i = F_i + \frac{1}{2} X_{ij}, \tag{3}$$

with $i, j \in \{1, 2, 3, 4\}$, $i \neq j$. F_i denotes the fixed wage payment which is used to ensure that the participation constraint of agent i holds. As our analysis focuses on the formation of the teams rather than the incentivization of the agents, there is no endogenous incentive rate in the compensation contract. The complete team output is shared equally among the agents, so that the share is given by $\frac{1}{n} = \frac{1}{2}$ for both team members in each team.[16]

The agents' reservation utility U_0 is set to zero without loss of generality. Denote $U_{ij} \equiv U(a_i, a_j)$ the utility function of agent i in a team with agent j. This utility

[14] The factor $(e_{ij} + e_{ji})$ is similar to the interaction term modelled by Hakenes and Katolnik (2018), with the difference being that their factor is a constant and cannot be influenced by the agents.

[15] In all following calculations of the expected profit, we refer to the constellation of agent i and j in one team and agent m and n in the other team. In order to keep the notation simple, we do not use the indexes ij and mn.

[16] We refer to the budget-balancing constraint of Holmström (1982) which determines that the sum of the shares has to be equal to one, $\sum_{i=1}^{n} s_i(x) = x$ (p. 326). Here, the budget-balancing constraint is $\sum_{i=1}^{n} \frac{1}{n} x = x$. Hakenes and Katolnik (2018) model the team output share similarly as they use $\frac{1}{n}$ for n agents. Note that in our model this implies a negative fixed wage.

function is modelled as

$$U_{ij} = F_i + \frac{1}{2}\, X_{ij} + v\, \lambda_{ij} - (\kappa - c\, \lambda_{ij})\, \frac{{e_{ij}}^2}{2}, \tag{4}$$

with $i, j \in \{1, 2, 3, 4\}$, $i \neq j$. We adopt the modelling of Bénabou and Tirole (2006) by using a "preference type" or "identity" (p. 1656) for the agents which is modelled in this paper by $\vec{v}_A \equiv (1, v) \in (\mathbb{R}^+)^2$ and is common knowledge.[17] While the monetary utility part is weighted with 1, v weights the so-called proximity factor λ_{ij} and depends on how much social distance matters for the agents. The term $v\lambda_{ij}$ can be seen as a private benefit due to the proximity between the teammates. As $v > 0$, we assume that agents directly benefit from a higher proximity towards their teammate. Overall, the proximity factor λ_{ij} directly affects the agent's utility through the term $v\lambda_{ij}$. In addition, it also has an indirect effect on the utility as it affects his cost of effort $C(e_{ij}) = (\kappa - c\lambda_{ij})\frac{{e_{ij}}^2}{2}$ and therefore his chosen effort level. If an agent works together with another agent he feels distanced towards, this exacerbates the communication and thereby the knowledge transfer between them. The parameter $\kappa > 0$ represents the effect of the complexity of the work environment on the agents' cost of effort and is an exogenously given, commonly known constant. The factor c is commonly known and determines whether proximity among the team members generally leads to a higher or lower productivity of the agents, as the agents' cost of effort is influenced by the proximity factor with $c\,\lambda_{ij} < \kappa$. Basically, we assume that $c \geq 0$, so that proximity among the team members leads to a more productive work environment as high proximity facilitates communication which leads to an improved knowledge transfer (Cha et al., 2014). If $c = 0$ and $v = 0$, the agents decide without the influence of any proximity considerations. In section 6, we also examine the impact of $c < 0$ if higher proximity leads to more chatting and slacking and thus, less productive work.[18]

[17] We assume that the utility function looks like $U_{ij} = v_m\, w_i + v_\lambda\, \lambda_{ij} - C(e_{ij})$ which is similar to the model of Bénabou and Tirole (2006). The parameter $v_m = 1$ is the personal weight of the monetary utility part $w_i = F_i + \frac{1}{2}\, X_{ij}$ whereas $v_\lambda = v$ is the non-negative constant that represents the priority on how much social distance matters. In contrast to Bénabou and Tirole (2006), we assume v to be common knowledge and equal for all agents.

[18] Note that the empirical findings on the impact of proximity on the productivity of the agents are ambiguous. Bandiera et al. (2010) find that the effect of working with a friend depends on the relative abilities of the co-workers. The study of Park (2019) shows that productivity declines when working with a friend that the agent socializes with. Setting $c > 0$, we assume that a higher proximity factor increases the productivity of the agents because it improves the social surroundings, leading to a better work climate and thus knowledge transfer. Thereby, the agents are assumed not to be close enough to be good friends, so that no extensive socialization takes place. However, the model can be interpreted differently if the opposite case with $c < 0$ is analyzed, see section 6.

The agents experience either high or low psychological proximity as a reciprocal feeling towards each other, which is represented by the symmetrical proximity factor $\lambda_{ij} = \lambda_{ji}$.[19] In our model, λ_{ij} bases on the social distance between agent i and j. This approach is based on the paper of Sally (2001). We assume the proximity factor λ_{ij} to be a discrete random variable which takes on the value λ_H (λ_L) for a high (low) proximity, $\lambda_{ij} \in \{\lambda_H, \lambda_L\}$, due to a low (high) social distance.[20] A high proximity $\lambda_H > 0$ occurs with probability p whereas a low proximity $\lambda_L < 0$ occurs with the counter-probability of $1-p$ which is common knowledge. The actual proximity value is not observable for the principal and thus, private information of the agents after contract signing. It is important to note that the feeling of proximity is assumed to be reciprocal since both agents experience the same underlying social distance.[21]

Figure 2 shows the timeline of the model and the following two paragraphs describe the processes of exogenous and endogenous team formation in more detail.

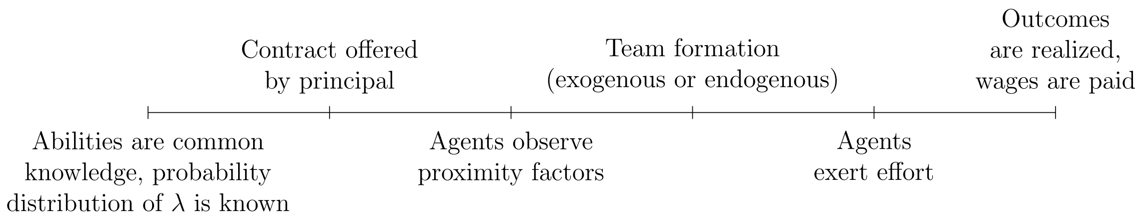


Figure 2: Timeline.

In the scenario of **exogenous team formation**, the principal forms the teams. Before the contract offer, the abilities are common knowledge for all players. Additionally, the probability distribution of the proximity factors λ is known, i.e. $P(\lambda_H) = p$ and $P(\lambda_L) = 1 - p$. The contracts offered by the principal depend on her preferred team composition and clearly state the abilities of the agents' teammates. Thus, the agents know their teammates' abilities when signing the contracts. Regarding the proximity factors, the principal can only use her

[19] Adam Smith (1759), uses the word "fellow-feeling" (p. 6) which can also be applied to proximity.

[20] Formally, proximity is a function of the social distance parameter Ψ_{ij}: $\lambda_{ij} = f(\Psi_{ij})$ with $i, j \in \{1, 2, 3, 4\}$, i $\neq$ j. Following Sally (2001) and Adam Smith (1759), λ_{ij} has to satisfy certain conditions which are the foundation of our proximity specifications: $f(\Psi_L) = \lambda_H > 0$: High proximity due to low social distance. $f(\Psi_H) = \lambda_L < 0$: Low proximity due to high social distance. Sally (2001) uses Adam Smith (1790) as a basis for his continuous modelling of the sympathy factor which is modelled analogously to our proximity factor. There, a distance of 0 leads to a high sympathy of 1 which is justified with "everyone fully sympathizes with one who is identical to the self" (Sally, 2001, p. 4). In contrast, the maximum distance leads to the lowest possible sympathy of 0 which is justified with "no fellow-feeling for another who is far away and foreign" (Sally, 2001, p. 4). Thus, sympathy declines as distance increases.

[21] The reciprocal character of proximity is considered in this or in a similar way by Rabin (1993), Rotemberg (1994) and Sally (2001).

information about the probability distribution but she is not able to observe the actual factors between the potential teammates. The agents also do not know their proximity towards the teammate before contract signing. After the contracts are signed, the agents privately observe their proximity factors towards each other, e.g. based on a first impression or previous work experiences. Then, the teams are formed as determined by the contracts. The agents exert effort and finally the team outputs are realized, the wages are paid and every player realizes his utility.

In case of **endogenous team formation**, the agents form the teams by themselves. The players' distribution of information before the contract offer is the same as in the exogenous team formation scenario. The proposed contract bases on the expectations about the teammates' ability-proximity constellations as these are unknown when the contracts are signed. After signing the contracts, the agents privately observe their proximity factors towards the other agents and form the teams by optimizing their expected utilities. After the team formation, the agents exert effort, the wages are paid and the outputs as well as the utilities are realized. In the following, the process of the endogenous team formation is laid out in more detail. Before the teams are formed by the agents, each agent compares his expected utilities for the possible team compositions after observing the proximity factors towards all potential teammates. Denote $X_{ij}^{\lambda_{ij}} \equiv X_{ij}(\lambda_{ij})$ the team output and $e_{ij}^{\lambda_{ij}} \equiv e_{ij}(\lambda_{ij})$ the effort with proximity consideration of agent i in a team with agent j with $i, j \in \{1, 2, 3, 4\}$, $i \neq j$. Agent i's expected utility in a team with agent j after observing λ_{ij} towards his teammate j is

$$E(U_{ij}|\lambda_{ij}) = F_i + \frac{1}{2}\, E(X_{ij}^{\lambda_{ij}}) + v\, \lambda_{ij} - C(e_{ij}^{\lambda_{ij}}), \tag{5}$$

with $E(X_{ij}^{\lambda_{ij}}) = (e_{ij}^{\lambda_{ij}} + e_{ji}^{\lambda_{ij}})\, a_i\, a_j$ since $E(\varepsilon_X) = 0$ for $i, j \in \{1, 2, 3, 4\}$, $i \neq j$. Depending on which potential teammate would lead to the highest expected utility, agent i announces the agent(s) he prefers to work with. Once every agent has made an announcement, the teams can be formed. If two agents announce each other, they build a team and the remaining two agents automatically build the other team. If there is a setting in which the agents' preferences are congruent and several team constellations are possible, the teams are determined by drawing lots.[22] Figure 3 illustrates the team formation process.

[22] This could happen if there is high proximity between all different ability agents but not between the high ability managers.

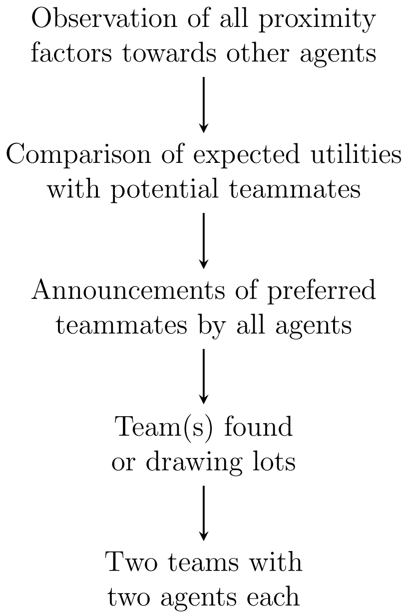


Figure 3: Process of the endogenous team formation.

4 Analysis of Benchmark

The following section examines the benchmark solution of the model which means that the agents are not influenced by proximity feelings, i.e. $c = 0$ and $v = 0$. Thus, the expected utility of agent i in a team with agent j is

$$E(U_{ij}) = E(w_{ij}) - \kappa \frac{e_{ij}^2}{2} = F_{ij} + \frac{1}{2} E(X_{ij}) - \kappa \frac{e_{ij}^2}{2}, \tag{6}$$

with $E(X_{ij}) = (e_{ij} + e_{ji})\, a_i\, a_j$ since $E(\varepsilon_X) = 0$ for $i, j \in \{1, 2, 3, 4\}$, $i \neq j$. Let $F_{ij} \equiv F(a_i, a_j)$ denote the fixed wage payment of agent i and $w_{ij} \equiv w(a_i, a_j)$ denote the compensation contract of agent i if agent i and j constitute a team. As there is no uncertainty in the benchmark solution since proximity is not considered and the agents' abilities are common knowledge, the principal is able to write team constellation-dependent contracts with F_{ij}. In order to maximize her expected profit, the principal considers two given teams of players i and j in one and m and n in the other team. Based on this, she optimizes the expected profit by finding the best fitting teams in ability terms. The expected profit of the principal equals

$$E(\Pi) = E\left(X_{ij} - w_{ij} - w_{ji} + X_{mn} - w_{mn} - w_{nm}\right). \tag{7}$$

4.1 First-Best Solution

First, we examine the first-best solution meaning that the effort is observable ex post for the principal. The agents choose the effort after signing the contract and the team formation. Thus, for given teams of agents i and j as well as m and n, the optimization problem of the principal is given by

$$\max_{\substack{e_{ij},e_{ji},\\ e_{mn},e_{nm}}} \; E(\Pi) \tag{8}$$

subject to

$$\begin{aligned} E(U_{ij}) &\geq 0, \\ E(U_{ji}) &\geq 0, \\ E(U_{mn}) &\geq 0, \\ E(U_{nm}) &\geq 0, \end{aligned} \tag{PC 1}$$

with $i, j, m, n \in \{1, 2, 3, 4\}$, being pairwise disjoint and dependent on the team composition. The effort choice is in line with the principals interests, i.e. the incentive constraints can be ignored. Since effort is observable and contractible in the first-best setting and the principal has to guarantee the agents their reservation utility of zero, the participation constraints in (PC 1) are binding for all four agents. Thus, the principal maximizes her expected profit by

$$\max_{\substack{e_{ij},e_{ji},\\ e_{mn},e_{nm}}} E(\Pi) = \max_{\substack{e_{ij},e_{ji},\\ e_{mn},e_{nm}}} E(X_{ij}) - \kappa\,\frac{e_{ij}^2}{2} - \kappa\,\frac{e_{ji}^2}{2} + E(X_{mn}) - \kappa\,\frac{e_{mn}^2}{2} - \kappa\,\frac{e_{nm}^2}{2}, \tag{9}$$

with $E(X_{ij}) = (e_{ij} + e_{ji})\, a_i\, a_j$ since $E(\varepsilon_X) = 0$ for $i, j \in \{1, 2, 3, 4\}$, $i \neq j$. The same holds for the team of agent m and n. This leads us to the first Lemma.

Lemma 1 *Without proximity consideration the first-best effort of agent i is*

$$e_{ij}^{FB} = \frac{a_i\, a_j}{\kappa}, \tag{10}$$

with $i, j \in \{1, 2, 3, 4\}$, $i \neq j$.

Proof: See the Appendix A1.

By inserting (10) into (9), the expected profit of the principal becomes

$$E(\Pi^{FB}) = \frac{a_i^2\, a_j^2 + a_m^2\, a_n^2}{\kappa}, \tag{11}$$

with $i, j, m, n \in \{1, 2, 3, 4\}$, being pairwise disjoint and dependent on the team composition. The expected profit of the principal only depends on the agents' abilities and the effort cost increasing factor κ. The fixed wage payment of agent i also contains his teammate's ability, $F_{ij}^{FB} = -\frac{a_i^2\, a_j^2}{2\kappa}$ with $i, j \in \{1, 2, 3, 4\}$, $i \neq j$, because the principal determines the teams ex ante.[23] Since the principal is able to reproduce the agents' endogenous team formation decisions as there is no information asymmetry in the benchmark setting, we only consider the exogenous team formation scenario in this first-best solution.[24] Dependent on whether the principal forms heterogeneous (-) or homogeneous (+) teams,

$$E(\Pi_{exo}^{FB-}) = \frac{2\, a_H^2\, a_L^2}{\kappa}, \tag{11a}$$

$$E(\Pi_{exo}^{FB+}) = \frac{a_H^4 + a_L^4}{\kappa}. \tag{11b}$$

Under the considered parameter values $a_H > a_L > 1$ and $\kappa > 0$, positive assortative matching is preferable, as $E(\Pi_{exo}^{FB+}) > E(\Pi_{exo}^{FB-})$. In sum, in the first-best solution without proximity consideration, the principal forms homogeneous teams. Thus, the agents with high ability receive $F^{FB}(a_H, a_H) = -\frac{a_H^4}{2\,k}$ while the agents with low ability receive $F^{FB}(a_L, a_L) = -\frac{a_L^4}{2\,k}$.

4.2 Second-Best Solution

In the second-best solution, the principal cannot observe the effort. As opposed to the first-best solution, the incentive constraints need to be considered. For given teams of agents i and j as well as m and n, the optimization problem is given by

[23] This means that there exist three possible fixed wages, $F^{FB}(a_H, a_H)$, $F^{FB}(a_L, a_L)$ and $F^{FB}(a_H, a_L)$.

[24] In case of endogenous team formation, the agents are indifferent between negative and positive assortative matching since $E(U_{ij}) = 0$ for any team composition due to the offered contract. Hence, endogenous team formation by the agents does not add any value for the principal in this case since they choose their teammate randomly.

$$\max_{\substack{w_{ij},w_{ji},\\ w_{mn},w_{nm}}} \quad E(\Pi) \tag{12}$$

subject to

$$\begin{aligned} E(U_{ij}) &\geq 0,\\ E(U_{ji}) &\geq 0,\\ E(U_{mn}) &\geq 0,\\ E(U_{nm}) &\geq 0, \end{aligned} \tag{PC 1}$$

$$\begin{aligned} e_{ij} &\in \underset{e'_{ij}}{argmax}\, E(U_{ij}),\\ e_{ji} &\in \underset{e'_{ji}}{argmax}\, E(U_{ji}),\\ e_{mn} &\in \underset{e'_{mn}}{argmax}\, E(U_{mn}),\\ e_{nm} &\in \underset{e'_{nm}}{argmax}\, E(U_{nm}), \end{aligned} \tag{IC 1}$$

with $i, j, m, n \in \{1, 2, 3, 4\}$, being pairwise disjoint and dependent on the team composition. From the incentive constraints (IC 1), we obtain the reactions of the agents to the contract offered by the principal. Each agent chooses his optimal effort level in accordance with the information about his ability type, his team partner's ability type and his share by optimizing his expected utility as given by (6).

The incentive constraints (IC 1) provide the second-best efforts of the agents, as shown in the next Lemma.

Lemma 2 *If proximity is not taken into account, the second-best effort for each agent i in a team with agent j is*

$$e_{ij}^{SB} = \frac{a_i\, a_j}{2\kappa} = \frac{1}{2}\, e_{ij}^{FB}, \tag{13}$$

with $i, j \in \{1, 2, 3, 4\}, i \neq j$ dependent on the team composition.[25]

Proof: See the Appendix A1.

[25] This result is driven by the usage of the budget-balancing constraint of Holmström (1982) with a share of $\frac{1}{2}$. If we assume that every agent receives 100% of the team output, the second-best effort equals the first-best effort.

Using the binding participation constraints and the resulting reduced profit function with the optimal efforts from (13), the principal determines her expected profit

$$E(\Pi^{SB}) = E(X_{ij}) - \kappa \frac{(e_{ij}^{SB})^2}{2} - \kappa \frac{(e_{ji}^{SB})^2}{2} + E(X_{mn}) - \kappa \frac{(e_{mn}^{SB})^2}{2} - \kappa \frac{(e_{nm}^{SB})^2}{2}, \quad (14)$$

with $E(X_{ij}) = (e_{ij} + e_{ji})\, a_i\, a_j$ since $E(\varepsilon_X) = 0$ for $i, j \in \{1, 2, 3, 4\}$, $i \neq j$. The same holds for the team of agent m and n. Therefore, the following expected profit results by inserting (13) into (14):

$$E(\Pi^{SB}) = \frac{3\,(a_i^2\, a_j^2 + a_m^2\, a_n^2)}{4\,\kappa} = \frac{3}{4}\, E(\Pi^{FB}), \quad (15)$$

with $i, j, m, n \in \{1, 2, 3, 4\}$, $i \neq j \neq m \neq n$ dependent on the team composition.

The fixed wage payment F_{ij} of agent i is determined by the binding participation constraint, $F_{ij}^{SB} = -\frac{3\, a_i^2\, a_j^2}{8\, k}$ with $i, j \in \{1, 2, 3, 4\}$, $i \neq j$, dependent on the team composition.

If the principal forms the teams **exogenously**, heterogeneous (-) and homogeneous (+) teams result in an expected profit of

$$E(\Pi_{exo}^{SB-}) = \frac{3\, a_H^2\, a_L^2}{2\,\kappa}, \quad (15a)$$

$$E(\Pi_{exo}^{SB+}) = \frac{3\,(a_H^4 + a_L^4)}{4\,\kappa}. \quad (15b)$$

Analogous to (11a) and (11b), it becomes clear that positive assortative matching (homogeneous teams) is more profitable for the principal as $a_H > a_L > 1$.

If the principal decided to waive her right on forming the teams exogenously in order to delegate the team formation decision to her agents **(endogenous team formation)**, all agents would announce an a_H-ability type agent as their preferred teammate. To see this, consider the expected utility of agent i with teammate j before the teams are formed from equation (6). Insert the second-best efforts given by (13) and calculate the derivative with respect to a_j,

$$\frac{\partial E(U_{ij})}{\partial a_j} = \frac{3\, a_i^2\, a_j}{4\, k} > 0. \quad (16)$$

Hence, the agents always prefer to work with a teammate that has the high ability a_H. Under consideration of the team formation process laid out in section 3, this leads to positive assortative matching. Thus, homogeneous teams are formed as in the exogenous team formation option.

Therefore, endogenous team formation does not add any value compared with exogenous team formation. Hence, the principal offers two payments and forms homogeneous teams: The agents with high ability receive $F^{SB}(a_H, a_H) = -\frac{3\,a_H^4}{8\,k}$ while the agents with low ability receive $F^{SB}(a_L, a_L) = -\frac{3\,a_L^4}{8\,k}$.

Proposition 1 *Without consideration of proximity, endogenous team formation does not add any value as the agents do not have any information advantages. As a result, the principal always forms the teams exogenously and prefers homogeneous teams. This result holds for the first-best as well as the second-best solution and thus, is independent of the observability of the agents' efforts.*

5 Analysis with Proximity among Agents

In this section, agents are influenced by individual proximity factors, as $c > 0$ and $v > 0$. Note that we consider two given teams of player i and j in one and m and n in the other team. For notation simplicity in the following calculations, let $e_{ij} \equiv e_{ij}^{\lambda_{ij}}$ denote the effort of agent i in a team with agent j with proximity consideration. The respective expected utility of agent i in a team with agent j is

$$E(U_{ij}(\lambda_{ij})) = \sum P(a_i, a_j; \lambda_{ij}) \left(E(w_{ij}) + v\,\lambda_{ij} - (\kappa - c\,\lambda_{ij}) \frac{e_{ij}^2}{2} \right), \tag{17}$$

with $E(w_{ij}) = F_i + \frac{1}{2} E(X_{ij}^{\lambda_{ij}})$ with $E(X_{ij}^{\lambda_{ij}}) = (e_{ij} + e_{ji})\, a_i\, a_j$ since $E(\varepsilon_X) = 0$ for $i, j \in \{1, 2, 3, 4\}$, $i \neq j$. The term $P(a_i, a_j; \lambda_{ij})$ illustrates the probability of agent i to be in a team with agent j and a corresponding proximity factor λ_{ij}. The expected utility sums up over all possible ability-proximity constellations for agent i with ability $a_i \in \{a_L, a_H\}$.[26] Based on this, the principal optimizes her expected profit by finding the best fitting teams in ability and proximity terms under consideration of the constraints and the team formation process. The principal's expected profit is calculated by

$$\begin{aligned} E(\Pi^{\lambda}) = \sum P\big[(a_i,a_j; \lambda_{ij}), (a_m, a_n; \lambda_{mn})\big] \\ \cdot E\left(X_{ij}^{\lambda_{ij}} - w_{ij} - w_{ji} + X_{mn}^{\lambda_{mn}} - w_{mn} - w_{mn} \right), \end{aligned} \tag{18}$$

with $i, j, m, n \in \{1, 2, 3, 4\}$, being pairwise disjoint and dependent on v and c. Note that $P\big[(a_i, a_j; \lambda_{ij}), (a_m, a_n; \lambda_{mn})\big]$ illustrates the probability of the respective team

[26] Each agent sums up over four possibilities: $(a_i, a_H; \lambda_H), (a_i, a_H; \lambda_L), (a_i, a_L; \lambda_H), (a_i, a_L; \lambda_L)$.

composition. The compositions are represented by the team members' abilities and the proximity factors. In order to determine the expected profit as in (18), the weighted expected profits of all possible team constellations are summed up over all constellations.[27]

5.1 First-Best Solution

First, we examine the first-best results meaning that the efforts and the proximity factors are observable ex post for the principal. The agents can observe the proximity factors before the team formation. The agents choose the effort after signing the contract and forming the teams. The effort choice is in line with the principal's interests, i.e. the participation constraints are binding and no incentive constraints need to be considered. Thus, for given teams of agents i and j as well as m and n, the optimization problem of the principal is given by

$$\max_{\substack{e_{ij},e_{ji},\\ e_{mn},e_{nm}}} \; E(\Pi^{\lambda}) \tag{19}$$

subject to

$$\begin{aligned} E(U_{ij}(\lambda_{ij})) &\geq 0, \\ E(U_{ji}(\lambda_{ij})) &\geq 0, \\ E(U_{mn}(\lambda_{mn})) &\geq 0, \\ E(U_{nm}(\lambda_{mn})) &\geq 0, \end{aligned} \tag{PC 2}$$

with $i, j, m, n \in \{1, 2, 3, 4\}$, being pairwise disjoint and dependent on the team composition.

Since effort and proximity are observable and contractible and the principal has to guarantee the agents their reservation utility of zero, the participation constraints are binding for all four agents. The principal maximizes her expected profit by

$$\begin{aligned} \max_{\substack{e_{ij},e_{ji},\\ e_{mn},e_{nm}}} \; \sum P\big[(a_i, a_j; \lambda_{ij}), (a_m, a_n; \lambda_{mn})\big] \Big(& E(X_{ij}^{\lambda_{ij}}) + E(X_{mn}^{\lambda_{mn}}) + 2\,v\lambda_{ij} + 2\,v\lambda_{mn} \\ & - (\kappa - c\lambda_{ij})\frac{e_{ij}^2}{2} - (\kappa - c\lambda_{ij})\frac{e_{ji}^2}{2} - (\kappa - c\lambda_{mn})\frac{e_{mn}^2}{2} - (\kappa - c\lambda_{mn})\frac{e_{nm}^2}{2} \Big), \end{aligned} \tag{20}$$

with $E(X_{ij}^{\lambda_{ij}}) = (e_{ij} + e_{ji})\, a_i\, a_j$ since $E(\varepsilon_X) = 0$ for $i, j \in \{1, 2, 3, 4\}$, $i \neq j$. The same

[27] There are seven constellations possible. For more details, see section 5.1.

holds for the team of agent m and n. Analogously to (18), the principal considers the sum of the weighted profits of the team constellations over all possible team constellations. This leads us to the next Lemma.

Lemma 3 *The first-best effort under consideration of proximity among the agents is*

$$e_{ij}^{FB,\lambda_{ij}} = \frac{a_i\, a_j}{(\kappa - c\,\lambda_{ij})}, \tag{21}$$

with $i, j \in \{1, 2, 3, 4\}$, $i \neq j$ *and* $\lambda_{ij} \in \{\lambda_H, \lambda_L\}$ *dependent on the team composition.*

Proof: See the Appendix A2.

The first-best solution with proximity consideration follows the endogenous timing regarding the team formation process. The agents always receive their reservation utility dependent on the constellation of proximity factors and abilities. Thus, they are indifferent concerning the team formation decision. This means that the agents always form the teams that are preferred by the principal. From the principal's view, there are seven different possible team constellations. These are the constellations that she sums up over in equations (18) and (20). Table 1 gives an overview of all seven possible team constellations.

Nr.	Team constellations	Teams
1	$(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_H)$	+
2	$(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_L)$	+
3	$(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_H)$	+
4	$(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_L)$	+
5	$(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_H)$	-
6	$(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_L)$	-
7	$(a_H, a_L; \lambda_L), (a_H, a_L; \lambda_L)$	-

Table 1: Team constellation opportunities dependent on ability and proximity.

The principal's preferred team constellation generally does not only depend on the abilities of the agents but also on the proximity factors among them. Hence, it is not necessarily optimal for the principal to build homogeneous (+) teams. Heterogeneous (-) teams might create a higher output as the principal can make use of the agents' increasing productivities and private benefits due to higher proximities.

The importance of the proximity constellations relative to the ability constellations is represented by the factors c and v. They represent the indirect and direct effect of proximity on the agents' utilities and thus, on the overall output of the firm. The higher these factors, the more important are the proximity factors in the agents' utilities and hence, in the principal's decision. For a given combination of proximity factors as well as the commonly known values of a_i, v and c, the principal is able to order her team preferences by comparing her expected profits from all seven possible team constellations. Thus, there exist different possibilities for the order of the principal's team preferences dependent on the values of v and c.[28]

Based on these orderings and since the general distribution of the proximity factor is known, the probability of occurrence for each possible constellation can be determined ex ante. Hence, the ex ante probabilities $P\big[(a_i, a_j; \lambda_{ij}), (a_m, a_n; \lambda_{mn})\big]$ occur dependent on the concrete values of c and v.[29] A comparison of these ex ante probabilities dependent on c and v leads to the following proposition:

Proposition 2 *The higher the agents' proximity preferences v and c, the higher (lower) the probability that the principal prefers heterogeneous (homogeneous) teams.*

Proof: See the Appendix A2.

Despite the increasing probability for heterogeneous teams with increasing v and c, the principal would never form heterogeneous teams in which all agents' proximity factors are low (respective probability of occurrence is always zero). Thus, the principal considers six team constellations. For each constellation, she ensures that the agents receive their respective reservation utility to act in her interest. These six possible payments are given by the fixed wages $F_{ij}^{FB,\lambda} = -\frac{a_i^2 a_j^2}{2(k-c\lambda_{ij})} - v\lambda_{ij}$ and $F_{mn}^{FB,\lambda} = -\frac{a_m^2 a_n^2}{2(k-c\lambda_{mn})} - v\lambda_{mn}$ with $i, j, m, n \in \{1, 2, 3, 4\}$, being pairwise disjoint and dependent on the team composition,

[28] For more details, see Tables 4a and 4b as well as the critical values for v in (43)-(43c) and c in(44)-(44b) in the Appendix A2.

[29] See Table 5 in the Appendix A2 for a detailed overview of all probabilities. The corresponding tree is shown in Figure 12 in Appendix A2 for the determination of the ex ante probabilities in the second-best solution.

$$F^{FB,\lambda} = \begin{cases} -\frac{a_H^2\,a_H^2}{2(\kappa-c\lambda_H)} - v\lambda_H, -\frac{a_L^2\,a_L^2}{2(\kappa-c\lambda_H)} - v\lambda_H \text{ for } (a_H, a_H; \lambda_H), (a_L, a_L; \lambda_H) \\ -\frac{a_H^2\,a_H^2}{2(\kappa-c\lambda_H)} - v\lambda_H, -\frac{a_L^2\,a_L^2}{2(\kappa-c\lambda_L)} - v\lambda_L \text{ for } (a_H, a_H; \lambda_H), (a_L, a_L; \lambda_L) \\ -\frac{a_H^2\,a_H^2}{2(\kappa-c\lambda_L)} - v\lambda_L, -\frac{a_L^2\,a_L^2}{2(\kappa-c\lambda_H)} - v\lambda_H \text{ for } (a_H, a_H; \lambda_L), (a_L, a_L; \lambda_H) \\ -\frac{a_H^2\,a_H^2}{2(\kappa-c\lambda_L)} - v\lambda_L, -\frac{a_L^2\,a_L^2}{2(\kappa-c\lambda_L)} - v\lambda_L \text{ for } (a_H, a_H; \lambda_L), (a_L, a_L; \lambda_L) \\ -\frac{a_H^2\,a_L^2}{2(\kappa-c\lambda_H)} - v\lambda_H, -\frac{a_H^2\,a_L^2}{2(\kappa-c\lambda_H)} - v\lambda_H \text{ for } (a_H, a_L; \lambda_H), (a_H, a_L; \lambda_H) \\ -\frac{a_H^2\,a_L^2}{2(\kappa-c\lambda_H)} - v\lambda_H, -\frac{a_H^2\,a_L^2}{2(\kappa-c\lambda_L)} - v\lambda_L \text{ for } (a_H, a_L; \lambda_H), (a_H, a_L; \lambda_L). \end{cases} \quad (22)$$

The probabilities of occurrence again depend on v and c. The fixed wages above ensure that the principal can implement her preferred solution depending on the values of v and c and the actual values of the proximity factors.

5.2 Second-Best Solution

In the second-best solution, the principal cannot observe the effort and proximity factors of the agents. The principal has to maximize her expected profit given by (18). The agents' participation constraints are constituted by their ex ante expected utilities. Further specification of (17) leads to the following expected utilities:

$$E(U_{ij}(\lambda_{ij})) = F_i + \sum P(a_i, a_j; \lambda_{ij}) \left(\frac{1}{2} E(X_{ij}^{\lambda_{ij}}) + v\,\lambda_{ij} - (\kappa - c\,\lambda_{ij}) \frac{e_{ij}^2}{2} \right), \quad (23)$$

with $E(X_{ij}^{\lambda_{ij}}) = (e_{ij}+e_{ji})\,a_i\,a_j$ since $E(\varepsilon_X) = 0$ for $i, j \in \{1, 2, 3, 4\}$, $i \neq j$, dependent on team composition. The principal needs to ensure that the agents receive their reservation utility of zero which leads to the participation constraints.

After the team formation, each agent chooses the effort that maximizes his expected utility given the proximity towards his teammate which leads to the incentive constraints. The agent's expected utility after observing the proximity towards the potential teammate is

$$E(U_{ij}|\lambda_{ij}) = E\left(w_{ij}\right) + v\,\lambda_{ij} - (\kappa - c\,\lambda_{ij}) \frac{e_{ij}^2}{2}, \quad (24)$$

with $E(w_{ij}) = F_i + \frac{1}{2} E(X_{ij}^{\lambda_{ij}})$ with $E(X_{ij}^{\lambda_{ij}}) = (e_{ij} + e_{ji})\,a_i\,a_j$ since $E(\varepsilon_X) = 0$ for $i, j \in \{1, 2, 3, 4\}$, $i \neq j$. Considering the equations (18), (23) and (24) for given teams of agents i and j as well as m and n, the optimization problem of the principal is

$$\max_{\substack{w_{ij},w_{ji},\\ w_{mn},w_{nm}}} \; E(\Pi) \tag{25}$$

subject to

$$\begin{aligned} E(U_{ij}(\lambda_{ij})) &\geq 0, \\ E(U_{ji}(\lambda_{ij})) &\geq 0, \\ E(U_{mn}(\lambda_{mn})) &\geq 0, \\ E(U_{nm}(\lambda_{mn})) &\geq 0, \end{aligned} \tag{PC 2}$$

$$\begin{aligned} e_{ij} &\in \underset{e'_{ij}}{argmax}\, E(U_{ij}|\lambda_{ij}), \\ e_{ji} &\in \underset{e'_{ji}}{argmax}\, E(U_{ji}|\lambda_{ij}), \\ e_{mn} &\in \underset{e'_{mn}}{argmax}\, E(U_{mn}|\lambda_{mn}), \\ e_{nm} &\in \underset{e'_{nm}}{argmax}\, E(U_{nm}|\lambda_{mn}), \end{aligned} \tag{IC 2}$$

with $i, j, m, n \in \{1, 2, 3, 4\}$, being pairwise disjoint and dependent on the team composition.

The incentive constraints (IC 2) provide the second-best efforts of the agents, as shown in Lemma 4.

Lemma 4 *The second-best effort under consideration of proximity is*

$$e_{ij}^{SB,\lambda_{ij}} = \frac{a_i\, a_j}{2\;(\kappa - c\,\lambda_{ij})} = \frac{1}{2}\, e_{ij}^{FB,\lambda_{ij}}, \tag{26}$$

with $i, j \in \{1, 2, 3, 4\}$, $i \neq j$ *dependent on the team composition.*

Proof: See the Appendix A2.

Using the binding participation constraints and the second-best efforts as in (26), the principal considers the reduced profit function

$$\begin{aligned} E(\Pi^{SB,\lambda}) = E\Bigg(& X_{ij}^{\lambda_{ij}} + 2\,\upsilon\lambda_{ij} - (\kappa - c\lambda_{ij})\frac{(e_{ij}^{SB,\lambda_{ij}})^2}{2} - (\kappa - c\lambda_{ij})\frac{(e_{ji}^{SB,\lambda_{ij}})^2}{2} \\ & + X_{mn}^{\lambda_{mn}} + 2\,\upsilon\lambda_{mn} - (\kappa - c\lambda_{mn})\frac{(e_{mn}^{SB,\lambda_{ij}})^2}{2} - (\kappa - c\lambda_{mn})\frac{(e_{nm}^{SB,\lambda_{ij}})^2}{2} \Bigg), \end{aligned} \tag{27}$$

with $i, j, m, n \in \{1, 2, 3, 4\}, i \cap j \cap m \cap n = \emptyset$ dependent on the team composition. Depending on how the teams are formed, the ex ante probabilities for each team composition and corresponding proximity factor vary, so that the principal's expected profit also differs. These differences are analyzed in the following two subsections.[30]

5.2.1 Exogenous Team Formation

In case of exogenous team formation, the principal decides about the team composition in terms of the agents' abilities. Thus, she only forms expectations concerning the proximity factors of the agents, $E(\lambda) = p\,\lambda_H + (1-p)\,\lambda_L$. Her expected profit given by (27) now becomes

$$\begin{aligned} E(\Pi^{SB,\lambda}_{exo}) = \\ & p\Bigg(E(X^{\lambda_H}_{ij}) + 2\,v\lambda_H - (\kappa - c\lambda_H)\frac{(e^{SB,\lambda_H}_{ij})^2}{2} - (\kappa - c\lambda_H)\frac{(e^{SB,\lambda_H}_{ji})^2}{2} \\ & + E(X^{\lambda_H}_{mn}) + 2\,v\lambda_H - (\kappa - c\lambda_H)\frac{(e^{SB,\lambda_H}_{mn})^2}{2} - (\kappa - c\lambda_H)\frac{(e^{SB,\lambda_H}_{nm})^2}{2}\Bigg) \\ +(1-p) & \Bigg(E(X^{\lambda_L}_{ij}) + 2\,v\lambda_L - (\kappa - c\lambda_L)\frac{(e^{SB,\lambda_L}_{ij})^2}{2} - (\kappa - c\lambda_L)\frac{(e^{SB,\lambda_L}_{ji})^2}{2} \\ & + E(X^{\lambda_L}_{mn}) + 2\,v\lambda_L - (\kappa - c\lambda_L)\frac{(e^{SB,\lambda_L}_{mn})^2}{2} - (\kappa - c\lambda_L)\frac{(e^{SB,\lambda_L}_{nm})^2}{2}\Bigg), \end{aligned} \tag{28}$$

with $E(X^{\lambda_{ij}}_{ij}) = (e_{ij} + e_{ji})\,a_i\,a_j$ since $E(\varepsilon_X) = 0$. The same holds for a team of agent m and n with $i, j, m, n \in \{1, 2, 3, 4\}$, being pairwise disjoint and dependent on the team composition.

If the principal decides to form heterogeneous teams, the expected profit is

$$E(\Pi^{SB,\lambda-}_{exo}) = \frac{3\,a_H^2 a_L^2\,(k - c((1-p)\lambda_H + p\lambda_L))}{2\,(k - c\lambda_H)\,(k - c\lambda_L)} + 4v\,(p\lambda_H + (1-p)\lambda_L)\,. \tag{28a}$$

In contrast, if she forms homogeneous teams, the expected profit is

$$E(\Pi^{SB,\lambda+}_{exo}) = \frac{3\,(a_H^4 + a_L^4)\,(k - c((1-p)\lambda_H + p\lambda_L))}{4\,(k - c\lambda_H)\,(k - c\lambda_L)} + 4v\,(p\lambda_H + (1-p)\lambda_L). \tag{28b}$$

[30] Note that the expected profits can be negative under certain conditions as e.g. the compensation of a very high weight v on proximity in combination with statistically low and thus, negative, proximity values through a low p is very expensive. However, we focus on relative effects in order to determine whether exogenous or endogenous team formation is preferable.

The corresponding fixed wage of agent i in a team with agent j is given by

$$F_{ij,exo}^{SB,\lambda} = -\frac{3\, a_i^2\, a_j^2\, (k - c((1-p)\lambda_H + p\lambda_L))}{8\,(k - c\lambda_H)\,(k - c\lambda_L)} - v\,(p\lambda_H + (1-p)\lambda_L). \tag{29}$$

Note that the expected profit with proximity consideration equates to a multiple of the expected profit without proximity consideration plus a constant term,

$$E(\Pi_{exo}^{SB,\lambda}) = E(\Pi_{exo}^{SB}) \cdot \frac{(k - c(p\lambda_L + (1-p)\lambda_H))}{(k - c(\lambda_H + \lambda_L - c\lambda_H\, \lambda_L)} + 4v\,(p\lambda_H + (1-p)\lambda_L). \tag{30}$$

The factor multiplied with $E(\Pi_{exo}^{SB})$ is bigger than one if $c < \frac{E(\lambda)}{\lambda_H\, \lambda_L}$. The added term on the right can be either positive or negative, depending on the actual value of $E(\lambda)$.[31] These explanations illustrate that the effect of proximity on the expected profit is ambiguous. The comparison of the above results leads to the same decision as in the benchmark solution: The principal always prefers homogeneous teams when forming the teams exogenously. Figure 4 confirms this result by illustrating the expected profit with exogenous team formation with both homogeneous (+) and heterogeneous (-) teams.

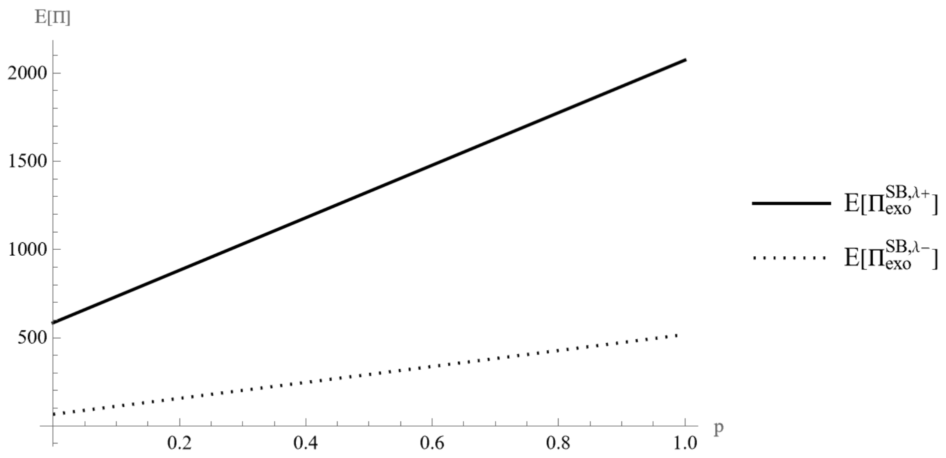


Figure 4: Comparison of second-best (SB) expected profits of principal in case of exogenous team formation with $\kappa = 5$, $c = 0.5$, $v = 4$, $\lambda_L = -5$, $\lambda_H = 5$, $a_L = 3$, $a_H = 9$.

As shown in Figure 4, the expected profit with homogeneous teams as in (28b) is strictly higher than the expected profit with heterogeneous teams, see (28a), if the teams are formed exogenously. In addition, both expected profits increase with the probability p for high proximity among the teammates.

[31] If the right part of equation (30) becomes negative and in terms of absolute values larger than the left part, the expected profit with exogenous team formation can become negative.

5.2.2 Endogenous Team Formation

If the agents form the teams endogenously, they announce the potential teammate based on their expected utilities. At this point, it is important to analyze whether an agent makes the decision mainly because of his proximity towards the other agent (proximity-based) or because of the ability type of the other agent (type-based). If an agent makes a type-based decision, he always prefers to form a team with an agent of the high ability type a_H, independent of the actual value of the proximity factor between them. Analogous to (16), it can be shown that agents never make type-based decisions for another agent of type a_L, as the expected utility from working with an agent of type a_L is always lower than from working with an agent of type a_H while the proximity factor is held constant. Thus, the question is whether agent i would prefer working with an a_H-type agent under low proximity λ_L over working with an a_L-type agent under high proximity λ_H,

$$E(U(a_i, a_H)|\lambda_L) > E(U(a_i, a_L)|\lambda_H). \tag{31}$$

Under consideration of the agents' expected utility functions after observing the proximity factors in (24) and the second-best effort level $e_{ij}^{SB,\lambda}$ as in (26), it is possible to determine conditions under which agents decide type-based and conditions under which they decide proximity-based. Thus, agent i decides based on the ability type of his potential teammate if the following conditions hold:

$$v < \frac{3\, a_i^2\, (a_H^2\, (k - c\lambda_H) - a_L^2\, (k - c\lambda_L))}{8\, (\lambda_H - \lambda_L)\, (k - c\lambda_H)\, (k - c\lambda_L)} = v^{crit}, \tag{32}$$

$$c < \frac{k\, (a_H - a_L)\, (a_H + a_L)}{a_H^2 \lambda_H - a_L^2 \lambda_L} = c^{crit}. \tag{33}$$

All parameters in (32) and (33) are known to everyone. This means that the principal can use this information to forecast the kind of decisions the agents will make.

Lemma 5 *The agents always decide type-based if the direct effect of the proximity on their expected utility and the indirect effect through their productivity are sufficiently small, as v and c do not exceed the boundary values v^{crit} and c^{crit} respectively. On the other hand, the agents decide based on their proximity if $v > v^{crit} \vee c > c^{crit}$.*

Proof: See the Appendix A2.

Before the teams are formed by the agents, each agent compares his expected utility after observing the proximity as in (24) for all possible team compositions as described in section 3. Each agent faces four possible team compositions: He can either be in a team with another agent of a high or low ability and they can experience high or low proximity towards each other. The four possibilities are illustrated in Table 2.

Preferences	Type-based $0 < v < v^{crit} \; \wedge \; 0 < c < c^{crit}$	Proximity-based $v^{crit} < v \; \vee \; c^{crit} < c$
1	$(a_i, a_H; \lambda_H)$	$(a_i, a_H; \lambda_H)$
2	$(a_i, a_H; \lambda_L)$	$(a_i, a_L; \lambda_H)$
3	$(a_i, a_L; \lambda_H)$	$(a_i, a_H; \lambda_L)$
4	$(a_i, a_L; \lambda_L)$	$(a_i, a_L; \lambda_L)$

Table 2: Team preferences of agent i with ability type a_i.

Table 2 shows that the order of the agents' team preferences depends on whether the agents decide proximity- or type-based. While the first and last preference stay the same in any case, the second and third preference switch places. It becomes obvious that this directly links to whether (31) holds or not. The agents' preferences shown in Table 2 in combination with the endogenous team formation process laid out in section 3 and the distribution of λ lead to the probabilities of occurrence for all possible team constellations $P(a_i, a_j; \lambda_{ij})$ for a team of agent i and j and $P(a_m, a_n; \lambda_{mn})$ for a team of agent m and n. Hence, $P\big[(a_i, a_j; \lambda_{ij}), (a_m, a_n; \lambda_{ij})\big]$ is the probability of receiving both teams from the principal's view. In order to determine these probabilities, all possible combinations of proximities among the agents need to be considered. With four agents and reciprocal proximity, there are six proximity factors to be considered.[32] As each proximity factor can take on two different values (λ_H or λ_L), there are $2^6 = 64$ combinations to be considered overall. The approach is sketched in Figure 5. Note that Figure 5 only shows the first two stages of the tree diagram (in this case the proximity factors between agents i and j and between agents i and m) whereby the further steps are indicated by the dots.[33] Each agent now considers which team he prefers, dependent on a given constellation of abilities, proximities and v as well as c-values. As soon as two agents name each other, this team is formed and the other two agents are automatically matched.[34]

[32] The proximity factors between all potential teammates are $\lambda_{ij}, \lambda_{im}, \lambda_{in}, \lambda_{jm}, \lambda_{jn}, \lambda_{mn}$.
[33] The whole tree can be found in Figure 12 in the Appendix.
[34] Example: The agents' with high abilities feel close to each other (high proximity λ_H), then they announce each other as preferred teammates in terms of their expected utility independent of c and v (first preference in both rankings) and form a team. Both agents with low ability are automatically matched in the other team.

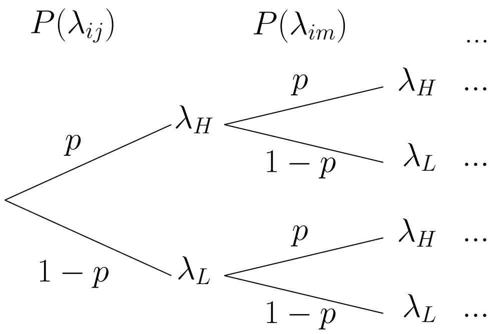


Figure 5: First steps of the tree diagram for calculating the ex ante probabilities of occurrence for the team constellations in case of endogenous team formation.

Each of the 2^6 combinations that can be displayed by the complete tree diagram leads to a combination of teams determined by the ability-proximity constellations of the agents. For each possible combination of the six proximity factors among the agents, the overall resulting team constellation can be determined. Therefore, the probabilities along the path are multiplied in order to calculate the overall probability of occurrence for this team constellation. As known from Table 1, there exist seven possible team constellations that are also displayed in Table 3. Based on the distribution of λ with $P(\lambda_H) = p$ and $P(\lambda_L) = 1 - p$, which is also used in the tree diagram in Figure 5, the probabilities of occurrence for each team constellation can be calculated as briefly described above. The results are shown in Table 3.[35]

$P\big[\text{Team A, Team B}\big]$	Teams	Type-based $0 < v < v^{crit} \;\wedge\; 0 < c < c^{crit}$		Proximity-based $v^{crit} < v \;\vee\; c^{crit} < c$
$P\big[(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_H)\big]$	+	p^2	=	p^2
$P\big[(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_L)\big]$	+	$p\,(1-p)$	=	$p\,(1-p)$
$P\big[(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_H)\big]$	+	$(1-p)\,p$	>	$(1-p)^5\,p$
$P\big[(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_L)\big]$	+	$(1-p)^2$	>	$(1-p)^6$
$P\big[(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_H)\big]$	-	0	<	$(1-p)(2\,p^2 - p^4)$
$P\big[(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_L)\big]$	-	0	<	$4\,p\,(1-p)^3$
$P\big[(a_H, a_L; \lambda_L), (a_H, a_L; \lambda_L)\big]$	-	0	=	0
$\sum$		1		1

Table 3: Probabilities of occurrence for team constellations in case of endogenous team formation.

The probabilities shown in Table 3 are used to calculate the agents' ex ante expected utilities as given by (23) and thus, the participation constraints (PC 2). When

[35] For a detailed illustration of the proximity-based probability determination process, see Table 7 and Figure 12 in the Appendix in combination with the preference orderings from Table 2.

calculating the agents' expected utilities, it is important to multiply the probabilities of occurrence from Table 3 with the respective payoffs from the agents' points of view which depend on their ability types. Thus, the participation constraints for agents of the low and the high ability type differ. For each preference ranking made by the agents, this leads to two different ability-dependent fixed wages.[36] Overall, the above probabilities are also crucial for the principal as they affect the fixed wages of the agents and the profitability of the endogenous team formation.

The critical value v^{crit} depends on $a_i \in \{a_L, a_H\}$, denote $v_i^{crit} \equiv v^{crit}(a_i)$ with $v_H^{crit} > v_L^{crit}$. Figure 6 illustrates these two critical values. The preference order of Table 2 focuses on the scenario that both ability types follow either the type-based or proximity-based preferences. Type-based preferences for both ability types occur if $v < v_L^{crit}$ since this is the lower critical value, see Figure 6. Proximity-based preferences for both ability types occur if $v > v_H^{crit}$ since this is the higher critical value. However, it is also possible that only one ability type has type-based but the other ability type has proximity-based preferences. If the high ability agents decide type-based whereas the low ability agents decide proximity-based, c has to be below c^{crit} and v has to be smaller than v_H^{crit} to ensure type-based decisions for the high ability type but v simultaneously has to be higher than v_L^{crit} for proximity-based decisions of the low ability type. Hence, v has to be in the middle range of Figure 6 between v_L^{crit} and v_H^{crit}. Then, the team constellation preferences are the same as in the type-based decision in Table 3.[37]

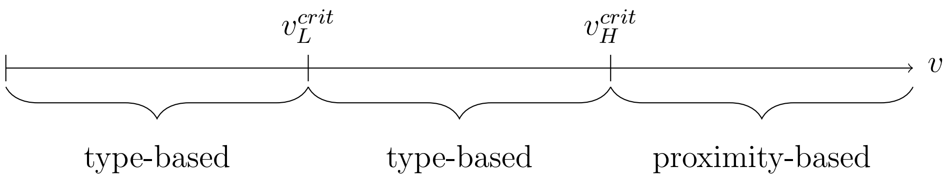


Figure 6: Preferences used in endogenous team formation dependent on v^{crit}.

In the following, we refer to $v < v_L^{crit}$ for type-based and $v > v_H^{crit}$ for proximity-based

[36] As opposed to the first-best solution, the fixed wage depends only on the own ability and not on the ability of the agent's teammate. If this was not the case, the agents would form the team solely based on the proximity towards each other and would not consider the abilities at all, as they would be covered by the fixed wage anyway. However, the first-best solution shows that it is not in the principal's interest to let the agents decide without consideration of the abilities. For the principal's expected profit, the ability and the proximity constellations within the team play a crucial role. The relative importance of both aspects depends on the values of c and v.

[37] A type-based decision of the low ability agents and a proximity-based decision of the high ability agents is not possible as v cannot be below v_L^{crit} and simultaneously higher than v_H^{crit}, as $v_H^{crit} > v_L^{crit}$.

decisions and thus, exclude the middle range scenario of Figure 6. For simplicity, we use the notation v^{crit}.

If the agents decide **type-based** ($0 < v < v^{crit} \wedge 0 < c < c^{crit}$), every agent always prefers to work with an agent of the high ability type, as shown in Table 2. This means that the two agents of type a_H always announce each other in the course of the endogenous team formation process and thus, build a team. Hence, the agents always form homogeneous teams if they decide based on the ability type. This is also reflected by the probabilities of occurrence in the second column of Table 3, as the probabilities for heterogeneous teams are zero in any case. The probabilities for the homogeneous teams only depend on the proximity constellations within the teams. This is similar to the case of exogenous team formation described in section 5.2.1. Forming homogeneous teams, the agents make exactly the same decision as the principal would if she formed the teams exogenously. Hence, the principal's expected profit is given by (28b) and the agents' fixed wage is calculated as in (29). This result is also displayed in Figure 7 that illustrates the expected profits with type-based endogenous team formation and exogenous team formation. It can be seen that the curves of the type-based endogenous team formation and of the exogenous team formation with homogeneous teams are the same.[38]

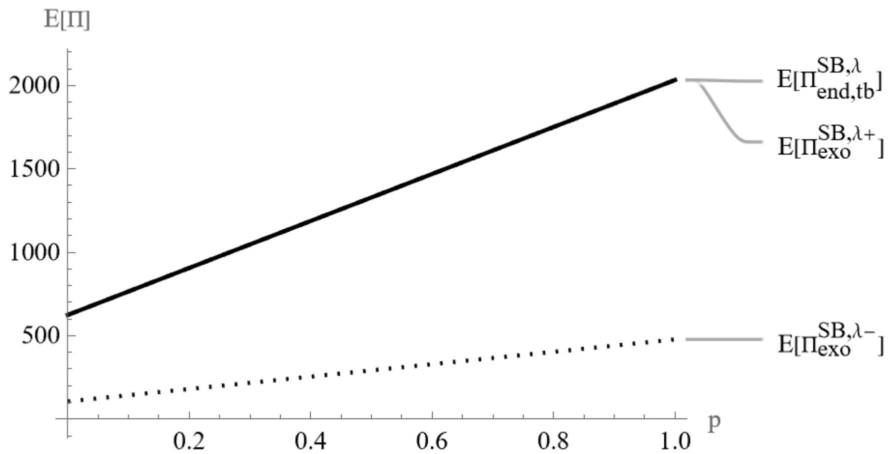


Figure 7: Comparison of second-best (SB) expected profits of principal with type-based (tb) decisions and $\kappa = 5$, $c = 0.5$, $v = 2$, $\lambda_L = -5$, $\lambda_H = 5$, $a_L = 3$, $a_H = 9$.

[38] To illustrate type-based preferences, both c and v have to be below the critical values in (32) and (33). In this example, c has to be smaller than $\frac{4}{5}$ (satisfied with $c = 0.5$) and v has to be smaller than 2.43 for the low ability agents and smaller than 21.87 for the high ability agents (both satisfied with $v = 2$). Note that the expected profit under endogenous team formation with type-based decisions cannot be negative.

In case of **proximity-based** decisions ($v^{crit} < v \ \vee \ c^{crit} < c$) by the agents, heterogeneous teams receive a positive probability of occurrence which is excluded in case of type-based decisions due to the principal's limited information. This can be seen in the third column of Table 3, as not all probabilities for heterogeneous teams are zero. Generally, this would not be desirable for the principal because she always prefers homogeneous teams in all other examined scenarios due to the limited amount of information available to her. However, the proximity-based decisions by the agents lead to statistically better proximity constellations within the teams as the agents have an information advantage regarding the proximity factor. Thus, endogenous team formation with proximity-based decisions by the agents is beneficial for the principal. Figure 8 shows the principal's expected profit in case of proximity-based endogenous team formation compared to the expected profit of exogenous team formation.[39]

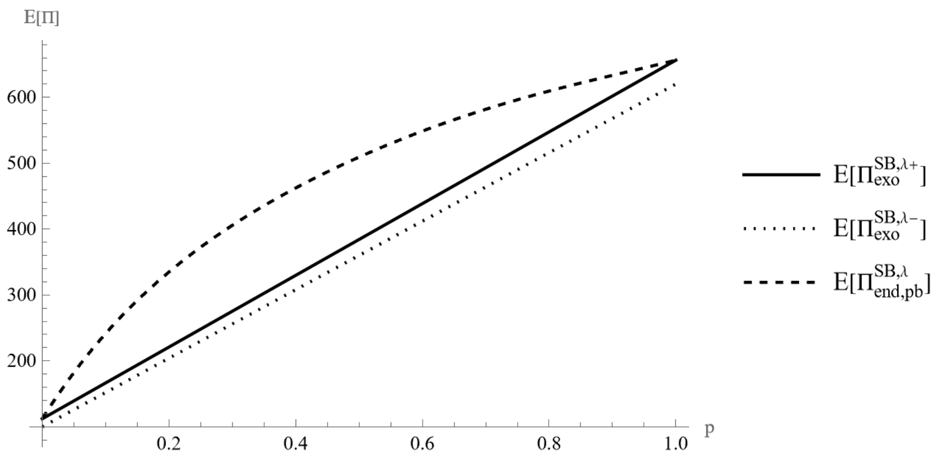


Figure 8: Comparison of second-best expected profits of principal with proximity-based (pb) decisions and $\kappa = 5$, $c = 0.5$, $v = 4$, $\lambda_L = -5$, $\lambda_H = 5$, $a_L = 5$, $a_H = 6$.

The curve of endogenous proximity-based team formation for $0 < p < 1$ is strictly higher than the one of exogenous team formation. This leads to the next proposition:

Proposition 3 *Endogenous team formation is strictly preferable over exogenous team formation if both agents decide proximity-based, i.e if the proximity parameters* c *and* v *are sufficiently high,* $v^{crit} < v \ \vee \ c^{crit} < c$. *In contrast to the other considered second-best scenarios, heterogeneous teams can occur under proximity-based endogenous team formation.*

[39] To illustrate proximity-based preferences, either c or v or both have to be higher than the critical values in (32) and (33). In this example, c has to be higher than $\frac{11}{61}$ (satisfied with $c = 0.5$) and v has to be higher than -4.875 for the low ability agents and higher than -7.02 for the high ability agents, thus, $v > 0$ needs to be satisfied (both satisfied with $v = 4$). Note that the expected profit of proximity-based endogenous team formation can also be negative.

If the proximity priorities are not sufficiently high, endogenous team formation does not add any value and the principal would form homogeneous teams herself. Focusing on the critical values c^{crit} and v^{crit}, the comparative statics results strongly depend on whether a_L or a_H or rather λ_L or λ_H increases.
Firstly, we focus on the derivatives with respect to a_H and λ_L:

$$\frac{\partial c^{crit}}{\partial a_H} = \frac{2\, a_H\, a_L^2\, k\, (\lambda_H - \lambda_L)}{(a_H^2\, \lambda_H - a_L^2\, \lambda_L)^2} > 0, \tag{34}$$

$$\frac{\partial v_H^{crit}}{\partial a_H} = \frac{3\, a_H \left(2\, a_H^2 - a_L^2 \frac{k - c\, \lambda_L}{k - c\lambda_H}\right)}{4\, (\lambda_H - \lambda_L)\, (k - c\lambda_L)} > 0, \quad \frac{\partial v_L^{crit}}{\partial a_H} = \frac{3\, a_H\, (2\, a_L^2 - a_L^2)}{4\, (\lambda_H - \lambda_L)\, (k - c\, \lambda_L)} > 0, \tag{35}$$

$$\frac{\partial c^{crit}}{\partial \lambda_L} = \frac{a_L^2\, (a_H^2 - a_L^2)\, k}{(a_H^2\, \lambda_H - a_L^2\, \lambda_L)^2} > 0, \tag{36}$$

$$\frac{\partial v_i^{crit}}{\partial \lambda_L} = \frac{3\, a_i^2 \left(\frac{a_H^2\, (k + c\, (\lambda_H - 2\, \lambda_L))}{(k - c\, \lambda_L)^2} - \frac{a_L^2}{k - c\, \lambda_H}\right)}{8\, (\lambda_H - \lambda_L)^2} > 0. \tag{37}$$

If the high ability $\boldsymbol{a_H}$ or the low proximity factor $\boldsymbol{\lambda_L}$ increases, the critical values increase which leads to a larger range of values (larger c or v) for decision-making based on the type-based ordering. This can be explained by the fact that a higher a_H makes the type-based ordering more interesting as a_H is the crucial parameter in type-based decisions because the advantage of homogeneous teams increases with an increasing difference between a_H and a_L. Furthermore, an increasing λ_L mitigates the negative effect of having bad proximity constellations within the teams so that the advantage of proximity-based decisions is not that big.
Now, we focus on the derivatives with respect to a_L and λ_H:

$$\frac{\partial c^{crit}}{\partial a_L} = -\frac{2\, a_H^2\, a_L\, k\, (\lambda_H - \lambda_L)}{(a_H^2\, \lambda_H - a_L^2\, \lambda_L)^2} < 0, \tag{38}$$

$$\frac{\partial v_H^{crit}}{\partial a_L} = -\frac{3\, a_L (2\, a_H^2 - a_H^2)}{4\, (\lambda_H - \lambda_L)(k - c\, \lambda_H)} < 0, \quad \frac{\partial v_L^{crit}}{\partial a_L} = -\frac{3\, a_L \left(2\, a_L^2 - a_H^2 \frac{k - c\, \lambda_H}{k - c\, \lambda_L}\right)}{4\, (\lambda_H - \lambda_L)\, (k - c\, \lambda_H)} < 0, \tag{39}$$

$$\frac{\partial c^{crit}}{\partial \lambda_H} = -\frac{a_H^2\, (a_H^2 - a_L^2)\, k}{(a_H^2\, \lambda_H - a_L^2\, \lambda_L)^2} < 0, \tag{40}$$

$$\frac{\partial v_i^{crit}}{\partial \lambda_H} = -\frac{3\, a_i^2 \left(\frac{a_H^2}{k - c\, \lambda_L} - \frac{a_L^2\, (k - c\, (2\, \lambda_H - \lambda_L))}{(k - c\, \lambda_H)^2}\right)}{8\, (\lambda_H - \lambda_L)^2} < 0. \tag{41}$$

If the low ability a_L or the high proximity factor λ_H increases, the critical values decrease which leads to a smaller range of values for type-based decision-making and a larger range of values for (smaller c or v) decision-making based on the proximity-based ordering. Proximity-based decisions mean that the probability to receive heterogeneous teams becomes positive and that the probability to have λ_H in the chosen teams is higher than for the type-based decision-making. Hence, heterogeneous teams as well as high proximity teams are more probable under proximity-based preferences so that the agents would benefit more from increasing a_L and λ_H and hence, decrease their critical value for deciding proximity-based.

6 Negative Effect of Proximity on Agents' Productivity

A crucial assumption for the above analysis is the positive effect of an increasing proximity on the productivity of the agents and thus, $c > 0$. However, as mentioned above, the literature shows that the effect of the proximity on the productivity of the employees is not so clear. There are several authors that discuss the possible negative effects of friendships in the workplace. Park (2019) finds that the productivity of the employees decreases when working together with a friend. As main reason he states that friends engage in socializing like chatting and gossip. Berman et al. (2002) also state that among the main risks of workplace friendships are office gossip and distractions from the actual work.[40] Besides that, friendships can also negatively affect hierarchies in firms and exacerbate solving conflicts of interest, as Morrison and Nolan (2007) show. Pillemer and Rothbard (2018) provide a theoretical framework that analyzes the negative impact of friendships on the organizational life. Overall, there exists a large body of literature that indicates the negative effects of friendships on the productivity of the employees. Also, the literature suggests that a low social distance, as we define it, leads to interpersonal attraction and thus, friendship between co-workers. Batool and Malik (2010) state that similarity in attitudes is a main aspect that leads to interpersonal attraction. As we define a low social distance by similarities in the personal characteristics, that goes along with the argument of Batool and Malik (2010) and therefore can be seen as a kind of friendship. Hence, the literature justifies the assumption that a higher proximity can also have a negative effect on the employees' productivity, which means that not only the positive effect

[40] Note that Methot et al. (2021) focus on the effects of small talk and state that although it is an important social interaction it can distract from the employees' work engagement.

in the form of $c > 0$ should be considered but also the negative effect and thus, $c < 0$. Hence, for the following analysis we consider $c < 0$ with $\kappa > c\lambda_L$, whereby all other assumptions from the model setup remain the same. Assuming $c < 0$ means that an increasing proximity decreases the productivity of the agents. This could happen if the low social distance between the teammates leads to a lot of chatting and other forms of unproductive socializing. Thus, the cost of (productive) effort increases with increasing proximity. This also means that the direct effect of the proximity (which is positive for the agents through v) is opposed to the indirect effect through the effort (described above through c), which leads to interesting implications as described below.

The focus of the following analysis lies on the second-best solution. Firstly, we consider the case of **exogenous team formation**. The results are analogous to the results for $c > 0$ in section 5.2.1. However, the expected profit of the principal looks differently, as shown in Figure 9.

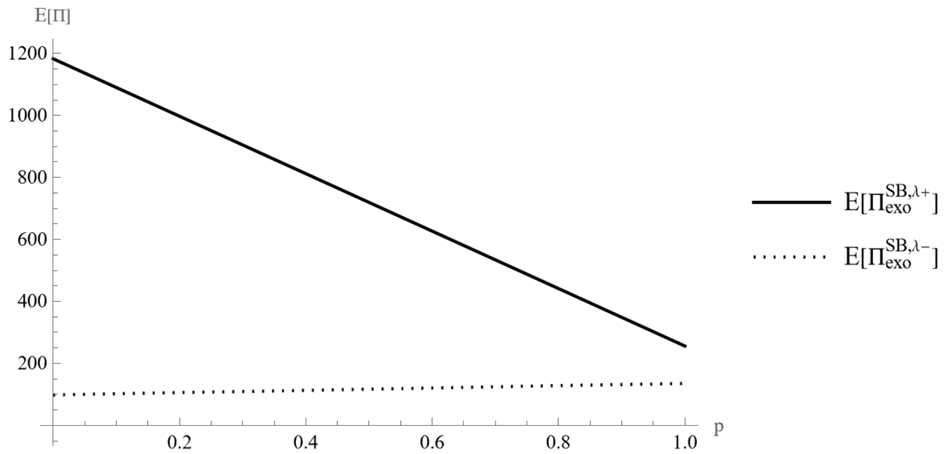


Figure 9: Comparison of second-best expected profits of principal in case of exogenous team formation with $\kappa = 7$, $c = -0.8$, $v = 4$, $\lambda_L = -7$, $\lambda_H = 7$, $a_L = 2$, $a_H = 7$.

Similar to the previous results, the principal prefers homogeneous over heterogeneous teams in any situation. With an increasing p the expected profit, especially in case of homogeneous teams, decreases, as a higher proximity becomes more likely and thus, they tend to spend more time and effort in unproductive activities.

The analysis of the **endogenous team formation** is also analogous to the analysis for $c > 0$. As before, the agents can decide about their teams based on the ability types or the proximity factors towards their potential teammates. However, with $c < 0$, there only exists a critical value for v that determines whether the agents decide type- or proximity-based. Thus, the agents decide type-based if

$$v < \frac{3\,a_i^2\,(a_H^2\,(k - c\lambda_H) - a_L^2\,(k - c\lambda_L))}{8\,(\lambda_H - \lambda_L)\,(k - c\lambda_H)\,(k - c\lambda_L)} = v^{crit,c<0} = v^{crit}. \tag{42}$$

Note that this critical value is exactly the same as in (32) for $c > 0$. In case of **type-based** decisions by the agents, the results are analogous to the case of $c > 0$. As every agent always prefers to team up with an agent with high ability, homogeneous teams are the logical consequence of the endogenous team formation. Hence, the result of the endogenous team formation would be exactly the same as the one of the exogenous team formation by the principal. Therefore, if the agents decide type-based, endogenous team formation does not add any value for the principal. This result is independent from the actual value of c (positive or negative).

If the agents decide **proximity-based** ($v > v^{crit}$), the results for $c < 0$ are also analogous to the results for $c > 0$. As before, endogenous team formation is always preferable with proximity-based decisions by the agents. Figure 10 shows this exemplary by illustrating the expected profits for endogeneous and proximity-based team formation as well as exogenous team formation.[41]

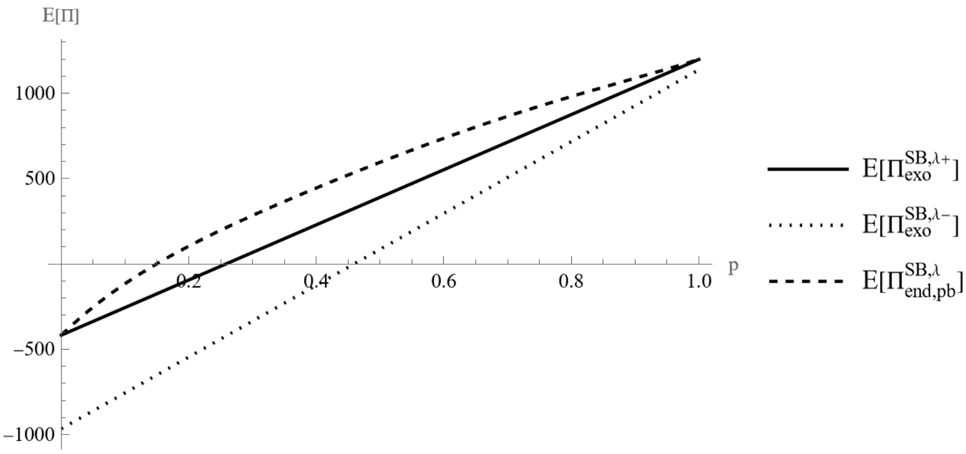


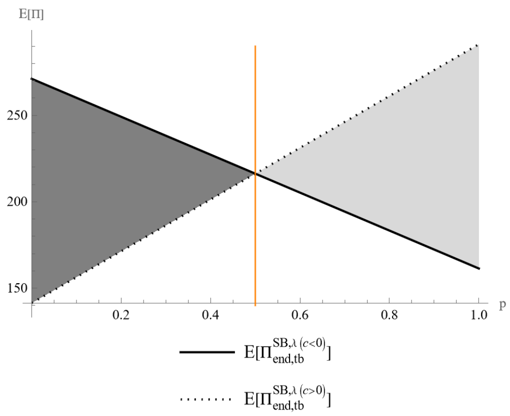
Figure 10: Comparison of second-best expected profits of principal in case of endogenous team formation and proximity-based decisions with $\kappa = 7$, $c = -0.8$, $v = 40$, $\lambda_L = -7$, $\lambda_H = 7$, $a_L = 2$, $a_H = 6$.

Note that for low values of p the principal's expected profits can become negative due to a high probability of $\lambda_L < 0$. Although an increasing p statistically leads to a higher proximity among the teammates and therefore a higher cost of effort, the

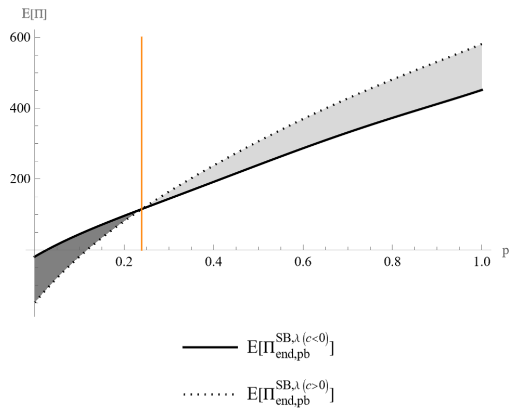
[41] To illustrate proximity-based preferences, v has to be higher than the critical value in (42) for the high as well as for the low ability type. In this example, v has to be higher than 2.72109 for the low ability agents and higher than 24.4898 for the high ability agents (both satisfied with $v = 40$).

principal's expected profits increase. Thus, for the given parameters, the positive direct effect of the higher proximity outweighs the negative indirect effect through the cost of effort. The above observations can be explained by the weight v of the direct proximity effect.[42] Since the direct effect is positive (negative) for high (low) proximity, an increasing p enhances the probability for the positive impact of high proximity and thereby the expected profit. When p is low, the proximity is also statistically low and the negative direct effect dominates so that the overall expected profit can even become negative.

Figures 11a and 11b compare the principal's expected profits for the second-best solution with $c > 0$ and $c < 0$. Figure 11a depicts the results for type-based decisions, whereas Figure 11b contains the comparison for proximity-based decisions.



(a) Type-based decisions.
$v = 0.5 < v_L^{crit} = 1.45$.



(b) Proximity-based decisions.
$v = 15 > v_H^{crit} = 13.05$.

Figure 11: Comparison of second-best expected profits ($c < 0$ and $c > 0$) in case of endogenous team formation with $a_H = 6$, $a_L = 2$, $\kappa = 5$, $\lambda_H = 5$, $\lambda_L = -5$, $c(c < 0) = -0.3$ and $c(c > 0) = 0.3 < c^{crit}$. The orange line marks $E(\Pi_{end}^{SB,\lambda(c<0)}) = E(\Pi_{end}^{SB,\lambda(c>0)})$.

In both cases, the two curves have an intersection which is marked in the figures. Also in both cases, the principal's expected profit for $c < 0$ is higher for $p < p^{crit}$ (dark grey area), whereby p^{crit} marks the intersection of the two curves. Low values of p indicate that the proximity among the agents is statistically low. In case of $c < 0$, decreasing values of p have a positive indirect effect through the cost of effort, whereas the opposite is the case for $c > 0$. With an increasing p, the positive effect through the effort in case of $c > 0$ becomes stronger and the opposite happens for $c < 0$, which is why the expected profit for $c > 0$ dominates (light grey area) above a certain value of p. Note that the slopes of the two curves have the same direction

[42] Note that v has to be higher than v_H^{crit} since otherwise, the high-ability agents would decide type-based, see Figure 6.

for proximity-based decisions and opposite directions for type-based decisions.
In sum, although chatting or friendship relations lead to higher effort costs with $c < 0$ due to the indirect proximity effect, endogenous team formation is still the preferred mean to make use of the agents' private information as long as they form their teams proximity-based (if $v > v^{crit}$).

7 Conclusion

We have shown that without taking proximity into account, endogenous team formation does not add any value and the employer decides to form homogeneous teams (positive assortative matching) regarding the employees' abilities by herself. On the contrary, if the agents' proximity priorities are sufficiently high, endogenous team formation is strictly preferable over exogenous team formation. If the agents decide proximity- rather than type-based, heterogeneous teams receive a positive ex ante probability of occurrence which is impossible under type-based preferences, exogenous team formation and especially without proximity consideration. The results partly carry over to the setting in which the proximity has a negative effect on the productivity of the agents. Self-organized team formation is still preferred by the employer as long as the proximity priorities of the agents are sufficiently high.

We are aware that this paper does not consider a control problem. As our paper uses a new model that examines the team formation process under proximity consideration analytically, we contribute to the literature by showing under which conditions self-organized team formation by the agents is strictly preferable over exogenous team formation by the principal. Future research could use our paper as a starting point in order to add a control problem to our approach.[43]

An extension of our paper in future research could also include the consideration of a second period in which new employees enter the team formation pool. Then, the incumbent team members could update their proximity considerations and have to decide whether they want to stay with their old team member or whether they prefer a new one. This could be interesting as several studies show that individuals' team preferences can depend on their familiarity towards the other team member.

[43] Reichelstein (1997) follows the same procedure. He uses goal congruence and thereby, no control problem.

Appendix

Appendix A1 - Benchmark Analysis

Proof of Lemma 1:

The principal faces the optimization problem as in (9), which is displayed in more detail:

$$\begin{aligned} &\underset{\substack{e_{ij},e_{ji},\\ e_{mn},e_{nm}}}{max}\ E(\Pi) \\ &= \underset{\substack{e_{ij},e_{ji},\\ e_{mn},e_{nm}}}{max}\ \{a_i a_j(e_{ij}+e_{ji}) - \kappa\frac{e_{ij}^2}{2} - \kappa\frac{e_{ji}^2}{2} + a_m a_n(e_{mn}+e_{nm}) - \kappa\frac{e_{mn}^2}{2} - \kappa\frac{e_{nm}^2}{2}\}. \end{aligned}$$

Thus, she considers the following derivation

$$\frac{\partial E(\Pi)}{\partial e_{ij}} = a_i a_j - \kappa e_{ij}.$$

As the first-order condition $\frac{\partial E(\Pi)}{\partial e_{ij}} = 0$ holds, it follows that $e_{ij} = e_{ij}^{FB}$.

In order to check the second-order condition, we form the hessian matrix:

$$H_f = \begin{pmatrix} \frac{\partial^2 E(\Pi)}{\partial e_{ij}^2} & \frac{\partial^2 E(\Pi)}{\partial e_{ij}\partial e_{ji}} & \cdots & \cdots \\ \frac{\partial^2 E(\Pi)}{\partial e_{ji}\partial e_{ij}} & \frac{\partial^2 E(\Pi)}{\partial e_{ji}^2} & \vdots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ \vdots & \vdots & & \ddots \end{pmatrix}$$

$$= \begin{pmatrix} -\kappa & 0 & 0 & 0 \\ 0 & -\kappa & 0 & 0 \\ 0 & 0 & -\kappa & 0 \\ 0 & 0 & 0 & -\kappa \end{pmatrix}$$

We now calculate the determinants of the principal minors:

$det\big(-\kappa\big) = -\kappa < 0$,

$$det\begin{pmatrix} -\kappa & 0 \\ 0 & -\kappa \end{pmatrix} = \kappa^2 > 0,$$

$$det\begin{pmatrix} -\kappa & 0 & 0 \\ 0 & -\kappa & 0 \\ 0 & 0 & -\kappa \end{pmatrix} = -\kappa^3 < 0,$$

$det(H_f) = \kappa^4 > 0.$

As the algebraic signs of the determinants are alternating, H_f is negative definite, which implies that e_{ij}^{FB} is a local maximum. ■

Proof of F_{ij}^{FB}:

In order to calculate the fixed wage of agent i, the binding participation constraint as given by (PC 1) needs to be considered:

$$F_{ij} + \frac{1}{2}(a_i a_j(e_{ij} + e_{ji})) - \kappa\frac{e_{ij}^2}{2} = 0.$$

Inserting the first-best effort given by (10) leads to:

$$F_{ij} + \frac{1}{2}\left(\frac{2a_i^2 a_j^2}{\kappa}\right) - \kappa\frac{a_i^2 a_j^2}{2\kappa^2} = 0.$$

Solving the above equation for F_{ij} leads to $F_{ij} = F_{ij}^{FB}$. ■

Proof of Lemma 2:

Agent i seeks to optimize his expected utility as in (6), which is displayed in more detail:

$$\max_{e_{ij}} E(U_{ij}) = \max_{e_{ij}} F_{ij} + \frac{1}{2}(a_i a_j(e_{ij} + e_{ji})) - \kappa\frac{e_{ij}^2}{2}.$$

Thus, he considers the following derivation

$$\frac{\partial E(U_{ij})}{\partial e_{ij}} = \frac{a_i a_j}{2} - \kappa e_{ij}.$$

As the first-order condition $\frac{\partial E(U_{ij})}{\partial e_{ij}} = 0$ holds, it follows that $e_{ij} = e_{ij}^{SB}$.

For the second-order condition, we obtain:

$$\frac{\partial^2 E(U_{ij})}{\partial {e_{ij}}^2} = -\kappa < 0.$$

Thus, $e_{ij} = e_{ij}^{SB}$ is the maximum of the agent's expected utility. ■

Proof of $\boldsymbol{F_{ij}^{SB}}$:

In order to calculate the fixed wage of agent i, the binding participation constraint as given by (PC 1) needs to be considered:

$$F_{ij} + \frac{1}{2}(a_i a_j (e_{ij} + e_{ji})) - \kappa \frac{e_{ij}^2}{2} = 0.$$

Inserting the second-best effort given by (13) leads to:

$$F_{ij} + \frac{1}{2}\left(\frac{a_i^2 a_j^2}{\kappa}\right) - \kappa \frac{a_i^2 a_j^2}{8\kappa^2} = 0.$$

Solving the above equation for F_{ij} leads to $F_{ij} = F_{ij}^{SB}$. ■

Proof of Proposition 1:

Under consideration of (11a) and (11b), the inequation $E(\Pi_{exo}^{FB+}) > E(\Pi_{exo}^{FB-})$ can be simplified as follows:

$$\begin{aligned} \frac{a_H^4 + a_L^4}{\kappa} &> \frac{2a_H^2 a_L^2}{\kappa} \\ \Leftrightarrow \quad a_H^4 - a_H^2 a_L^2 &> a_H^2 a_L^2 - a_L^4 \\ \Leftrightarrow a_H^2(a_H^2 - a_L^2) &> a_L^2(a_H^2 - a_L^2) \\ \Leftrightarrow \quad a_H^2 &> a_L^2. \end{aligned}$$

As we assume $a_H > a_L$, the above inequation holds. Due to the above and (15), $E(\Pi_{exo}^{SB}) = \frac{3}{4}E(\Pi_{exo}^{FB})$, it follows that $E(\Pi_{exo}^{SB+}) > E(\Pi_{exo}^{SB-})$. ■

Appendix A2 - Analysis with Proximity

Proof of Lemma 3:

The principal seeks to induce the effort that maximizes her expected profit given the abilities and proximity factors of the agents. Thus, she faces the following optimization problem:

$$\begin{aligned}
&\underset{\substack{e_{ij},e_{ji},\\ e_{mn},e_{nm}}}{max}\ E(\Pi|\lambda_{ij},\lambda_{mn})\\
&= \underset{\substack{e_{ij},e_{ji},\\ e_{mn},e_{nm}}}{max}\ \{a_i a_j(e_{ij}+e_{ji}) + v\lambda_{ij} - (\kappa - c\lambda_{ij})\kappa\frac{e_{ij}^2}{2} + v\lambda_{ij} - (\kappa - c\lambda_{ij})\kappa\frac{e_{ji}^2}{2}\\
&\quad + a_m a_n(e_{mn}+e_{nm}) + v\lambda_{mn} - (\kappa - c\lambda_{mn})\kappa\frac{e_{mn}^2}{2} v\lambda_{mn} - (\kappa - c\lambda_{mn})\kappa\frac{e_{nm}^2}{2}\}.
\end{aligned}$$

Thus, she considers the following derivation

$$\frac{\partial E(\Pi|\lambda_{ij},\lambda_{mn})}{\partial e_{ij}} = a_i a_j - (\kappa - c\lambda_{ij})e_{ij}.$$

As the first-order condition $\frac{\partial E(\Pi|\lambda_{ij},\lambda_{mn})}{\partial e_{ij}} = 0$ holds, it follows that $e_{ij} = e_{ij}^{FB,\lambda}$.

We check the second-order condition analogous to the proof for Lemma 1:

$$H_f = \begin{pmatrix} \text{-}(\kappa\text{-}c\lambda_{ij}) & 0 & 0 & 0\\ 0 & \text{-}(\kappa\text{-}c\lambda_{ij}) & 0 & 0\\ 0 & 0 & \text{-}(\kappa\text{-}c\lambda_{mn}) & 0\\ 0 & 0 & 0 & \text{-}(\kappa\text{-}c\lambda_{mn}) \end{pmatrix}$$

We now calculate the determinants of the principal minors:

$det\big(\text{-}(\kappa\text{-}c\lambda_{ij})\big) = \text{-}(\kappa\text{-}c\lambda_{ij}) < 0,$

$$det\begin{pmatrix} \text{-}(\kappa\text{-}c\lambda_{ij}) & 0\\ 0 & \text{-}(\kappa\text{-}c\lambda_{ij}) \end{pmatrix} = (\kappa\text{-}c\lambda_{ij})^2 > 0,$$

$$det\begin{pmatrix} \text{-}(\kappa\text{-}c\lambda_{ij}) & 0 & 0\\ 0 & \text{-}(\kappa\text{-}c\lambda_{ij}) & 0\\ 0 & 0 & \text{-}(\kappa\text{-}c\lambda_{mn}) \end{pmatrix} = \text{-}(\kappa\text{-}c\lambda_{ij})^2(\kappa\text{-}c\lambda_{mn}) < 0,$$

$det(H_f) = (\kappa\text{-}c\lambda_{ij})^2(\kappa\text{-}c\lambda_{mn})^2 > 0.$

As the algebraic signs of the determinants are alternating, H_f is negative definite, which implies that $e_{ij}^{FB,\lambda}$ is a local maximum. ■

Proof of Proposition 2:

The following tables illustrate the six possible preference orderings from the principals view. The higher the critical values for v and c, the further up are heterogeneous teams (grey) in the ordering. Type-based means a decision based on the ability type of the teammates whereas proximity-based means a decision where the teammates' proximity is at least in one comparison more important than the teammate's ability.

Preferences	Type-based $0 < v < v^c \wedge 0 < c < c^c$	Proximity-based I $v^c < v < v^{c'} \wedge 0 < c < c^{c'}$	Proximity-based II $v^{c'} < v < v^{c''} \wedge 0 < c < c^c$
1	$(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_H)$	$(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_H)$	$(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_H)$
2	$(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_L)$	$(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_L)$	$(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_L)$
3	$(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_H)$	$(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_H)$	$(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_H)$
4	$(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_L)$	$(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_H)$	$(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_H)$
5	$(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_H)$	$(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_L)$	$(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_L)$
6	$(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_L)$	$(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_L)$	$(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_L)$
7	$(a_H, a_L; \lambda_L), (a_H, a_L; \lambda_L)$	$(a_H, a_L; \lambda_L), (a_H, a_L; \lambda_L)$	$(a_H, a_L; \lambda_L), (a_H, a_L; \lambda_L)$

(a)

Preferences	Proximity-based III $v^{c''} < v < v^{c'''} \wedge 0 < c < c^c$	Proximity-based IV $v^{c'''} < v \wedge 0 < c < c^{c''}$	Proximity-based V $v^{c'''} < v \wedge c^{c''} < c < \frac{k}{\lambda_H}$
1	$(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_H)$	$(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_H)$	$(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_H)$
2	$(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_L)$	$(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_H)$	$(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_H)$
3	$(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_H)$	$(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_H)$	$(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_H)$
4	$(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_H)$	$(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_H)$	$(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_L)$
5	$(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_L)$	$(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_L)$	$(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_H)$
6	$(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_L)$	$(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_L)$	$(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_L)$
7	$(a_H, a_L; \lambda_L), (a_H, a_L; \lambda_L)$	$(a_H, a_L; \lambda_L), (a_H, a_L; \lambda_L)$	$(a_H, a_L; \lambda_L), (a_H, a_L; \lambda_L)$

(b)

Table 4: Team preferences of principal.
Black: homogeneous (+) teams; Grey: heterogeneous (-) teams.

The critical values are determined by the comparison of the principal's expected profit dependent on the team constellations:

$$v^c = \frac{a_H^4 (\kappa - c\lambda_H) - 2a_H^2 a_L^2 (\kappa - c\lambda_L) + a_L^4 (\kappa - c\lambda_H)}{4(\lambda_H - \lambda_L)(\kappa - c\lambda_H)(\kappa - c\lambda_L)}, \tag{43}$$

$$v^{c'} = \frac{a_H^4 (\kappa - c\lambda_H) - 2a_H^2 a_L^2 (\kappa - c\lambda_L) + a_L^4 (\kappa - c\lambda_L)}{2(\lambda_H - \lambda_L)(\kappa - c\lambda_H)(\kappa - c\lambda_L)}, \tag{43a}$$

$$v^{c''} = \frac{a_H^4 (\kappa - c\lambda_H) + a_H^2 a_L^2 (c(\lambda_H + \lambda_L) - 2\kappa) + a_L^4 (\kappa - c\lambda_H)}{2(\lambda_H - \lambda_L)(\kappa - c\lambda_H)(\kappa - c\lambda_L)}, \tag{43b}$$

$$v^{c'''} = \frac{a_H^4 (\kappa - c\lambda_L) - 2a_H^2 a_L^2 (\kappa - c\lambda_L) + a_L^4 (\kappa - c\lambda_H)}{2(\lambda_H - \lambda_L)(\kappa - c\lambda_H)(\kappa - c\lambda_L)}, \tag{43c}$$

with $0 < v^c < v^{c'} < v^{c''} < v^{c'''}$ and

$$c^c = \frac{\kappa\,(a_H^2 - a_L^2)^{\,2}}{\lambda_H\,(a_H^4 + a_L^4) - 2a_H^2 a_L^2 \lambda_L}, \tag{44}$$

$$c^{c'} = \frac{\kappa\,(a_H^2 - a_L^2)}{a_H^2\lambda_H + a_L^2\,(\lambda_H - 2\lambda_L)}, \tag{44a}$$

$$c^{c''} = \frac{\kappa\,(a_H^2 - a_L^2)}{a_H^2\lambda_H - a_L^2\lambda_L}, \tag{44b}$$

with $0 < c^c < c^{c'} < c^{c''} < \frac{\kappa}{\lambda_H}$. In order to determine the ex ante probabilities, the principal considers a game tree with six stages (λ_{ij}, λ_{im}, λ_{in}, λ_{jm}, λ_{jn} and λ_{mn}) and two possible proximity values each, either λ_H with probability p or λ_L with probability $1 - p$. Thus, $2^6 = 64$ possibilities have to be considered. The corresponding tree is shown for the determination of the ex ante probabilities in the second-best solution, see Figure 12. Dependent on v and c (type-based or proximity-based decision I-V) as well as the ability-proximity combination, the principal decides which team composition she prefers. Hence, the ex ante probabilities $P\big[(a_i, a_j; \lambda_{ij}), (a_m, a_n; \lambda_{mn})\big]$ occur dependent on the actual values of c and v. A comparison of these ex ante probabilities dependent on c and v leads to the proposition. The following tables provide more detail concerning the actual probabilities of occurrence.

$P\big[$Team A, Team B$\big]$	Teams	Type-based $0 < v < v^c \;\wedge\; 0 < c < c^c$	Proximity-based I $v^c < v < v^{c'} \;\wedge\; 0 < c < c^{c'}$
$P\big[(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_H)\big]$	+	p^2	p^2
$P\big[(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_L)\big]$	+	$p\,(1-p)$	$p\,(1-p)$
$P\big[(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_H)\big]$	+	$(1-p)\,p$	$(1-p)\,p$
$P\big[(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_L)\big]$	+	$(1-p)\,(1-p)$	$(1-p)^4\,(1+p)^2$
$P\big[(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_H)\big]$	-	0	$(1-p)^2\,(2\,p^2 - p^4)$
$P\big[(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_L)\big]$	-	0	0
$P\big[(a_H, a_L; \lambda_L), (a_H, a_L; \lambda_L)\big]$	-	0	0
$\sum$		1	1

(a) Type-based and Proximity-based I.

$P\big[\text{Team A, Team B}\big]$	Teams	Proximity-based II $v^{c'} < v < v^{c''} \ \wedge \ 0 < c < c^{c}$	Proximity-based III $v^{c''} < v < v^{c'''} \ \wedge \ 0 < c < c^{c}$
$P\big[(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_H)\big]$	+	p^2	p^2
$P\big[(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_L)\big]$	+	$p\,(1-p)$	$p\,(1-p)$
$P\big[(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_H)\big]$	+	$p\,(1-p)^3\,(1+p)^2$	$p\,(1-p)^3\,(1+p)^2$
$P\big[(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_L)\big]$	+	$(1-p)^4\,(1+p)^2$	$(1-p)^6$
$P\big[(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_H)\big]$	-	$(1-p)\,(2\,p^2-p^4)$	$(1-p)\,(2\,p^2-p^4)$
$P\big[(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_L)\big]$	-	0	$(1-p)^4\,4\,p$
$P\big[(a_H, a_L; \lambda_L), (a_H, a_L; \lambda_L)\big]$	-	0	0
$\sum$		1	1

(b) Proximity-based II and III.

$P\big[\text{Team A, Team B}\big]$	Teams	Proximity-based IV $v^{c'''} < v \ \wedge \ 0 < c < c^{c''}$	Proximity-based V $v^{c'''} < v \ \wedge \ c^{c''} < c < \frac{k}{\lambda_H}$
$P\big[(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_H)\big]$	+	p^2	p^2
$P\big[(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_L)\big]$	+	$p\,(1-p)^3\,(1+p)^2$	$p\,(1-p)^3(1+p)^2$
$P\big[(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_H)\big]$	+	$p\,(1-p)^3\,(1+p)^2$	$p\,(1-p)^5$
$P\big[(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_L)\big]$	+	$(1-p)^6$	$(1-p)^6$
$P\big[(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_H)\big]$	-	$(1-p^2)\,(2\,p^2-p^4)$	$(1-p^2)\,(2\,p^2-p^4)$
$P\big[(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_L)\big]$	-	$(1-p)^4\,4\,p$	$(1-p)^3\,4\,p$
$P\big[(a_H, a_L; \lambda_L), (a_H, a_L; \lambda_L)\big]$	-	0	0
$\sum$		1	1

(c) Proximity-based IV and V.

Table 5: Probabilities of occurrence for team constellations in the first-best solution.

$P\big[\text{Team A, Team B}\big]$	Teams	T		PI		PII		PIII		PIV		PV
$P\big[(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_H)\big]$	+		$=$		$=$		$=$		$=$		$=$	
$P\big[(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_L)\big]$	+		$=$		$=$		$=$		$>$		$=$	
$P\big[(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_H)\big]$	+		$=$		$>$		$=$		$=$		$>$	
$P\big[(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_L)\big]$	+		$>$		$=$		$>$		$=$		$=$	
$P\big[(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_H)\big]$	-		$<$		$<$		$=$		$<$		$=$	
$P\big[(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_L)\big]$	-		$=$		$=$		$<$		$=$		$<$	
$P\big[(a_H, a_L; \lambda_L), (a_H, a_L; \lambda_L)\big]$	-		$=$		$=$		$=$		$=$		$=$	

Table 6: Comparison of team constellation probabilities dependent on v and c based on Table 5.

■

Proof of $F_{ij}^{FB,\lambda}$:

In order to calculate the fixed wage of agent i, the binding participation constraint as given by (PC 2) needs to be considered:

$$F_{ij} + \frac{1}{2}(a_i a_j(e_{ij} + e_{ji})) + v\lambda_{ij} - (\kappa - c\lambda_{ij})\frac{e_{ij}^2}{2} = 0.$$

Inserting the first-best effort given by (21) leads to:

$$F_{ij} + \frac{1}{2}\left(\frac{2a_i^2 a_j^2}{\kappa - c\lambda_{ij}}\right) + v\lambda_{ij} - (\kappa - c\lambda_{ij})\frac{a_i^2 a_j^2}{2(\kappa - c\lambda_{ij})^2} = 0.$$

Solving the above equation for F_{ij} leads to $F_{ij} = F_{ij}^{FB,\lambda}$. ■

Proof of Lemma 4:

Agent i seeks to optimize his expected utility given the proximity factor as in (24), which is displayed in more detail:

$$\max_{e_{ij}} E(U_{ij}|\lambda_{ij}) = \max_{e_{ij}} F_{ij} + \frac{1}{2}(a_i a_j(e_{ij} + e_{ji})) - (\kappa - c\lambda_{ij})\frac{e_{ij}^2}{2}.$$

Thus, he considers the following derivation

$$\frac{\partial E(u_{ij}|\lambda_{ij})}{\partial e_{ij}} = \frac{a_i a_j}{2} - (\kappa - c\lambda_{ij})e_{ij}.$$

As the first-order condition $\frac{\partial E(u_{ij}|\lambda_{ij})}{\partial e_{ij}} = 0$ holds, it follows that $e_{ij} = e_{ij}^{SB,\lambda}$.

For the second-order condition, we obtain:

$$\frac{\partial^2 E(u_{ij}|\lambda_{ij})}{\partial {e_{ij}}^2} = -(\kappa - c\lambda_{ij}) < 0.$$

Thus, $e_{ij} = e_{ij}^{SB,\lambda}$ is the maximum of the agent's expected utility. ■

Proof of equation (29) - $F_{ij,exo}^{SB,\lambda+}$:

In order to calculate the fixed wage of agent i, the binding participation constraint as given by (PC 2) needs to be considered:

$$F_{ij} + p\left(\frac{1}{2}(a_i a_j(e_{ij}^{SB,\lambda_H} + e_{ji}^{SB,\lambda_H})) + v\lambda_H - (\kappa - c\lambda_H)\frac{(e_{ij}^{SB,\lambda_H})^2}{2}\right)$$
$$+(1-p)\left(\frac{1}{2}(a_i a_j(e_{ij}^{SB,\lambda_L} + e_{ji}^{SB,\lambda_L})) + v\lambda_L - (\kappa - c\lambda_L)\frac{(e_{ij}^{SB,\lambda_L})^2}{2}\right) = 0.$$

Inserting the second-best effort given by (26) leads to:

$$F_{ij} + p\left(\frac{3\,a_i^2 a_j^2}{8(\kappa - c\lambda_H)}\right) + (1-p)\left(\frac{3\,a_i^2 a_j^2}{8(\kappa - c\lambda_L)}\right) + pv\lambda_H + (1-p)v\lambda_L = 0.$$

Solving the above equation for F_{ij} leads to $F_{ij} = F_{ij,exo}^{SB,\lambda}$. ■

Proof of equations (32) and (33) - v^{crit} and c^{crit} in Lemma 5:

With $e_{ij}^{SB,\lambda_L} = e_{ji}^{SB,\lambda_L} = \frac{a_i a_j}{2(\kappa - c\lambda_L)}$ and $e_{ij}^{SB,\lambda_H} = e_{ji}^{SB,\lambda_H} = \frac{a_i a_j}{2(\kappa - c\lambda_H)}$, (31) becomes:

$$\frac{1}{2}(a_i\,a_H(e_{ij}^{SB,\lambda_L} + e_{ji}^{SB,\lambda_L})) + v\lambda_L - (\kappa - c\lambda_L)\frac{(e_{ij}^{SB,\lambda_L})^2}{2}$$
$$> \frac{1}{2}(a_i\,a_L(e_{ij}^{SB,\lambda_H} + e_{ji}^{SB,\lambda_H})) + v\lambda_H - (\kappa - c\lambda_H)\frac{(e_{ij}^{SB,\lambda_H})^2}{2}$$
$$\Leftrightarrow\ v\lambda_L + \frac{3\,a_H^2\,a_i^2}{8(\kappa - c\lambda_L)} > v\lambda_H + \frac{3\,a_L^2\,a_i^2}{8(\kappa - c\lambda_H)}.$$

Rearranging with respect to v leads to (32) and with respect to c leads to (33). ■

Proof of Table 3:

$P\big[$Team A, Team B$\big]$	Proximity-based decisions $v^{crit} < v\ \vee\ c^{crit} < c$
$P\big[(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_H)\big]$	p^2
$P\big[(a_H, a_H; \lambda_H), (a_L, a_L; \lambda_L)\big]$	$p(1-p)$
$P\big[(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_H)\big]$	$(1-p)^5 p$
$P\big[(a_H, a_H; \lambda_L), (a_L, a_L; \lambda_L)\big]$	$(1-p)^5(1-p)$
$P\big[(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_H)\big]$	$(1-p)(2\,p^2 - p^4)$
$P\big[(a_H, a_L; \lambda_H), (a_H, a_L; \lambda_L)\big]$	$4\,p\,(1-p)^3$
$P\big[(a_H, a_L; \lambda_L), (a_H, a_L; \lambda_L)\big]$	0
$\sum$	1

Table 7: Probabilities of occurrence for team constellations in case of proximity-based endogenous team formation.

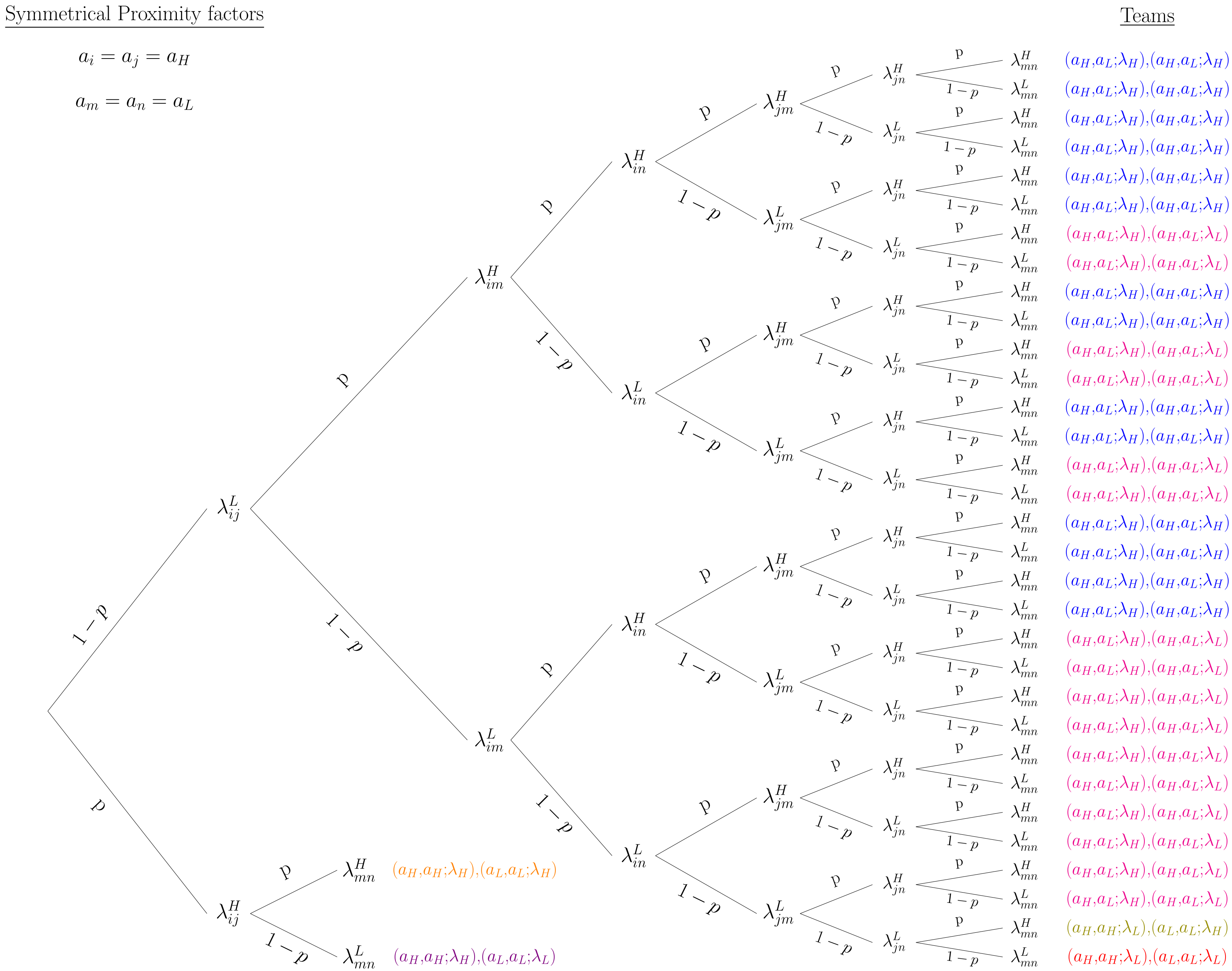


Figure 12: Probability tree of proximity factor occurrence and preferred team constellations under proximity-based ordering.

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Essay II

Center of Excellence: Accounting Trade-offs of Partial Centralization*

Abstract

This paper studies whether the trend of implementing a Center of Excellence (CoE) is as beneficial as it is claimed to be. A CoE is a centralized business unit which should increase control and thus, decrease compliance risks by adopting an expertise-based service process that is needed by more than one decentralized unit. We show that the advantageousness of a CoE depends on the firm's focus and human resources. On the one hand, we show that a CoE improves the compliance performance since earnings manipulation strictly decreases and the corresponding added value through a consulting activity increases in many cases. On the other hand, the effort for the main process exerted in the division is reduced in the same ratio as earnings manipulation in the presence of a CoE. The effort for the service process as well as the expected profit are not always higher with a CoE. The higher the variance of the division manager's ability, the more likely is a higher expected profit without a CoE. With a low ability variance and a high penalty on earnings manipulation, a CoE can generate higher expected profits even if its ability is lower than the division manager's expected ability.

* This chapter is joint work with Nicola Bethmann (formerly Leibniz Universität Hannover).

1 Introduction

For decades, decentralization has been seen as the key factor for business success and the predominant corporate structure. Now, due to increased compliance regulations and digitization, more and more firms implement so called Shared Service Centers (SSCs) to comply with these requirements. SSCs should centralize some service processes in a separate business unit to get a mixed approach between centralization and decentralization. It aims at increasing efficiency by being an independent unit which adopts and pools some processes that are needed by more than one division (KPMG, 2013). Well known firms such as American Express, IBM and Hewlett Packard have already implemented initiatives regarding Shared Services (Bergeron, 2003).[1] The study of Eßer et al. (2020) shows that more than 75% of the asked companies expect higher official compliance requirements in the next years whereas already now every second firm misses its tax compliance goals. To achieve these compliance goals, a frequently proposed solution approach is the implementation of a Center of Excellence (CoE). A CoE is a special form of a SSC which only adopts processes that need specialized and deep knowledge (Marciniak, 2012; Tracy, 2013).[2] According to Aguirre et al. (2015), a shared service for the expertise-based function tax results in savings between 5% and 20%. Bergeron (2003) also names taxes as well as general accounting as an appropriate opportunity for SSCs.

In our paper, we analyze whether an implementation of a Center of Excellence is as beneficial as it is claimed to be regarding effort, profit, earnings manipulation (compliance goals) and added values through consulting. To examine this issue, we adopt an analytical approach in a one-period multi-task principal-agent setting with two agents and carry out a comparison between a model without and with a CoE.[3] In the model without a CoE, the division manager has to exert two processes and a consultant undertakes a consulting activity in order to improve the division's earnings with legals means. With a CoE, the division manager is responsible for the first process (main process) and the CoE for the second one (service process)

[1] A study realized by Deloitte (2011) examines the implementation of SSC in the year 2011. One result is that more than a third of the in 2011 existing SSC are established in the years between 2008 and 2011. Additionally, they investigate the percentage distribution of implemented Shared Service Centers among different regions and conclude an increase from 2007 to 2011, e.g. in Asia-Pacific from 11% to 13% and in Latin America from 10% to 17%. These developments show the increasing interest in this kind of restructuring organizations.

[2] Marciniak (2012) uses the same definition for a Center of Excellence as Tracy (2013) for a Center of Expertise. In this paper, the definitions of a Center of Excellence and a Center of Expertise are congruent. For simplicity, we only use the term Center of Excellence (CoE).

[3] Acc. to Kagelmann (2001), the principal-agent approach is a (restricted) appropriate measure to analyze the SSC model analytically and provides single explanation attempts.

as well as the consulting activity. All players are assumed to be risk neutral and all agents are provided with different abilities. While the division managers are endowed with uncertain abilities which are either low or high, the CoE has a certain and commonly known ability which is assumed to be higher than the managers' low ability since a CoE needs highly qualified experts per definition (KPMG, 2013).[4] Since the division's results are not observable, the division manager's report about the division's result serves as the performance measure for the effort and as the consulting basis. There exists an incentive for earnings manipulation from the manager's view in order to increase the performance measure. A CoE is able to refine the firm's profit report in contrast to a model without a CoE by exerting the second process itself. The CoE has no incentive for earnings manipulation and hence, improves internal control by providing a more precise and transparent contribution to the firm value.

The main contribution of our paper is to show that it is not always beneficial to implement a CoE. It crucially depends on the firm's objectives and human resources: If a firm wants to improve its compliance performance and highly fears reputational damages, a CoE is the right approach to lower the troublesome earnings manipulation. At the same time, if the aim is to increase the added value through consulting, a CoE is also the right tool, if the penalty payment on earnings manipulation is not too high. In contrast, the effort for the main process decreases in the presence of a CoE but it is not possible to say anything clearly about the effect of a CoE on the service process effort as well as the expected profit without specifying certain conditions. A CoE is only beneficial regarding the expected profit if the CoE's ability exceeds a critical value which can in fact be lower than the division manager's expected ability. This critical values crucially depends on the division manager's ability variance combined with the penalty value. Very high penalty values also increase the interval in which a CoE generates higher expected service process efforts and expected profits. Considering the purpose and named trade-off in our paper's title, more centralization is beneficial since it results in less manipulated reports and thereby more precise accounting information which leads to a higher profit increasing consulting activity in the majority of cases. On the contrary, decentralization results in better effort incentives for the main process. This also holds for the service process with a high ability variance.

As a first step in this paper, we state the multitude of definitions regarding a CoE or more general, SSC. According to Brühl et al. (2017), the processes within a SSC are

[4] We denote the principal (she) as headquarters and the agents as managers (he) and a consultant (he) or a CoE (it).

predominantly supporting processes and the main goals are achieving cost savings as well as quality enhancements. Schulman et al. (1999) hold the same opinion that supporting processes have to be pooled in an own business unit. To achieve the named savings, Marciniak (2012) mentions process-automatization as the key driver. This would only be possible in a so called "Center of Scale". According to KPMG (2013), a Center of Scale (CoS) exerts processes which can be easily standardized with high volume to achieve high economies of scale. These processes are often called transaction-based processes (Becker et al., 2009). In contrast, a CoE exerts low-volume processes which need highly qualified experts (KPMG, 2013), e.g. tax or IT services. These processes are called expertise-based processes (Becker et al., 2009). Frost et al. (2002) make use of a literature review as well as of a survey regarding 99 subsidiary firms in Canada which are foreign-owned. They consider a CoE not as a new built business unit but rather as a division which evolved to a CoE. Knol et al. (2014) base their definition of SSCs on Bergeron (2003) and Schulz and Brenner (2010) by considering SSCs "as semi-autonomous organisation units that deliver previously distributed support services to internal clients within organisations" (p. 92). They aim at investigating the challenges of a SSC-implementation with a literature review and a case study research. They focus on cost-savings which is closer to a CoS instead of a CoE. The consideration of Schulz and Brenner (2010)'s and Bondarouk (2014)'s reviews regarding SSC definitions highlights the wide range of existing definitions. The most common definition, also used by Rothwell et al. (2011), originates from Bergeron (2003): "Shared services is a collaborative strategy in which a subset of existing business functions are concentrated in a new, semiautonomous, business unit that has a management structure designed to promote efficiency, value generation, cost savings and improved service for internal customers of the parent corporation."(p. 3).[5] Thus, one could say that a SSC is "somewhere between a function and an organisation" (Borman, 2010, p. 221). While many firms are using the SSC model and there exist some articles regarding the implementation in practice, there is still few scientific literature considering SSCs. Especially the book of Kagelmann (2001) emphasizes the lack of adequate literature regarding this topic.

In addition to the concepts of SSCs and CoEs, the compliance aspect is one focus in this paper. In many organizations, as e.g. in consulting firms, compliance receives high attention. Basically, compliance as a synonym of norm conformity

[5] The literature uses the terms "service" as well as "supporting process" for the processes which are pooled within a SSC. Based on the name of a Shared **Service** Center, we use the term "service process" in our paper, but both terms can be used synonymously.

regarding firm activities aims at bringing firms and their structure in accordance with the current laws (v. Werder and Grundei, 2006). v. Werder and Grundei (2006) mention the Sarbanes-Oxley-Act of 2002 as an appropriate example which has been a reaction to earnings manipulation to a great extent. The law exacerbates the responsibility regarding the correctness of the accounting as well as the structural organization of firms. Since contracts often rely on financial accounts, managers may have an incentive to undertake earnings management, or even manipulation, to increase their compensation which is likely in conflict with the compliance goals. The theoretical description of this reporting bias is based on the model of Fischer and Verrecchia (2000). In detail, earnings management can be classified by real and accounting earnings management.[6] In this paper, we exactly address the incentive for accounting earnings management in order to analyze the necessity of a CoE since stricter compliance and accounting regulations particularly influence accounting earnings management. Mainly the illegal form of earnings management (manipulation) is the target of tighter compliance rules and therefore an important part of our examination. According to §153 AO in the German tax law, if a taxable person considers any mistakes in the provided explanation, he has to report it immediately. To prevent some problems with norms like this, many firms use so called Tax Compliance Management Systems (TCMS). The existence of a TCMS is an indication that there is no gross negligence regarding §153 AO. Thus, a CoE can be considered as a Tax Compliance Management approach.

As mentioned above, compliance as well as efficiency gains through a mix of decentralization and centralization attract more and more of attention. Mostly, to achieve greater compliance with current laws, many firms assume stricter control as a key factor. More control usually comes with a higher degree of centralization. This is why a combined system of decentralization and centralization could be a solution to achieve more compliance and to reduce corresponding risks while retaining the benefits from decentralized business units. The question arises whether the presence of more centralization through a CoE results in an advantage regarding savings, efficiency gains and compliance goals. This paper adresses this issue.

The rest of the paper is organized as follows: Section 2 gives an overview of relevant literature and categorizes our contribution to the literature. In section 3, we introduce the model without and with a CoE and conduct the equilibrium analysis for each model. Section 4 compares the results of the previous section for both model variants and Section 5 summarizes.

[6] For more details, see Ewert and Wagenhofer (2012).

2 Contribution to Literature

Our paper is related to the literature on performance measures in multi-task models. Holmström and Milgrom (1991), Feltham and Xie (1994) and Datar et al. (2001) constitute the standard literature regarding this topic. In these papers, the agent has to perform multiple tasks with the available effort and the principal's objective is not contractible. This only holds for our modelling of the division manager whose goal is to maximize his compensation base, i.e. his report about his division's result, instead of the principal's objective. This incongruity of the performance measure leads to agency costs even if the agents are risk neutral.[7] The effort costs for each task in our paper are modelled equally and only dependent on the exerted effort. If an agent has to exert two tasks, we sum up the effort costs from the separate tasks. In contrast, Reichmann and Rohlfing-Bastian (2014) also consider a model in which a second task has to be allocated to one of two agents, but they consider an additional effort cost parameter which is multiplied with the second effort costs. Baker (1992) considers a model with risk neutral agents in one-shot games with private predecision information. This means that the agent can privately observe his own productivity after contract signing similar as the division manager in our approach. Schöndube-Pirchegger and Schöndube (2019) also consider a model in which a principal can delegate two tasks to an agent but the agent faces a time-constraint regarding the tasks' effort. The principal can either decide to perform the tasks by herself or delegate one or both tasks to the agent. If the principal delegates at least one task, the firm value is nonverifiable and an incongruent performance measure is used. The mentioned papers make conclusions that even with risk neutral agents, agency costs can be possible if there is no congruity between the performance measure and the principal's objective. Bushman et al. (2000) differentiate between two different systems (centralized and decentralized) regarding task delegation as we do in our paper.[8] Their paper is the closest to ours regarding the modelling of decentralization and centralization. In their centralized system, the agent's effort can be used as a contract base whereas he has no private information. In contrast, the effort is non-contractible with a decentralized system and the agent can privately observe his productivity. Our paper considers these two regimes but within one model approach: Our division manager's (decentralized system) effort is

[7] Feltham and Xie (1994) define congruity as "the degree of congruence between the impact of the agent's action on his performance measure and on the principal's expected gross payoff" (p. 434).

[8] Since we consider the CoE to act in the principal's interest as its effort and ability are observable, delegation models as in Itoh (1994) are also partly comparable to our approach.

unobservable and he has private predecision information about his ability realization while the CoE's (centralized system) effort is observable and the CoE's ability is common knowledge and thus, there is no private information.

Regarding earnings management, our model is based on Fischer and Verrecchia (2000) and our analysis is connected to Ewert and Wagenhofer (2005) who also focus on stricter accounting regulations and differentiate between real and accounting earnings management.[9] They argue that stricter accounting regulations can only influence accounting earnings management and not real earnings management. Thus, we consider accounting earnings management as the only earnings management being influenced by stricter compliance rules and therefore, disregard real earnings management. We find similar results as Ewert and Wagenhofer (2005) who state that earnings quality is enhanced with stricter accounting standards but they do not consider a multi-task problem as well as a form of Inhouse Outsourcing.[10] Additionally, Dye (2002) also analyzes efficiency considering accounting standards by analyzing earnings management. Reliability of the report is the most important part for good consulting in our model. Dye and Sridhar (2004) also investigate reliability and relevance of such accounting information. Stocken and Verrecchia (2004) study information precision in the reporting system with earnings management as well.

The paper by Ewert and Niemann (2014) is closely related to our paper from a modeling perspective. They consider a multi-task principal-agent setting of a LEN-type considering tax planning.[11] In our paper, the consulting activity can be seen as a similar factor since the consulting activity in our model illustrates the optimization of the division's earnings by means of the commercial and fiscal law, e.g. with tax planning or other legal means. Ewert and Niemann (2014) aim at determining results about tax avoidance whereas they define tax avoidance and legal tax planning as equivalent and illegal tax planning activities as tax evasion. In our paper, consulting means the use of legal margins to improve the division's earnings whereas earnings manipulation means illegal accrual shifts of earnings. To the best

[9] For a summary of earnings management in economic models, see Ewert and Wagenhofer (2012).

[10] A SSC can be classified to the Business Process Outsourcing context (Becker et al., 2008). Outsourcing means the usage of external services, these can be (sub)functions or -processes, as in our paper. Kagelmann (2001) splits outsourcing in three categories: "Inhouse Outsourcing" (transaction of accomplishments within an organization), "Internal Outsourcing" (transaction of accomplishments from internal to organizational independent firm) and "External Outsourcing" (transaction of accomplishments from internal to external service provider) (pp. 54-55). Based on these definitions, a SSC belongs to the Inhouse Outsourcing concept.

[11] Niemann (2008) also considers a multi-task principal-agent model with taxation. But there, tax planning is not a possible agent's activity.

of our knowledge, Ewert and Niemann (2014) are currently the only ones who handle a multi-task principal-agent model with an agent who has to exert effort as well as a consulting activity, there tax planning. Our model includes similar ingredients but, in addition, two agents and a task-shifting between the agents.
We contribute to the literature of multi-task agency-models with multiple agents, agency models considering legal consulting activities and earnings management and to the literature that deals with decentralization and centralization.

3 Model Setup and Equilibrium Solutions

We consider a one-period principal-agent setting with a division manager and a headquarters. Additionally, a third player can be either a consultant or a Center of Excellence (CoE). All players are risk neutral.

The aim is to determine conditions under which the implementation of a CoE is more or less beneficial than a fully decentralized firm structure. We do so by comparing the settings without and with a CoE regarding exerted effort, earnings manipulation (related compliance risks), an added value through consulting and expected profits. Without a CoE, the division manager has to exert two processes, a main process and a service process, and the consultant undertakes a consulting activity in order to optimize the divisions' earnings by using means of the commercial and fiscal law.[12] With a CoE, which is located physically near to the corporate headquarters, the division manager is responsible for the first process (main process) and the CoE for the second one as well as the consulting activity. The second process is considered to be a service process which has to be exerted for all divisions of the firm. It has no direct productive impact on the main process but it has its own contribution to the firm's total earnings. Thus, the second process is predestinated to be centralized in accordance with the previous definitions regarding a CoE's purpose.[13] The following subsections explain both scenarios in detail and derive the equilibrium solutions for a benchmark case and the second-best solution.

[12] This consulting activity can include e.g. legal earnings management or tax planning as in Ewert and Niemann (2014). The most important aspect of the consulting activity is that it bases on the available accounting information and only makes use of legal margins within the range of the commercial and fiscal law. The player that undertakes the consulting activity is not responsible for detecting illegal earnings management (earnings manipulation) per assumption. Instead, we aim at showing the impact of imprecise accounting information on the firm's total profits with this model part.

[13] KPMG (2013) support this assumption. They state that similar processes are leached from divisions and pooled in an independent unit, a Shared Service Center (SSC).

3.1 Model Setup without CoE

First, the headquarters offers a contract to the division manager and the consultant. Let $a \in \{a_L, a_H\}$ denote the manager's ability, i.e. how well the manager is suited for the characteristics of the job based on his ability and his knowledge. We assume $a_H > a_L \geq 1$ and the probability for the manager being of a_H-type is denoted by p which is common knowledge. The contribution of the manager's division to the principal's outcome is generated by the manager's effort e_j in the two processes $j \in \{1, 2\}$ combined with his ability. It is defined by

$$x = a\,(e_1 + e_2)\,. \tag{1}$$

The manager's ability is the same for both the main and the service process. The outcome x is not observable for the headquarters, thus, it is non-contractible information. To incentivize the manager, the headquarters uses the performance measure y for the contract with the manager. It is defined by

$$y = x + b. \tag{2}$$

The parameter y is the accounting income of the manager's division. It is reported by the manager and depends on a (potential) bias b by the division manager which is also not observable for the headquarters. The ability a is unknown to all parties when the contract is signed. After the contract-signing but before the division manager chooses his actions, he observes his type privately. As the manager learns his true productivity only after the contracting date, there is no adverse selection problem in the model but a hidden information problem with hidden action. Thus, the headquarters offers a pooling contract, that is only one contract no matter of which type the manager is. Similar to Baker (1992), we assume that the headquarters offers a linear contract $w_{Div} = F_{Div} + s_{Div}\, y$ to the manager where F_{Div} denotes the fixed wage and s_{Div} the incentive rate. Effort and earnings manipulation are costly for the division manager, thus, his disutility is $C_e(e_j) = \frac{e_j^2}{2}$ and $C_b(b) = \frac{k\,b^2}{2}$. Here, $k \geq 1$ is an exogenous measure of intra-organizational control, where a higher k means a higher internal control, which makes it more costly for the manager to undertake earnings manipulation.[14] The manager's reservation utility is set to zero without loss of generality. As the manager takes one of the two types a_L or a_H, for the proceeding analysis it is helpful to define outcome, performance measures and

[14] A similar modeling can be found in Nieken and Sliwka (2015) and Hensel and Schöndube (2022).

utilities depending on the manager's type. In particular, we define for $i \in \{H, L\}$

$$x_i = a_i\,(e_{1i} + e_{2i}), \tag{3}$$

$$y_i = x_i + b, \tag{4}$$

where a_i is the manager's ability realization. In the above expressions, e_{ji} denotes the effort of a manager of type i in process $j \in \{1, 2\}$ and b is the manipulation effort which turns out to be type-invariant. When we conduct the equilibrium analysis, we will use this notation in most cases in what follows. Denote $U_{Div_i} \equiv U_{Div}(a_i)$ the manager's utility conditional on being type a_i. It is given by

$$U_{Div_i} = F_{Div} + s_{Div}\,y_i - \frac{e_{1i}^2}{2} - \frac{e_{2i}^2}{2} - \frac{k\,b^2}{2}, \tag{5}$$

with $i = H, L$.

Ex ante the division manager rationally anticipates a_H with probability p and a_L with $1 - p$ and the corresponding efforts e_{jH} and e_{jL} such that the performance measures y_H and y_L result with probability p and $1-p$. Then the division manager's ex ante expected utility can be written as

$$E(U_{Div}) = p\,U_{Div_H} + (1 - p)\,U_{Div_L}. \tag{6}$$

The consultant observes the reported accounting income y by the manager and invests his effort in optimizing this reported accounting income of the division's earnings with consulting activity τ. This consulting activity adds value to y by $y\,\tau$ such that the optimized report $y\,(1+\tau)$ results. The consulting values increase in the magnitude of y and thus also include earnings manipulation. Since x is independent of earnings manipulation, consulting improves the firm's non-contractible outcome to $(y-b)(1+\tau) = x\,(1+\tau)$.[15] If the consulting value τ is positive, the added value to the firm's profit is obvious. The consulting value τ can also be negative and thereby decrease the firm's optimized outcome before compensation, $x\,(1 + \tau)$. This can be beneficial if a lower optimized outcome can be outweighed by e.g. lower fees, taxes or penalties based on the negative consulting value in order to enhance the firm's

[15] Thus, τ is lower than optimal for x due to the imprecise information in y if there is some earnings manipulation. Ewert and Niemann (2014) model tax planning with $x\,(1 - \tau)$ since they model τ as the tax rate that has to be paid. Models using tax rates usually aim at minimizing the tax payment to maximize profits. In contrast, in our model, a tax payment is not considered but τ constitutes the profit optimization through a value enhancing consulting activity which can e.g. include tax planning in order to reduce the tax payments. Thus, we aim at optimizing the profits $x\,(1+\tau)$ by the mean of the consulting value τ. In sum, both modelling variations pursue the same target of maximizing the profits just with different approaches.

total expected profit. To induce the consultant to conduct the desired value of τ, a performance-based contract on $y\,\tau$ or $y\,(1+\tau)$, respectively, would be possible. However, since y is observable ex post, a forcing contract on τ is also possible. As our focus is on the manager's effort and earnings management incentives in the first place, we therefore assume that the principal contracts on $\tau(y)$ paying the consultant a compensation $w_{Con}(\tau(y))$ if and only if he conducted the desired $\tau(y)$.[16] Consulting is costly for the consultant, his disutility is $C_\tau(\tau(y)) = \frac{(y\,\tau(y))^2}{2}$. This disutility depends on the consultant's effort and on the report y since consulting becomes more difficult for a higher reported income. To induce the consultant to participate, the principal chooses $w_{Con}(\tau(y))$ such that the consultant is provided with exactly his reservation wage of zero if he performed the desired effort $\tau(y)$ for every realization of y. Thus, the offered contract has the form $w_{Con}(\tau(y)) = C_\tau(\tau(y))$. With this compensation contract the consultant's utility conditional on y is given by

$$U_{Con}(y) = w_{Con}(\tau(y)) - \frac{(y\,\tau(y))^2}{2} = 0. \tag{7}$$

As (7) is satisfied for every realization of y, the consultant's participation constraint is satisfied ex ante as well. The optimized report $y\,(1+\tau)$ is audited by an auditor with success probability q, with $0 < q \leq 1$.[17] Thus, we assume that an auditor will check the optimized report in any case, but his probability of detecting earnings manipulation is based on his audit competence and is assumed to be q. If the auditor finds the earnings manipulation b, the headquarters faces a penalty that consists of a payment $T > 0$ per Euro based on the earnings manipulation and the corresponding unjustified consulting value.[18] Thus, the expected penalty is given by $q\,T\,b\,(1+\tau)$.[19]

Due to the lack of information about the manager's type, ex ante the headquarters rationally anticipates the manager's types a_H and a_L with probability p and $1-p$. Denote $\tau_i \equiv \tau(y_i)$ the consulting activity based on the received report from manager type a_i and $G_i \equiv G(a_i)$ the firm profit generated with manager type a_i. G_i is given

[16] Alternatively, we could model the observable effect of consulting with a random term, i.e. $y\,\tau+\eta$. In this case, a forcing contract would not be possible. However, due to the risk neutrality of the consultant, there exists a performance-based compensation contract that induces the same effort τ than the forcing contract.

[17] We do not model the auditor as a strategic player. The optimized report is used synonymously for the annual financial statement.

[18] The penalty T can be compliance infringement consequences or adverse (reputational) effects on the external or internal labor market, for example.

[19] It would also be possible to include that penalty in the agent's compensation contract. We exclude this scenario since we want to focus on the negative impact of discovered earnings manipulation for the firm's compliance goals in order to be able to conclude whether a CoE decreases that manipulation successfully. This is why a possible detection of earnings manipulation is only possible after the agents' compensation payment, see Figure 1.

by

$$G_i = x_i\,(1+\tau_i) - F_{Div} - s_{Div}\,y_i - w_{Con}(\tau_i) - q\,T\,b\,(1+\tau_i),$$

with $i = H, L$. The ex ante expected profit of the headquarters is determined by

$$E(G) = p\,G_H + (1-p)\,G_L. \tag{8}$$

Figure 1 illustrates the corresponding timeline.

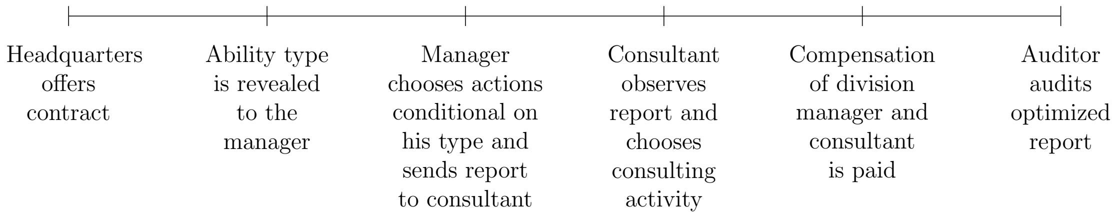


Figure 1: Timeline without a Center of Excellence.

3.2 Equilibrium Solutions without CoE

In this section, we examine the benchmark and second-best solution in the model approach without a CoE.

3.2.1 Benchmark Solution: No Earnings Manipulation

In the benchmark solution, we consider the case where no earnings manipulation is possible. Although efforts and ability are unobservable to the headquarters, the manager is not able to undertake earnings manipulation (e.g. due to appropriate corporate governance structures). Thus, the headquarters' optimization problem is

$$\max_{w_{Div},\tau(y)} \; E(G) \tag{9}$$

s.t.

$$E(U_{Div}) \geq 0, \tag{PC 1}$$

$$(e_{1i}, e_{2i}) \in \underset{e'_{1i}, e'_{2i}}{argmax}\, U_{Div_i},\; i = H, L. \tag{IC 1}$$

The headquarters' optimization problem is subject to two constraints. (PC 1) ensures participation of the manager and (IC 1) is the incentive constraint for the manager.

Since the headquarters can contract upon the consultant's effort $\tau(y)$ paying a wage $\frac{(y\,\tau(y))^2}{2}$, the optimal consulting activity from the headquarters' view after observing y maximizes

$$E(x(1+\tau(y))|y) - \frac{(y\,\tau(y))^2}{2}. \tag{10}$$

The solution to this problem is given by

$$\tau(y) = \frac{1}{y}. \tag{11}$$

By applying the first-order condition to (IC 1), the incentive constraint of the division manager (after observing his type) can be written as

$$e_{1i} = e_{2i} = a_i\, s_{Div}. \tag{12}$$

The headquarters has to guarantee the manager at least his reservation utility (which is zero in our model) ex ante. At the optimum, as usually, the participation constraint is binding. The optimal incentive rate of the division manager $s^B_{Div} = 1$ results from maximizing the reduced optimization problem of the agency relationship which is obtained by inserting (PC 1) as a binding equation into (9) as well as the optimal efforts from (11) and (12). Conducting the following optimization

$$\begin{aligned} \underset{s_{Div}}{max}\; & p\left(x_H\,(1+\tau_H) - \frac{e^2_{1H}}{2} - \frac{e^2_{2H}}{2} - \frac{(y_H\,\tau_H)^2}{2}\right) \\ & + (1-p)\left(x_L\,(1+\tau_L) - \frac{e^2_{1L}}{2} - \frac{e^2_{2L}}{2} - \frac{(y_L\,\tau_L)^2}{2}\right) \end{aligned} \tag{13}$$

leads us to the first Lemma.

Lemma 1 *When the manager is unable to undertake earnings manipulation, the manager's incentive rate and the manager's and consultant's actions are given by:*

$$s^B_{Div} = 1, \tag{14}$$

leading to

$$e^B_1 = e^B_2 = a_i,\; i = H, L, \tag{15}$$

$$\tau^B(y) = \frac{1}{y}. \tag{16}$$

Proof: See the Appendix A1.

Since all parties are risk neutral and all actions can be controlled perfectly by the incentive rate and fixed wages, there are no frictions in the game, thus, the first-best solution results. Therefore, any frictions in our model stem solely from the manager's possibility to undertake earnings manipulation.

The expected profit of the headquarters in the benchmark setting becomes

$$E(G^B) = \frac{1}{2} + p\,a_H^2 + (1-p)\,a_L^2. \tag{17}$$

3.2.2 Second-best Solution with Earnings Manipulation

In contrast to the benchmark solution, in the second-best solution the division manager is able to undertake earnings manipulation when sending his report to the consultant. Thus, the optimization problem of the headquarters is

$$\max_{w_{Div},\tau(y)} \; E(G) \tag{18}$$

s.t.

$$E(U_{Div}) \geq 0, \tag{PC 1.1}$$

$$(e_{1i}, e_{2i}, b_i) \in \underset{e'_{1i},e'_{2i},b'_i}{argmax}\, U_{Div_i},\; i = H, L. \tag{IC 1.1}$$

As before, the headquarters and the consultant can contract on $\tau(y)$ and the wage $w_{Con}(\tau(y))$ is again chosen such that the consultant's effort costs are exactly offset. Maximizing

$$E(x(1+\tau(y))|y) - \frac{(y\,\tau(y))^2}{2} - q\,T\,b\,(1+\tau(y)) \tag{19}$$

under the earnings manipulation opportunity yields

$$\tau(y) = \frac{y - b\,(1+q\,T)}{y^2}. \tag{20}$$

After applying the first-order condition to the manager's incentive rate (IC 1.1), the incentive constraint can be written as

$$e_{1i} = e_{2i} = a_i\,s_{Div}, \tag{21}$$

$$b = \frac{s_{Div}}{k}. \tag{22}$$

The incentive constraints for the main and service process effort turn out to be the same as in the benchmark setting in (12). The consulting value $\tau(y)$ in (20) is $\tau(y)$

from (11) reduced by the positive term $\frac{b\,(1+q\,T)}{y^2}$. The earnings manipulation variable increases with the incentive rate s_{Div} but decreases with the intra-organizational control k as a higher k makes it more costly to undertake earnings manipulation.

The next Lemma presents the optimal incentive rate and induced actions. They are determined by conducting the reduced optimization of (18) with a binding (PC 1.1) and the optimal efforts from (20), (21) and (22),

$$\begin{aligned}&\underset{s_{Div}}{max}\ p\left(x_H\,(1+\tau_H)-\frac{e_{1H}^2}{2}-\frac{e_{2H}^2}{2}-\frac{k\,b^2}{2}-\frac{(y_H\,\tau_H)^2}{2}-q\,T\,b\,(1+\tau_H)\right)\\&+(1-p)\left(x_L\,(1+\tau_L)-\frac{e_{1L}^2}{2}-\frac{e_{2L}^2}{2}-\frac{k\,b^2}{2}-\frac{(y_L\,\tau_L)^2}{2}-q\,T\,b\,(1+\tau_L)\right).\end{aligned}\tag{23}$$

Lemma 2 *When the manager is able to undertake earnings manipulation, the manager's optimal incentive rate and the manager's and the consultant's corresponding equilibrium actions are given by:*

$$s_{Div}^{SB}=\frac{2\,k\,(p\,a_H^2+(1-p)\,a_L^2)-q\,T}{2\,k\,(p\,a_H^2+(1-p)\,a_L^2)+1}=\frac{2\,k\,E(a^2)-q\,T}{2\,k\,E(a^2)+1},\tag{24}$$

leading to

$$e_{1i}^{SB}=e_{2i}^{SB}=a_i\,s_{Div}^{SB},\ i=H,L,\tag{25}$$

$$b^{SB}=\frac{s_{Div}^{SB}}{k},\tag{26}$$

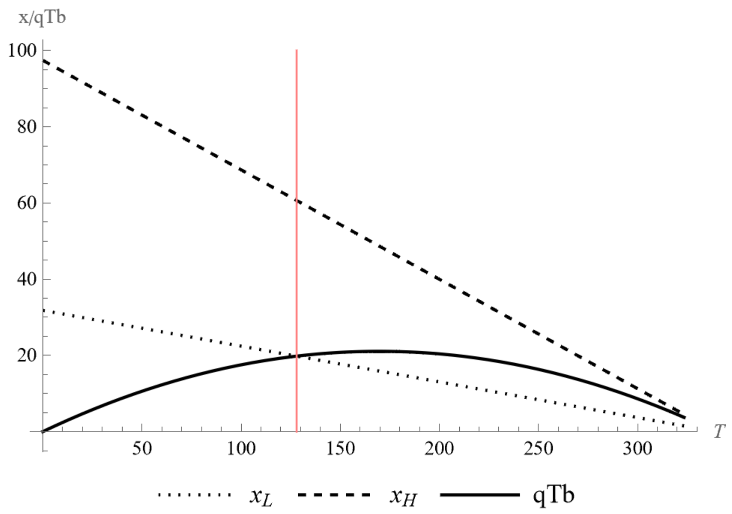
$$\tau^{SB}(y)=\frac{y-b^{SB}\,(1+q\,T)}{y^2}.\tag{27}$$

Proof: See the Appendix A1.

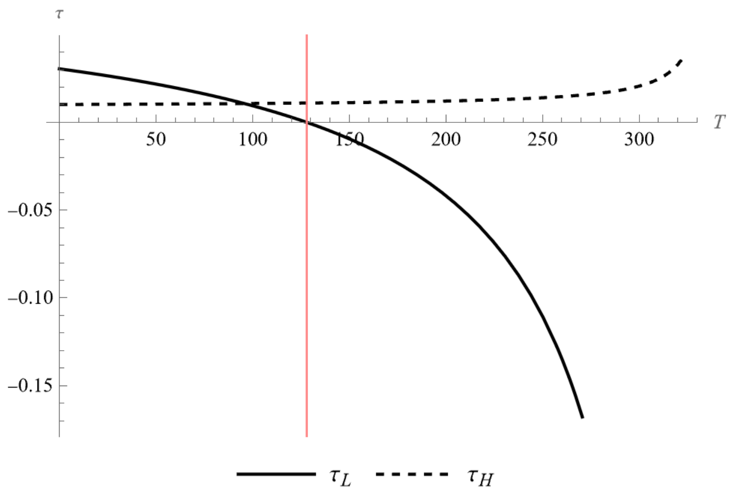
The incentive rate s_{Div}^{SB} increases with ability realization a_i, intra-organizational complexity k, type probability p and decreases with audit success rate q and the corresponding payment T. To ensure that $s_{Div}^{SB}>0$, T has to be limited to

$$\hat{T}_{s_{Div}}=\frac{2\,k\,(p\,a_H^2+(1-p)\,a_L^2)}{q}=\frac{2\,k\,E(a^2)}{q}.\tag{28}$$

This limitation ensures that the main and service process efforts as well as the earnings manipulation effort are also positive. The consulting value $\tau^{SB}(y)$ from (27) becomes negative if $x^{SB}<q\,T\,b^{SB}$. Figures 2a and 2b illustrate the conditions for $x^{SB}<q\,T\,b^{SB}$ (Figure 2a) and hence, the conditions for a negative consulting value $\tau^{SB}(y)$ (Figure 2b).



(a) x_L^{SB}, x_H^{SB} and $q\,T\,b^{SB}$.



(b) τ_L^{SB} and τ_H^{SB}.

Figure 2: Determination of sign of τ_L and τ_H dependent on T, plotted for $k = 2$, $q = 0.5$, $p = 0.8$, $a_L = 4$ and $a_H = 7$. The light red line marks $T = \frac{2\,a_L^2\,k}{q}$.

Both Figures show that the consulting value with a low ability manager can become negative, i.e. $\tau_L^{SB} < 0$, as $x_L^{SB} < q\,T\,b^{SB}$ for $\frac{2\,a_L^2\,k}{q} < T < \hat{T}_{s_{Div}}$ with $x_L^{SB} = a_L\,(e_{1L}^{SB} + e_{2L}^{SB})$.[20] The red line in Figures 2a illustrates the critical value for $x_L^{SB} = q\,T\,b^{SB}$ ($T = \frac{2\,a_L^2\,k}{q}$) whereas it is obvious that x_H^{SB} always exceeds $q\,T\,b^{SB}$. Hence, $x_H^{SB} < q\,T\,b^{SB}$ and thereby $\tau_H^{SB} < 0$ is excluded. Since $a_L < a_H$, only $\tau_L^{SB} < 0$ is possible. If $x_L^{SB} < q\,T\,b^{SB}$, the enhancement of the firm's expected profit

[20] Note that $\tau_L < -1$ is basically possible, but we restrict our attention to examples in which τ_L is limited to $-1 \leq \tau_L$ without loss of generality. Otherwise, τ_L would result in a refund which is not in the sense of our definition of penalty T. A limitation to $-1 \leq \tau_L$ is possible by limiting penalty T to a lower critical value than $\hat{T}_{s_{Div}}$ or $\hat{T}_{s^C_{Div}}$. Considering the parameter restrictions in Figure 2a and 2b, T has to be lower than 323.419 to ensure $-1 \leq \tau_L^{SB}$.

via less penalty payments ($q\,T\,b\,(1+\tau)$) with a negative consulting value τ outweighs the decrease of the firm's expected profit via a lower optimized outcome ($x\,(1+\tau)$). Figure 2b confirms this statement by illustrating τ_i^{SB} with $i = H, L$. Once $T > \frac{2\,a_L^2\,k}{q}$, τ_L^{SB} becomes negative while τ_H^{SB} always stays positive. Hence, as the sign of the consulting value depends on the relation between x and $q\,T\,b$, a higher consulting value is not necessarily more beneficial regarding the total expected profit.
The next result reveals three important effects from considering the benchmark and second-best solution with inserted optimal actions from Lemma 1 and 2.

Result 1 *When the manager has the leeway to undertake earnings manipulation, three effects drive the equilibrium results:*

- *Efficiency effect: The induced efforts e_j^B and e_j^{SB} increase in ability a for $j = 1, 2$ such that the expected efforts $E(e_j^B)$ and $E(e_j^{SB})$ also increase with ability realization a_i, $i = H, L$, $\frac{\partial E(e_j^B)}{\partial a_i} = \frac{\partial E(e_j^{SB})}{\partial a_i} \geq 0$.*
- *Direct distortion effect: Earnings manipulation increases with the division manager's ability realization a_i, $i = H, L$, $\frac{\partial b^{SB}}{\partial a_i} \geq 0$.*
- *Indirect distortion effect: This effect refers to the impact of the manager's ability on the optimal consulting activity τ via report y. A higher reported value of y makes consulting more costly. As y ceteris paribus increases in the value of the manager's ability, a higher ability reduces the optimal consulting activity. However, as in the second-best solution τ is corrected for the earnings manipulation penalty, the marginal effect of ability is weaker. In contrast to $\tau^B = \frac{1}{y}$, τ_L^{SB} can be negative since the low ability manager cannot compensate all possible values for penalty T to ensure that $x_L^{SB} < q\,T\,b^{SB}$.*

Proof: See the Appendix A1.

The effects stem from the varying influence of the division manager's ability on the equilibrium actions and can explain the difference between second-best and benchmark solution.

First, both the induced efforts in the benchmark solution are always higher than the corresponding efforts in a model which allows earnings manipulation, $\Delta e = e^B - e^{SB} > 0$. This is due to the fact that $s_{Div}^{SB} < 1$ to counteract earnings manipulation incentives.
Second, since $b^B = 0$ but b^{SB} increases with s_{Div}^{SB} and s_{Div}^{SB} increases with a_i, the difference between the second-best and the benchmark earnings manipulation

($\Delta b = b^{SB} - b^{B} > 0$) increases with the manager's ability realization a_i. This means that the higher the manager's ability, the higher the earnings manipulation and thus, the higher the compliance violations. On the contrary, the earnings manipulation decreases with penalty T and thus, the second-best earnings manipulation converges to the benchmark one with increasing T and is therefore, less harmful.

Third, without inserting the incentive rate and the equilibrium efforts, the consulting activity $\tau(y)$ without any earnings manipulation is always positive and higher than in the second-best solution, see equations (11) and (20),

$$\frac{1}{y^B} > \frac{y^{SB} - (1 + q\,T)\,b^{SB}}{(y^{SB})^2} \quad \Leftrightarrow \quad \frac{1}{y^B} > \frac{1}{y^{SB}} - \frac{(1 + q\,T)\,b^{SB}}{(y^{SB})^2}, \tag{29}$$

with $b^{SB} = \frac{s_{Div}}{k} > 0$, $y = x + b > 0$, $T > 0$ and $0 < q \leq 1$.

With the inserted equilibrium efforts, both reports y^B and y^{SB} differ. If $y^B > y^{SB}$, $\frac{1}{y^B} < \frac{1}{y^{SB}}$. Then, there can be certain conditions under which the reduction of $\frac{1}{y^{SB}}$ by $-\frac{(1+q\,T)\,b^{SB}}{(y^{SB})^2}$ in $\tau^{SB}(y)$ is not high enough and $\tau^B(y) < \tau^{SB}(y)$ results. This is possible since a higher consulting value is not always preferable, as explained in section 3.1. Based on the assumptions for the manager's ability, $a_H > a_L \geq 1$, and the restriction of T for ensuring $s_{Div}^{SB} > 0$ (see equation (28)), $\Delta\tau_L = \tau_L^B - \tau_L^{SB}$ is always positive, i.e. the consulting value after receiving report y_L is higher in the benchmark setting without earnings manipulation than in the second-best solution. In contrast, $\Delta\tau_H = \tau_H^B - \tau_H^{SB}$ can be negative as $y_H^B > y_H^{SB}$ which leads to $\frac{1}{y_H^B} < \frac{1}{y_H^{SB}}$. Hence, the consulting value with the consideration of earnings manipulation $\tau^{SB}(y)$ can in fact be higher than without earnings manipulation under certain conditions if the consultant receives the report from a high ability manager. Earnings manipulation reduces y_H^{SB} compared to y_H^B via the incentive rate although the earnings manipulation is added to y_H^{SB}.[21] This lower y_H^{SB} leads to lower consulting effort costs and thus a higher consulting value. The penalty payment T on earnings manipulation counteracts this consulting-enhancing effect with $-\frac{(1+q\,T)\,b^{SB}}{(y_H^{SB})^2}$. If $T > \frac{y_H^{SB}}{q\,b^{SB}}\left(1 - \frac{y_H^{SB}}{y_H^B}\right) - \frac{1}{q}$, the impact of the consulting-decreasing penalty cannot be compensated by the consulting-enhancing effect of the lower y_H^{SB} with earnings manipulation.[22] Hence, if T exceeds this value, the consulting activity in the second-best solution is below the one in the benchmark solution. Otherwise, the consulting-enhancing effect of a lower report in the second-best solution can compensate the consulting-decreasing effect of the penalty payments.

[21] $y^B = a\,(e_1 + e_2) = 2\,a^2$ and $y^{SB} = a\,(e_1 + e_2) + \frac{s_{Div}}{k} = 2\,a^2\,s_{Div} + b$.

[22] This critical value can be determined by solving the following inequality with regard to T: $\tau_H^B > \tau_H^{SB} \Leftrightarrow \frac{1}{y_H^B} > \frac{y_H^{SB} - (1+q\,T)b^{SB}}{(y_H^{SB})^2}$.

The comparative statics of τ_H^{SB} underline these results: τ_H^{SB} strictly increases with T as earnings manipulation decreases while τ_H^{B} is unaffected by T due to the missing manipulation opportunity.
Overall, the expected profit in the benchmark solution is always higher than in the second-best solution by restricting the lower bound of the consulting activity based on report y_L to -1, i.e. $-1 \leq \tau_L$, see footnote 20.

3.3 Model Setup with CoE

Now, we consider the case where a CoE is implemented by the firm near to the headquarters, replaces the consultant and adopts the second process, the service process. The division manager still exerts the first process, the main process. Predominantly, we use the same model assumptions as in the previous section 3.1 without a CoE. Hence, we only mention the deviating assumptions with a CoE in this section.

At the beginning, the firm offers linear contracts to the division manager and the CoE. The employees in the CoE are endowed with ability a_C which is common knowledge. We assume $a_C > a_L \geq 1$ since the employees in a CoE need deep and specialized knowledge per definition. The manager's contribution to the principal's outcome is generated by the manager's main process effort e_1 combined with his ability. It is defined by

$$x_1 = a\,e_1. \tag{30}$$

The outcome x_1 is not observable and therefore, non-contractible information. Thus, the headquarters uses the reported accounting income y as the manager's compensation base which is now defined by

$$y = x_1 + b. \tag{31}$$

Similar to the previous section, we define for $i \in \{H, L\}$

$$x_{1i} = a_i\,e_{1i}, \tag{32}$$

$$y_i = x_{1i} + b, \tag{33}$$

where e_{1i} denotes the effort of a manager of type i in the main process (process 1) and b is again the manipulation effort which also turns out to be type-invariant. Denote $U^C_{Div_i} \equiv U^C_{Div}(a_i)$. After observing his type, the manager maximizes his utility

$$U^C_{Div_i} = F_{Div} + s_{Div}\, y_i - \frac{e^2_{1i}}{2} - \frac{k\, b^2}{2}, \tag{34}$$

with $i = H, L$. The division manager's ex ante expected utility can be written as

$$E(U^C_{Div}) = p\, U^C_{Div_H} + (1-p)\, U^C_{Div_L}. \tag{35}$$

The division manager reports the accounting income y to the CoE which in turn invests his effort in the service process, e_2, and in optimizing the reported accounting income of the division's earnings y with consulting activity τ. The service process does not need to be optimized by the consulting activity since its result is not part of the division's earnings and it is observable.[23] The centralized service process is exerted by the specialized CoE with its certain ability a_C. Its outcome is defined by

$$x_2 = a_C\, e_2. \tag{36}$$

Since x_1 is independent of earnings manipulation, consulting improves the firm's non-contractible outcome to $(y-b)(1+\tau) = x_1\,(1+\tau)$. A performance-based contract on $y\,\tau$ or $y\,(1+\tau)$, respectively, would again be possible to induce the CoE to conduct the desired value of τ but since not only y but also x_2 is observable ex post, a forcing contract on τ and e_2 is also possible. We therefore assume that the principal contracts on e_2 and $\tau(y)$ paying the CoE a compensation $w_{CoE}(e_2, \tau(y))$ if and only if he conducted the desired e_2 and $\tau(y)$.[24] To induce the CoE to participate, the principal chooses $w_{CoE}(e_2, \tau(y))$ such that the CoE is provided with exactly its reservation wage of zero if he performed the desired efforts e_2 and $\tau(y)$, for every realization of y. Thus, the offered contract has the form $w_{CoE}(e_2, \tau(y)) = C_e(e_2) + C_\tau(\tau(y))$. With this compensation contract the CoE's utility conditional on y is given by

$$U_{CoE}(y) = w_{CoE}(e_2, \tau(y)) - \frac{e_2^2}{2} - \frac{(y\,\tau(y))^2}{2} = 0. \tag{37}$$

The optimized report $y\,(1+\tau)$ is reviewed by the auditor with the same assumptions as in the previous section.

[23] In the model without a CoE, the main and the service process are optimized through consulting activity τ since both processes are done by the division (manager) and their outcome x is not observable. In the approach with a CoE, the result of the centralized service process x_2 is observable individually, contractible information and not part of the division's earnings.

[24] Alternatively, we could model the observable effect of consulting with a random term, i.e. $y\,\tau + \eta$ as already explained in footnote 16.

Denote $\tau_i \equiv \tau(y_i)$ the consulting activity of the CoE based on the received report from manager type a_i and denote $G_i^C \equiv G^C(a_i)$ the firm profit generated with manager type a_i. G_i^C is given by

$$G_i^C = x_{1i}\,(1+\tau_i) + x_2 - F_{Div} - s_{Div}\,y_i - w_{CoE}(e_2,\tau_i) - q\,T\,b\,(1+\tau_i),$$

with $i = H, L$.

The ex ante expected profit of the headquarters is determined by

$$E(G^C) = p\,G_H^C + (1-p)\,G_L^C. \tag{38}$$

Figure 3 illustrates the timeline.

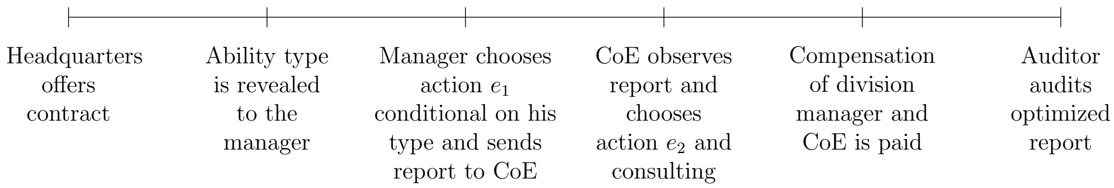


Figure 3: Timeline with a Center of Excellence.

3.4 Equilibrium Solutions with CoE

In this section, we examine the benchmark and second-best solution in the model with a CoE. As the procedure is equivalent to the one in section 3.2 without a CoE, we limit this section to the illustration of the approach and equilibrium solutions whereas the detailed analysis of the equilibrium results is shown in the Appendix.

3.4.1 Benchmark Solution: No Earnings Manipulation

The headquarters' optimization problem is

$$\underset{w_{Div}^C,e_2,\tau(y)}{max} \quad E(G^C) \tag{39}$$

s.t.

$$E(U_{Div}^C) \geq 0, \tag{PC 2}$$

$$e_{1i} \in \underset{e_{1i}'}{argmax}\, U_{Div_i}^C,\; i = H, L. \tag{IC 2}$$

The CoE's participation constraint is fulfilled ex ante since the headquarters can contract upon the CoE's efforts e_2 and $\tau(y)$ paying a wage $C_e(e_2)+C_\tau(\tau(y))$. Solving the optimization problem leads us to the following Lemma.

Lemma 3 *If earnings manipulation is not possible, the manager's optimal incentive rate and the manager's and the CoE's optimal actions are:*

$$s_{Div}^{C,B} = 1, \tag{40}$$

leading to

$$e_{1i}^{C,B} = a_i,\ i = H, L, \tag{41}$$

$$e_2^{C,B} = a_C, \tag{42}$$

$$\tau^{C,B}(y) = \frac{1}{y}. \tag{43}$$

Proof: See the Appendix A2.

Similar to Lemma 1, there are no frictions in the game without earnings manipulation, and thus, the first-best solution results since all parties are risk neutral and all actions can be perfectly controlled by the incentive rate and fixed wages.

The expected profit of the headquarters becomes

$$E(G^{C,B}) = \frac{1}{2}(1 + a_C^2 + p\, a_H^2 + (1-p)\, a_L^2). \tag{44}$$

3.4.2 Second-best Solution with Earnings Manipulation

Following the reasoning and solving procedure as in the case without CoE, the optimization problem with unobservable efforts becomes

$$\max_{w_{Div}^C, e_2, \tau(y)} \quad E(G^C) \tag{45}$$

$$\text{s.t.}$$

$$E(U_{Div}^C) \geq 0, \tag{PC 2.1}$$

$$(e_{1i}, b_i) \in \underset{e'_{1i}, b'_i}{argmax}\, U_{Div_i}^C \text{ for } i = H, L. \tag{IC 2.1}$$

As before, the wage $w_{CoE}(e_2, \tau(y))$ is chosen such that the CoE's effort costs for e_2 and $\tau(y)$ are exactly offset. Hence, the CoE's participation constraint is satisfied ex ante.

Solving the optimization problem leads us to the next Lemma.

Lemma 4 *When the manager is able to undertake earnings manipulation, the optimal incentive rates and the manager's and the CoE's corresponding equilibrium actions are given by:*

$$s_{Div}^{C,SB} = \frac{k\,(p\,a_H^2 + (1-p)\,a_L^2) - q\,T}{k\,(p\,a_H^2 + (1-p)\,a_L^2) + 1} = \frac{k\,E(a^2) - q\,T}{k\,E(a^2) + 1}, \tag{46}$$

leading to

$$e_{1i}^{C,SB} = a_i\,s_{Div}^{C,SB}, i = H, L, \tag{47}$$

$$e_2^{C,SB} = a_C, \tag{48}$$

$$b^{C,SB} = \frac{s_{Div}^{C,SB}}{k}, \tag{49}$$

$$\tau^{C,SB}(y) = \frac{y - b\,(1+qT)}{y^2}. \tag{50}$$

Proof: See the Appendix A2.

Without inserted optimal incentive rate $s_{Div}^{C,SB}$, the incentive constraint for effort e_1 is the same as in the benchmark setting as well as the one in the model without CoE, i.e. $a_i\,s_{Div}$. For the incentive constraint of the earnings manipulation and the consulting activity, we obtain the same structure as in the model without CoE in (20) and (22), i.e. $b = \frac{s_{Div}}{k}$ and $\tau(y) = \frac{y-b\,(1+qT)}{y^2}$. The incentive rate for the division manager includes similar effects regarding comparative statics as the model without a CoE.

To ensure that $s_{Div}^{C,SB} > 0$, payment T has to be limited to

$$\hat{T}_{s_{Div}^C} = \frac{k\,(p\,a_H^2 + (1-p)\,a_L^2)}{q} = \frac{k\,E(a^2)}{q}. \tag{51}$$

By comparing equation (28) and (51), it becomes obvious that $\hat{T}_{s_{Div}}$ from the model without a CoE is exactly twice as large as $\hat{T}_{s_{Div}^C}$. Thus, in the comparison between both models in section 4, we limit our calculations to the lower one, i.e. $\hat{T}_{s_{Div}^C}$.[25] Similar as in section 3.2.2, the consulting value $\tau^{C,SB}(y)$ from equation (50) becomes negative if $x_1^{C,SB} < q\,T\,b^{C,SB}$, as already shown in Figures 2a and 2b for the model without CoE. However, the critical value for penalty T for a negative consulting value halves with a CoE since the acceptable limitation for payment T also halves.

[25] The same holds for the critical values to ensure $-1 \leq \tau_L^{C,SB}$ as the critical value with CoE for $-1 \leq \tau_L^{C,SB}$ is the lowest critical value of all of them. It is used in the examples if necessary.

If $\frac{a_L^2\,k}{q} < T < \hat{T}_{s^C_{Div}}$, $x_{1L}^{C,SB} < q\,T\,b^{C,SB}$ and thus, $\tau_L^{C,SB} < 0$.
As in the model without CoE, the next result reveals three effects from the benchmark and second-best solution with the optimal actions from Lemma 3 and 4.

Result 2 *When the manager has the leeway to undertake earnings manipulation but the second task is exerted by the CoE, three effects drive the equilibrium results:*

- *Efficiency effect: The induced effort $e_1^{C,SB}$ increases in ability a such that the expected efforts $E(e_1^{C,B})$ and $E(e_1^{C,SB})$ increase with ability realizations a_H and a_L but not with a_C, $\frac{\partial E(e_1^{C,B})}{\partial a_i} = \frac{\partial E(e_1^{C,SB})}{\partial a_i} \geq 0$ but $\frac{\partial E(e_1^{C,B})}{\partial a_C} = \frac{\partial E(e_1^{C,SB})}{\partial a_C} = 0$. In contrast, the CoE's efforts $e_2^{C,SB} = e_2^{C,B} = a_C$ are not influenced by a_H and a_L and increase linearly only with its own ability a_C.*
- *Direct distortion effect: As without a CoE, earnings manipulation increases with the manager's ability realization a_i, $\frac{\partial b^{C,SB}}{\partial a_i} \geq 0$. The CoE's ability a_C has no influence on this activity.*
- *Indirect distortion effect: As in Result 1, a higher reported value y makes consulting more costly. Ceteris paribus, y increases in the manager's ability but the consulting value is corrected for penalty T. Thus, the marginal effect of ability on τ is weaker. Additionally, $\tau_L^{C,SB}$ is able to be negative while $\tau^{C,B}$ is not. Moreover, $\tau^{C,B}$ and $\tau^{C,SB}$ are not influenced by the CoE's ability a_C.*

Proof: See the Appendix A2.

The benchmark effort for the first process is always higher than in the second-best solution, $\Delta e_{1i}^C = e_{1i}^{C,B} - e_{1i}^{C,SB} > 0$. Since both the benchmark and the second-best main process efforts increase with the ability realization a_i, the sign of Δe_{1i}^C depends on the concrete values of a_i and p as they are crucial for each effort's gradient. On the contrary, the efforts for the second task are equal, $\Delta e_2^C = e_2^{C,B} - e_2^{C,SB} = 0$. This can be explained by the fact that the CoE and the headquarters can contract on x_2 and $\tau(y)$. In contrast to the model without a CoE where the service process effort is also exerted by the division manager, Δe_2^C does not strictly decrease or increase with a_C, a_H or a_L. This is due to the nonexistent difference between the benchmark and the second-best solution.
As in the model without CoE, earnings manipulation ($b = b^C = \frac{s_{Div}}{k}$) increases with a_i as the incentive rate increases with a_i. Although the effort costs for earnings manipulation ($\frac{k\,b^2}{2}$) also increase with a_i, the increasing added value of the manager through compensation for earnings manipulation ($s_{Div}\,b$ via $s_{Div}\,y$) dominates the

effort costs, ($s_{Div}^{SB}\, b^{SB} = \frac{(s_{Div}^{SB})^2}{k} > \frac{(s_{Div}^{SB})^2}{2\,k} = \frac{k\,(b^{SB})^2}{2}$).[26] Since the benchmark case is unaffected by earnings manipulation, i.e. $b^{C,B} = 0$, the difference between the benchmark and second best earnings manipulation increases with increasing ability realization a_i but is unaffected by the CoE's ability a_C. Regarding a trade-off, an increasing ability of the division manager improves the main process effort via the efficiency effect but simultaneously, exacerbates the compliance related earnings manipulation via the direct distortion effect. As without a CoE, the earnings manipulation effort decreases with penalty T and hence, the difference between $b^{C,B}$ and $b^{C,SB}$ decreases with T.
The sign of the consulting value difference, $\Delta\tau^C = \tau^{C,B} - \tau^{C,SB}$, is subject to the same considerations and explanations as without a CoE since the structure of in $\tau^{C,B}(y)$ in (43) and $\tau^{C,SB}(y)$ in (50) is the same as in the section without a CoE. Again, the expected profit in the benchmark solution is always higher than in the second-best solution by restricting the lower bound of the consulting activity based on report y_L to -1, i.e. $-1 \leq \tau_L^{C,SB}$, see footnotes 20 and 25.

4 Comparison and Implications

To unravel differences between the regimes without and with a CoE, we examine the impact of several parameters on the equilibrium outcomes. Notice that we only compare the second-best results from Lemma 2 and Lemma 4 due to their implementation of earnings manipulation in contrast to the benchmark solution. For simplicity, we omit the exponent SB.[27]

First of all, the incentive rates have an impact on all actions of the division manager which is why we start by comparing the compensation without and with a CoE. The comparative statics of the incentive rates have already been mentioned in 3.2.2 and 3.4.2.[28] The manager's incentive rate is lower with a CoE than without one, $s_{Div} - s_{Div}^C > 0$, as with a CoE, only the main process remains in the division and the division manager has to be paid for less tasks. In contrast, the manager's fixed wage without CoE is lower than with a CoE, $F_{Div} < F_{Div}^C$.[29] When we examine the manager's expected total compensation payment, it becomes clear that a manager without CoE is more expensive than one with a centralized second process, i.e.

[26] This holds for both, the setting without and with a CoE.
[27] Since $\hat{T}_{s_{Div}} = 2\,\hat{T}_{s_{Div}^C}$, $\hat{T}_{s_{Div}^C}$ is the lower critical value and used for the following calculations. The critical value for $-1 \leq \tau_L^C$ is the lowest one of all. It is used in the examples if necessary.
[28] See the Appendix for a complete illustration of these comparative statics.
[29] See the Appendix for a complete illustration of all players' fixed wages.

$E(w_{Div}) > E(w^C_{Div})$.[30] In contrast, the CoE's expected wage is always higher than the consultant's, $E(w_{CoE}(e_2, \tau(y))) > E(w_{Con}(\tau(y)))$, because the consultant only exerts the consulting activity whereas the CoE is in charge for the second process in addition to the consulting activity.[31] In sum, as $E(w_{Div}) > E(w^C_{Div})$ but $E(w_{Con}(\tau(y))) < E(w_{CoE}(e_2, \tau(y)))$, there is no unambiguous direction without detailed parameter considerations concerning the (dis)advantageousness of a CoE regarding the expected total compensation.
The incentive rates influence nearly all actions taken and in the next step, we compare these actions regarding the potential advantageousness of a CoE and the strength of the efficiency and distortion effect.

Effort:

All efforts of the division manager directly depend on the ability realization and incentive rate, whereas the CoE's effort solely depends on its own ability. The next result summarizes the findings concerning the efforts in both processes.

Result 3 *The division manager exerts more main process effort when no CoE exists, i.e.* $\Delta e_1 = E(e_1) - E(e^C_1) > 0$. *In turn, the sign of the service process effort difference* $\Delta e_2 = E(e_2) - e^C_2$ *is ambiguous. If* $a_C \geq E(a)$, *the service process effort with CoE is always higher than without a CoE. In contrast, if* $a_C < E(a)$, *the sign of the service process effort difference is dependent on* a_C *and* T.
If $a_L < \boldsymbol{a_C} < a'_C < E(a)$: *With a rather* ***low ability*** $\boldsymbol{a_C}$, *the expected effort without a CoE is higher than with one, i.e.* $\boldsymbol{\Delta e_2 > 0}$.
If $a_L < 2a'_C < \boldsymbol{a_C} < E(a)$: *With a rather* ***high ability*** $\boldsymbol{a_C}$, *the expected effort without a CoE is lower than with one, i.e.* $\boldsymbol{\Delta e_2 < 0}$.
If $a'_C < \boldsymbol{a_C} < 2\,a'_C$: *The sign of* Δe_2 *depends on* T: *For a* T *below (above)* T', *the expected effort without a CoE is higher (lower) than with one.*

Proof: See the Appendix A3.

The lowered incentive rate for the division manager is responsible for a lower effort for the main process in case of implementing a CoE. However, the difference $\Delta e_1 = E(e_1) - E(e^C_1)$ is not unambiguously shrinking with a_i. The ability realization affects directly and positively the effort in both scenarios. Additionally, it increases the incentive rates and can lead to a convergence of s_{Div} and s^C_{Div} under certain

[30] With $E(w_{Div}) = F_{Div} + s_{Div}E(y)$ and $E(w^C_{Div}) = F^C_{Div} + s^C_{Div}E(y^C)$.
[31] $E(w_{Con}(\tau(y))) = p\,w_{Con}(\tau_H) + (1-p)\,w_{Con}(\tau_L)$ and $E(w_{CoE}(e_2, \tau(y))) = p\,w_{CoE}(e_2, \tau_H) + (1-p)\,w_{CoE}(e_2, \tau_L)$. The relation between $w_{Con}(\tau_i)$ and $w_{CoE}(e_2, \tau_i)$ also holds for every realization of y_i with $i = H, L$.

parameter constellations so that s_{Div}^C increases more than s_{Div}. In addition, both main process efforts are negatively dependent on T. Since effort $E(e_1^C)$ decreases more with T, the difference Δe_1 increases with T.

Regarding the service process effort, it is not possible to determine the sign of $\Delta e_2 = E(e_2) - e_2^C$ without determining certain conditions.[32] These conditions are driven by the penalty T and the value of a_C due to $e_2^C = a_C$. As soon as $a_C \geq E(a)$, the service process effort with a CoE is always higher. However, the division manager's service process effort can only be higher than the CoE's effort if $a_L < a_C < E(a)$ for certain combinations of the CoE's ability a_C and penalty T. Figure 4 illustrates the critical values of a_C and the dependence of Δe_2 on a_C and penalty T.

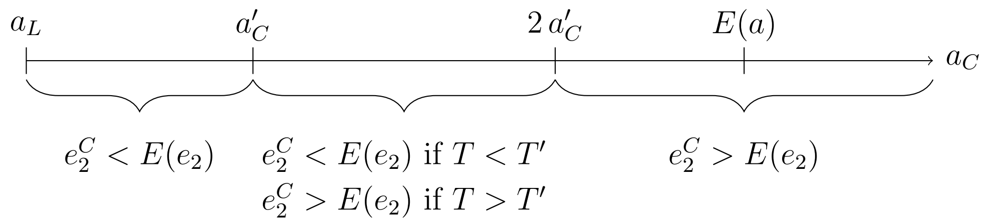


Figure 4: Service process effort advantageousness dependent on ability a_C and penalty T.

The critical values in Figure 4 are $a'_C = \frac{k\,E(a)\,E(a^2)}{1+2\,k\,E(a^2)}$ for the CoE's ability and $T' = \frac{2\,k\,E(a^2)+a_C}{q} \cdot \left(\frac{(2\,k\,a_H\,a_L-1)}{E(a)} - 2\,k\,(a_H + a_L)\right)$ for the penalty.[33] Figure 4 underlines Result 3 by showing that a CoE leads to a higher (lower) expected service process effort for very high (low) own ability values $a_C > 2\,a'_C$ ($a_C < a'_C$). If the CoE's ability is in between these two critical values, the sign of the difference is determined by penalty T. Penalty T cannot have an impact on e_2^C as $e_2^C = a_C$ but it influences $E(e_2)$ via the incentive rate. The penalty T has a negative effect on the incentive rates and therefore on the division manager's efforts. Despite $E(a) > a_C$ and even with $a'_C < a_C < 2\,a'_C$, the service process effort exerted by the CoE can in fact be higher than the manager's service process effort as soon as the critical value T' with $0 < T' < \hat{T}_{s_{Div}^C}$ (for which $\Delta e_2 = 0$) has been exceeded.

Figure 5 and 6[34] show that interplay for three values of the CoE's ability a_C. Figure 5 illustrates the expected services process effort with p on the x-axis.

[32] We use e_2^C instead of $E(e_2^C)$ since the CoE's ability is certain.
[33] With $E(a) = p\,a_H + (1-p)\,a_L$ and $E(a^2) = p\,a_H^2 + (1-p)\,a_L^2$.
[34] Considering the parameter restrictions, T has to be lower than 106.67 in Figure 5 and lower than 533.33 in Figure 6 to ensure that $s_{Div} > 0$ and $s_{Div}^C > 0$.

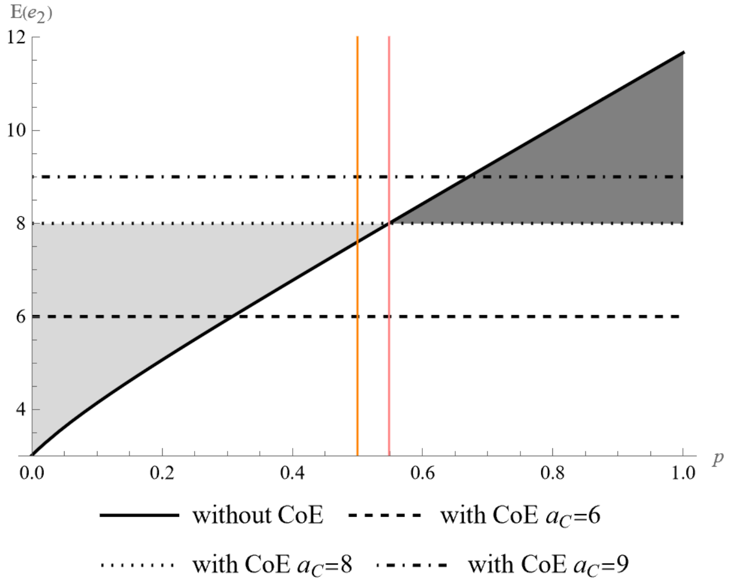


Figure 5: Service process effort comparison dependent on p, plotted for $k = 2$, $q = 0.3$, $a_L = 4$, $a_H = 12$ and $T = 50$. The orange (red) line marks $E(a) = 8$ ($E(e_2) = e_2^C(a_C = 8)$).

We focus on the CoE's dotted expected effort with $a_C = 8$ in Figure 5 and the other two serve as the illustration of the direction of e_2^C for decreasing or increasing ability values of the CoE. One would expect that $e_2^C = E(e_2)$ if $a_C = E(a)$. This is in fact not the case: Figure 5 shows that $E(e_2)$ increases with p and as long as $E(a) \leq a_C$, the second process effort by a CoE is higher than without one if $T = 0$ (light grey area until orange line). A positive penalty T decreases the division manager's effort $E(e_2)$ which makes it possible that the CoE's effort e_2^C can exceed $E(e_2)$ even if $a_C < E(a)$ (small light grey triangle between orange and red line). The red line marks the value of p in which $E(e_2) = e_2^C$ with $a_C < E(a)$ and with $T = 50$. It is clear that if the division manager's ability increases, it is easier for him to exert effort which, in turn, makes it less profitable to install a CoE even though the CoE's ability is known. Figure 6 illustrates the expected services process effort with penalty T on the x-axis.

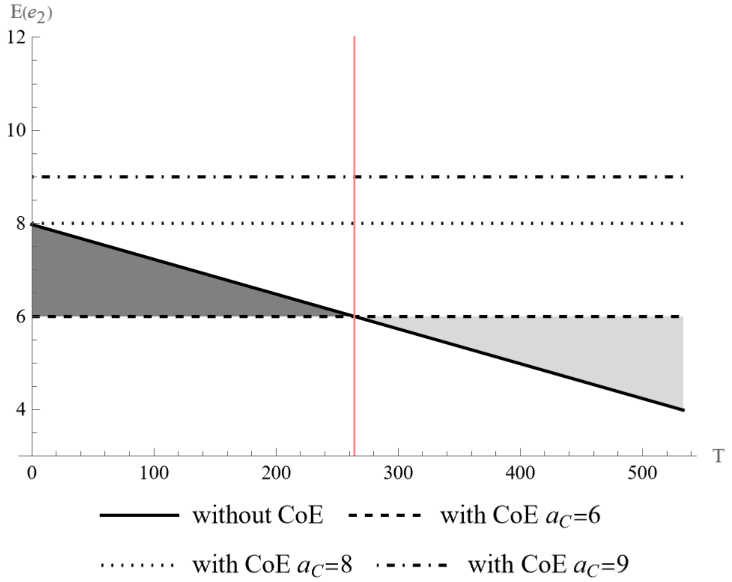


Figure 6: Service process effort comparison dependent on T, plotted for $k = 2$, $q = 0.3$, $a_L = 4$, $a_H = 12$ and $p = 0.5$. The red line marks $E(e_2) = e_2^C(a_C = 6)$.

Figure 6 underlines the statements of Result 3 and Figure 4 that the CoE's expected service process effort strictly exceeds the one of the division manager if $a_C > E(a)$, here for the parameterization $a_C = 9 > 8 = E(a)$. Additionally, Figure 6 emphasizes the effort-decreasing effect of penalty T on $E(e_2)$. If we focus on the dashed line for $a'_C = 3.9875 < a_C = 6 < 2\,a'_C = 7.975 < E(a) = 8$, we can underline Result 3 and Figure 4 that the division manager's expected effort is higher than the CoE's one until the critical point T', although the expected ability of the division manager unambiguously exceeds the ability of the CoE. If T exceeds that point (here $T' = 264.167$), the CoE's effort e_2^C exceeds the division manager's expected effort $E(e_2)$ although the CoE's ability is considerably smaller with $E(a) = 8 > 6 = a_C$.

In sum, these explanations underline Result 3 and Figure 4 that the combination of $E(a)$, a_C and T decide about the sign of Δe_2. All in all, the higher penalty T (decreases division manager's effort) and the higher the CoE's ability a_C (increases the CoE's effort), the higher the chance that the service process effort of a CoE exceeds the expected service process effort of the division manager even if $a_C < E(a)$.

When we examine the allocation of the efforts, this relation is $\frac{E(e_1)}{E(e_2)} = 1$ without a CoE, which means that both efforts are identical and the division manager works equally on both processes. In contrast, $\frac{E(e_1^C)}{e_2^C} \lesseqgtr 1$ if we only consider the efforts with a CoE. The dominance in $\frac{E(e_1^C)}{e_2^C}$ depends on p (via the expected ability $E(a)$) or rather a_C. If p is very high (i.e. $a_C < E(a)$), the expected main process effort exceeds the service process effort, i.e. $E(e_1^C) > e_2^C$, and vice versa, if p is rather low. However, when a CoE works on the second process, two different players with differing incentives work on the tasks. As a result, efforts are not equally distributed.

Earnings manipulation:

Regarding the aim to reduce compliance risks, the implementation of a Center of Excellence is successful as the following result shows.

Result 4 *Even though the implementation of a CoE effectively reduces the earnings manipulation of the division manager, $\Delta b = b - b^C > 0$, this advantage decreases (increases) with the manager's increasing ability realization a_i (penalty T).*

Proof: See the Appendix A3.

The distortion effect of an increasing ability realization a_i on the optimal earnings manipulation is larger with a CoE than without one as the earnings manipulation with a CoE increases more with a_i than without a CoE. Since earnings manipulation b is dependent on k and s_{Div}, this can be explained by the fact that s_{Div}^C increases more than s_{Div} with a_i, i.e. $\frac{\partial s_{Div}^C}{\partial a_i} > \frac{\partial s_{Div}}{\partial a_i}$. Figure 7 illustrates Result 4 with increasing a_H.

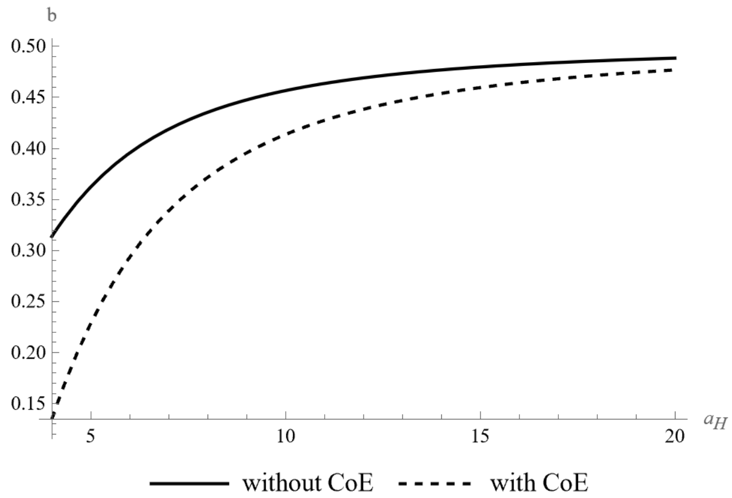


Figure 7: Earnings manipulation comparison dependent on a_H, plotted for $k = 2$, $a_L = 3$, $p = 0.5$, $q = 0.3$ and $T = 60$.

Figure 8 illustrates both optimal earnings manipulation activities with penalty T on the x-axis. It can be seen that the advantage of a CoE in order to reduce the undesired earnings manipulation becomes higher, the higher the penalty T. However, both earnings manipulation values decrease with penalty T.[35]

[35] Considering the parameter restrictions, T has to be lower than 83.33 in Figure 7 (for $a_H \geq 4$) and lower than 510 in Figure 8 to ensure that $s_{Div} > 0$ and $s_{Div}^C > 0$.

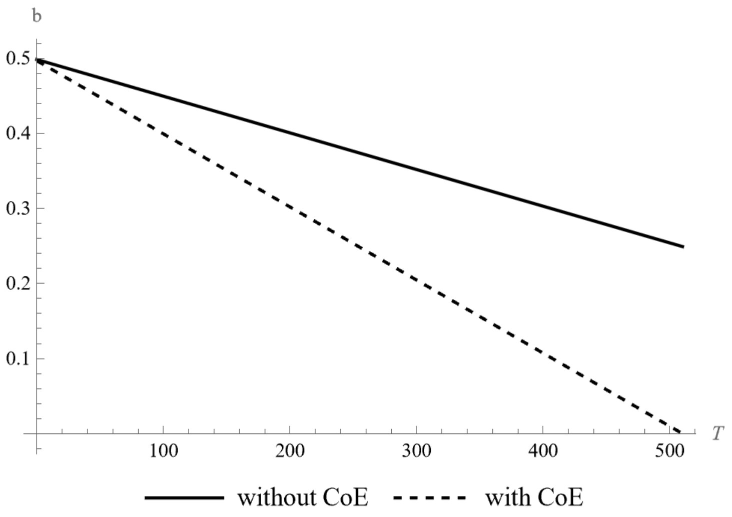


Figure 8: Earnings manipulation comparison dependent on T, plotted for $k = 2$, $p = 0.5$, $a_L = 3$, $a_H = 12$ and $q = 0.3$.

All countries successfully increase compliance with increasing penalties T as earnings manipulation decreases with T independently of whether the firm makes use of a CoE or not. However, earnings manipulation with a CoE decreases more which leads on to the conclusive advice to implement a CoE especially in high penalty countries to reduce compliance risks. The highest effect of a CoE concerning compliance can be achieved in divisions with few high ability division managers and high penalties on earnings manipulation. The next result shows the relation between the efficiency and distortion effect.

Result 5 *In exchange for a lower distortion effect with a CoE, a reduction in the expected efficiency in the same ratio has to be accepted.*[36]

$$0 < \frac{E(e_1^C)}{E(e_1)} = \frac{b^C}{b} < 1.$$

Proof: See the Appendix A3.

The aim of reducing undesired earnings manipulation with a CoE can be confirmed as being successful. But while the earnings manipulation exerted by the division manager with a CoE is always lower than without a CoE, the division manager reduces the exerted effort regarding the main process in the same ratio.

[36] This result holds for $1 \leq a_L < a_H$, $0 \leq p \leq 1$, $k \geq 1$, $0 < q \leq 1$ and $0 < T < \hat{T}_{s^C_{Div}}$.

Consulting:

The consultant and the CoE exert a consulting activity whose efficiency crucially depends on the report y and thus, the exerted earnings manipulation of the division manager. Although the CoE exerts the consulting activity in the second model approach, the optimal consulting activity is independent of its certain and high ability a_C and only dependent on the received report of the division manager. The next result shows the impact of a CoE on the expected consulting value.

Result 6 *The effect of a CoE on the expected consulting value is ambiguous,* $\Delta E(\tau(y)) = E(\tau^C(y)) - E(\tau(y)) \lesseqgtr 0$. *The consulting value based on report* y_H *is always higher with a CoE. The consulting value based on report* y_L *is higher with a CoE until a certain penalty value* T *from which on a CoE leads to a lower consulting value than the expected consulting value in a fully decentralized firm.*

Proof: See the Appendix A3.

The result is driven by penalty T as well as the height of x_L. Additionally, the indirect distortion effect has much impact: The ability realization of the division manager affects the CoE's and the consultant's activity. A higher ability leads to a higher outcome in addition to a higher report due to increased earnings manipulation. Since the division manager exerts both processes and more earnings manipulation without a CoE, the report is higher and the consulting value is consequently lower. In both models, the consulting value can become negative if $x_L < b\,q\,T$. The consulting value τ_L^C becomes negative for a lower penalty T than τ_L, see section 3.2.2 and 3.4.2. This explains why the sign of the consulting value difference after report y_L switches and $\tau_L > \tau_L^C$ can occur after a certain T. Again, a lower consulting value is not necessarily less beneficial as it affects the expected profit through the optimized earnings (higher $\tau(y)$ is preferable) as well as the expected penalty payment (lower $\tau(y)$ is preferable).
Consulting after report y_H strictly decreases with a_H as expected. In contrast, this only holds until a certain value of T for τ_L. These statements are valid for both models, without and with CoE. Overall, both expected consulting activities, i.e. $E(\tau(y))$ and $E(\tau^C(y))$, are shrinking in a_H as long as penalty T is sufficiently low. Otherwise, with T being sufficiently high, the consulting value-increasing effect of a lower earnings manipulation due to higher penalties seems to be stronger than the consulting value-decreasing effect of an increasing earnings manipulation through a higher a_H, so that above a certain value of T, $E(\tau^C)$ increases with a_H while $E(\tau)$ still decreases. A similar result can be found by examining the effect of an increasing ability realization a_L on the expected consulting activity.

Expected profit:

The previous comparison showed that there exist several effects which are not all in favor for a CoE. Thus, it is not possible to say that the overall expected profit is always higher in case of an implemented CoE. This strongly depends on the concrete values of the CoE's ability a_C and the expected ability (variance) of the manager as well as the penalty value T. A similar relation was already shown in Result 3 regarding the service process effort e_2. The next result shows that the interplay of the manager's expected ability $E(a)$ and the CoE's ability a_C with the penalty T are crucial for these effects.[37]

Result 7 *A CoE does not yield unambiguously higher expected profits than a conventional decentralized firm structure, not even with the CoE's ability* $a_C = E(a)$*. The implementation of a CoE is advantageous regarding profits if the critical ability value* $\hat{a}_C$ *for the CoE is exceeded. This value greatly depends on the variance of the manager's ability and on the value of* T*. Moreover, it does not necessarily have to be higher than* $E(a)$*. The lower the variance of the division manager's ability and the higher the penalty on earnings manipulation, the more likely is a higher expected profit with a CoE compared with a fully decentralized firm structure (without a CoE).*

Proof: See the Appendix A3.

If the variance of the division manager's ability a is quite high, a_C has to be higher than $E(a)$ to ensure a higher expected profit with a CoE, i.e. $E(G^C) > E(G)$. The same result holds if $a_C < E(a)$ but only with a rather low ability variance. This effect becomes stronger with a high T. In contrast, a CoE does not result in higher expected profits, i.e. $E(G) > E(G^C)$, if $a_L < a_C < \hat{a}_C$.[38] The comparison of the headquarters' target functions regarding the optimal effort e_2 without penalty considerations shows that a high variance in the manager's ability can be beneficial for the conventional decentralized firm structure, $\frac{1}{2}[Var(a)+E(a)^2] \lesseqgtr \frac{1}{2}a_C^2$, dependent on the concrete values of a_C and a_i. If $E(a) = a_C$, $\frac{1}{2}[Var(a) + a_C^2] > \frac{1}{2}a_C^2$ if $Var(a) > 0$ and then, a task exerted by the division itself generates higher expected profits than a CoE since the effort choice becomes better attuned to the manager's ability while the CoE only has a constant ability. This effect explains the potential lower expected profit of a CoE. The only parameter which acts against

[37] Note that in case the CoE's ability always succeeds the ability of the division manager, the headquarters is always better off implementing a CoE.

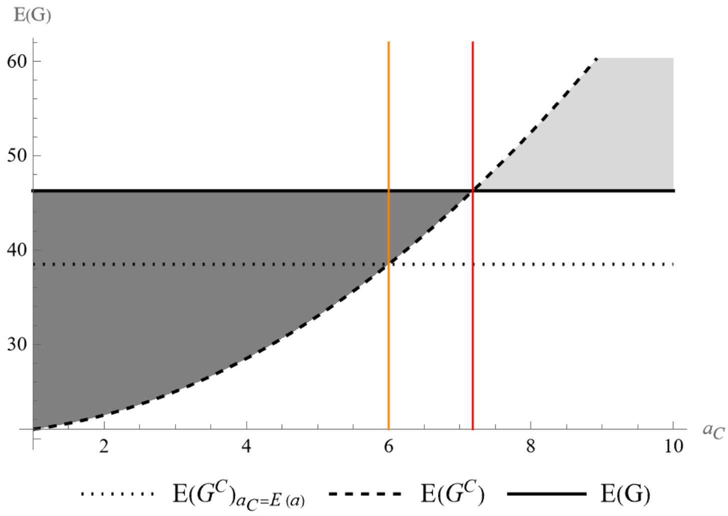
[38] The full terms of $E(G)$ and $E(G^C)$ can be found in the Appendix. The term of $\hat{a}_C$ can be determined by equalizing $E(G)$ and $E(G^C)$: $\hat{a}_C(a_H, a_L, p, q, T, k)$ is a very long term and can be delivered by the authors on demand.

this is the penalty value T. It lowers the profit of the firm while the penalty base b increases with the manager's ability a which enhances the profit decreasing effect of the penalty $(-q\,T\,b\,(1+\tau(y)))$. As already shown, the earnings manipulation without a CoE is higher than with one. Thus, an increasing T makes a CoE more and more beneficial in several aspects. If the variance of a is quite high, it exceeds the CoE-supportive impact of penalty T and a_C has to be much higher than $E(a)$ to achieve a higher expected profit with a CoE. This explains the lower expected profit of a CoE than without one if the penalty value T is quite low. If the variance of a is quite low, the impact of a very high value of T exceeds the one of the variance on the advantageousness of either a setting with or without a CoE. Therefore, even with $a_C < E(a)$, the expected profit with CoE can be higher than without one.

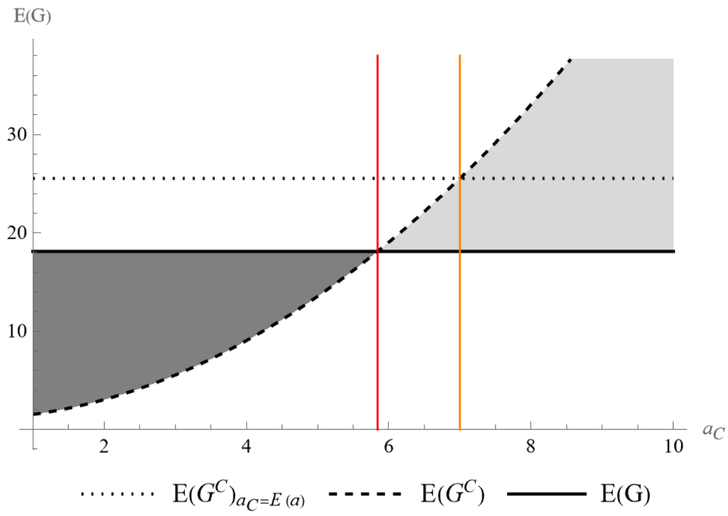
Taking a closer look at the optimized earnings before compensation payments ($x(1+\tau)$ without a CoE and $x_1(1+\tau)+x_2$ with a CoE) gives more insight into the relation between the values of a_C and $E(a)$. First of all, we consider the benchmark setting without an option for earnings manipulation and thus, without a penalty T to keep it as simple as possible. We do not consider a consulting activity for the service process if it is exerted by the CoE ($x_2^{C,B}$ vs. $x_2^B(1+\tau(y))$). Hence, compared with a setting where either both service processes are not optimized ($x_2^{C,B}$ vs. x_2^B) or where both service processes are optimized ($x_2^{C,B}(1+\tau^C(y))$ vs. $x_2^B(1+\tau(y))$), the critical value of a_C for a CoE being more beneficial than the decentralized structure is higher.[39] Thus, a decentralized structure is beneficial for higher a_i-values and a CoE needs even more capable employees (a higher a_C with $a_C > E(a)$) for being beneficial regarding profits with a service process outcome being only optimized if it is done by the division manager. This can be explained by the fact that the CoE's ability a_C has to compensate the missing consulting value on x_2. In the second-best solutions, these values are also influenced by the earnings manipulation b as well as the corresponding penalty T. This makes this interplay even more complex and enables the critical value of a_C to be below the manager's expected ability $E(a)$ under certain conditions.

[39] We consider the (optimized) earnings before compensation payments in the benchmark solution in order to show the effect of τ on x_2. $x_2^{C,B} > E(x_2^B)$ if $a_C > \sqrt{s_{Div}(p\,a_H^2+(1-p)a_L^2)} > E(a)$ with $s_{Div}=1$. In contrast and as modelled in our paper, $x_2^{C,B} > E(x_2^B(1+\tau))$ if $a_C > \sqrt{s_{Div}(p\,a_H^2+(1-p)a_L^2)+\frac{1}{2}} > E(a)$ with $s_{Div}=1$. Thus, since the service process outcome is optimized with τ if it is exerted by the division manager, this optimization increases the earnings before compensation payment and hence, the CoE's ability has to be even higher in order to ensure an advantageousness of the CoE regarding the expected profits. If we decide to optimize also the service process outcome of the CoE ($x_2^{C,B}(1+\tau^C(y))$), the critical value for a_C decreases again. However, if both processes shall be optimized with τ, this also increases the effort costs.

Figure 9a and 9b underline the significance of the abilities and penalty value. They show the expected profits with and without a CoE with the CoE's ability a_C on the x-axis. Figure 9a considers a high variance of the manager's ability and Figure 9b the low counterpart.



(a) Expected profit with $\sigma^2(a) = 16$.
Plotted for $k = 3$, $q = 0.3$, $p = 0.5$, $a_L = 2$, $a_H = 10$ and $T = 60$.



(b) Expected profit with $\sigma^2(a) = 1$.
Plotted for $k = 3$, $q = 0.3$, $p = 0.5$, $a_L = 6$, $a_H = 8$ and $T = 400$.

Figure 9: Expected profit comparison dependent on a_C.
The orange line marks $a_C = E(a)$, the red one $E(G^C) = E(G)$, thus $\hat{a}_C$.

The dotted line in both graphs illustrates the CoE's expected profit if its ability a_C equals the expected ability of the division manager. It is clear that with increasing ability a_C, a CoE's expected profits increase. As soon as its ability exceeds a cut-off value $\hat{a}_C$ (red line) for $E(G^C) = E(G)$, a CoE is more beneficial than a fully decentralized firm structure. For lower values, a CoE does not generate higher

expected profits. The cut-off value $\hat{a}_C$ (red line) for $E(G^C) = E(G)$ regarding Figure 9a[40] is $\hat{a}_C = 7.18125 > 6 = E(a)$ (orange line) in this setting. Thus, the ability of the CoE has to be sufficiently higher than the expected ability of the division manager to generate higher expected profits in this setting of a high ability variance. If a_C exceeds $E(a)$, $E(G^C)$ is higher than $E(G)$ when $a_C > \hat{a}_C$.
Figure 9b shows that even if the CoE's ability is lower than the division manager's expected ability (orange line) with a small ability variance but higher than $\hat{a}_C$ (red line), $\hat{a}_C = 5.8439 < a_C < 7 = E(a)$, the expected profit with a CoE is higher than without one if penalty T is sufficiently high. Then, the impact of the penalty via e.g. the lower earnings manipulation with a CoE dominates all other effects.

Figure 10 shows this strong impact of penalty T on the expected profit by illustrating the expected profit with and without a CoE with penalty T on the x-axis.

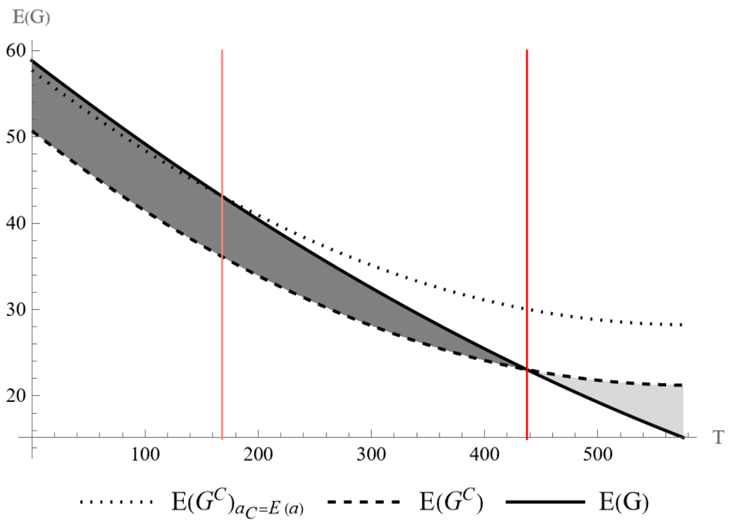


Figure 10: Expected profit comparison dependent on T with low variance $\sigma^2(a) = 2.25$. Plotted for $k = 3$, $q = 0.3$, $p = 0.5$, $a_L = 6$, $a_H = 9$ and $a_C = 6.5 < 7.5 = E(a)$. The light red line marks $E(G^C)_{a_C=E(a)} = E(G)$ and the red line marks $E(G^C) = E(G)$.

This Figure shows that even if $a_C = E(a)$ (dotted line), the expected profit without a CoE is higher than with one until a certain penalty value T (light red line). In contrast, if $a_C \leq E(a)$ (dashed line), sometime the expected profit with CoE $E(G^C)$ exceeds the one without a CoE, $E(G)$, as soon as T is high enough (red line). In sum, the lower p and a_H and the higher a_C and T, the higher the chance that a CoE is beneficial in terms of the expected profit.

[40] Considering the parameter restrictions for Figure 9a (9b) [10], T has to be lower than 166.75 (494.858) [575.4]. All restrictions ensure that $-1 \leq \tau_L$, $-1 \leq \tau_L^C$, $s_{Div} > 0$ and $s_{Div}^C > 0$.

5 Conclusion

In this paper, we analyze a one-period principal-agent setting with a division manager, a headquarters and a third player which can be either a consultant or a Center of Excellence. Our goal is to compare the settings without and with a CoE regarding exerted effort, earnings manipulation, consulting value and expected profits. We show that a CoE improves compliance since earnings manipulation significantly decreases and the corresponding expected value through consulting increases in places as well compared with a conventional decentralized firm structure. On the contrary, the division manager reduces the effort for the main process in the presence of a CoE in the same ratio as earnings manipulation decreases. The effort for the service process as well as the expected profit are not always higher with a CoE. This crucially depends on the division manager's and the CoE's ability, the division manager's ability variance and the penalty on earnings manipulation in the corresponding country. The higher the variance of the division manager's ability, the more likely is a higher expected profit without a CoE. With a low ability variance and a high penalty on earnings manipulation, a partially centralized approach with a CoE can generate better expected profits even if the CoE's ability is lower than the division manager's expected ability.

All in all, a CoE is successful regarding lower earnings manipulation, and thus better compliance and mostly, higher consulting values. A CoE is advisable concerning the profit view if the CoE's ability and penalty T are sufficiently high while the variance of the division manager's ability is sufficiently low. The implementation of a CoE can be recommended for firms that either fear reputation losses from compliance infringements or which focus on profit enhancements. In the latter case, they should be located in high-penalty countries, have low ability variances or rather very high-skilled employees in the CoE in relation to their division managers. Nevertheless, there is still much room for further scientific investigation. A potential extension of our model could include costs for switching the systems from decentralization to partial centralization. An examination of these costs could decrease the CoE's benefit and thus, provide new insights into the trade-offs between centralization and decentralization within an accounting context.

Appendix

Appendix A1 - Without CoE

Proof of Lemma 1:

The optimal consulting activity from the headquarters' view after observing y maximizes

$$\underset{\tau(y)}{max}\ E(x\,(1+\tau(y))|y) - \frac{(y\,\tau(y))^2}{2} \Leftrightarrow \underset{\tau(y)}{max}\ y\,(1+\tau(y)) - \frac{(y\,\tau(y))^2}{2}.$$

Applying the first-order condition leads to equation (11).

The consultant receives the report y from the division manager. By following the backward-induction procedure, we analyze the first stage by

$$\frac{\partial U_{Div_i}}{\partial e_{ji}} = 0 \Leftrightarrow a_i\, s_{Div} - e_{ji} = 0 \Leftrightarrow e_{ji} = a_i\, s_{Div},$$

with $j = 1, 2$ and $i = H, L$. The principal's problem is given in equation (9). By substituting the binding participation constraint (PC 1) as well as the optimal efforts from (11) and (12), the problem can be simplified to (13). The first-order condition of the reduced optimization problem in (13) regarding s_{Div} is

$$2\,(s_{Div} - 1)\left((p-1)\,a_L^2 - p\,a_H^2\right) = 0.$$

Rearranging with respect to s_{Div} leads to $s_{Div}^B = 1$. Inserting the incentive rate into the optimal division manager's efforts and accounting for the uncertain ability at contract termination date brings us the equilibrium actions in (15) and (16). ■

Inserting the incentive rate and actions from Lemma 1 in the objective function (9) leads to the expected profit given in (17).

Proof of Lemma 2:

The proof follows the procedure of Lemma 1 but with earnings manipulation b.

$$\underset{\tau(y)}{max}\ E(x\,(1+\tau(y))|y) - \frac{(y\,\tau(y))^2}{2} - q\,T\,b\,(1+\tau(y))$$
$$\Leftrightarrow \underset{\tau(y)}{max}\ (y-b)(1+\tau(y)) - \frac{(y\,\tau(y))^2}{2} - q\,T\,b\,(1+\tau(y)),$$

since $y = x + b$. Applying the first-order condition leads to equation (20).

First stage (division manager's decision):

$$\frac{\partial U_{Div_i}}{\partial e_{ji}} = 0 \Leftrightarrow a_i\, s_{Div} - e_{ji} = 0 \Leftrightarrow e_{ji} = a_i\, s_{Div},$$
$$\frac{\partial U_{Div}}{\partial b} = 0 \Leftrightarrow s_{Div} - kb = 0 \Leftrightarrow b = \frac{s_{Div}}{k},$$

with $j = 1, 2$ and $i = H, L$. The reduced optimization problem is given in (23). The first-order condition regarding s_{Div} is given by

$$\frac{2\,k\,(p\,a_H^2 + (1-p)\,a_L^2) - q\,T - (1 + 2\,k\,(p\,a_H^2 + (1-p)\,a_L^2))\,s_{Div}}{k} = 0.$$

Rearranging with respect to s_{Div} provides s_{Div}^{SB} in (24). Inserting s_{Div}^{SB} in the optimal effort choices, we obtain the equilibrium actions given by (25) - (27). ■

Inserting the incentive rate and optimal actions from Lemma 2 into the objective function (18) leads to the expected profit of the headquarters:

$$E(G^{SB}) = \frac{o}{z} \text{ with}$$

$$\begin{aligned}
o =& 16a_L^8k^4(p-1)^2\left(2a_H^2k+1\right)^2 + 4a_H^4k^2p\left(2a_H^2kp\left(2a_H^2k+k+2\right)+k+p\right)\\
&-4a_H^2kpqT\left(k\left(4a_H^4k+2a_H^2(kp+2)+1\right)+1\right)\\
&+q^2T^2\left(2a_H^2k\left(k\left(2a_H^2\left(1+k(1-p)\left(2p\left(a_H^2k+1\right)+1\right)\right)-p+2\right)+2\right)+k+1\right)\\
&+8a_H^2a_L^2k^2p\left(a_H^2k\left(k\left(8a_H^4kp+4a_H^2(kp+p+1)-p+3\right)-2p+4\right)-p+1\right)\\
&+4a_L^2kqT\left(k\left(4a_H^2(k((p-1)p-1)-1)+p-1\right)+p-1\right)\\
&+16a_H^2a_L^2k^3qT\left(2a_H^4kp(k(p-1)-2)-a_H^2((k+3)p+k+1)\right)\\
&+2a_L^2kq^2T^2\left(k\left(4a_H^2\left(a_H^2k\left(k(p-1)^2+2\right)+2k(p-1)p+k+2\right)+p+1\right)+2\right)\\
&+8a_L^6k^3(1-p)\left(k\left(16a_H^6k^2p+pq^2T^2-p+1\right)-2(p+qT-1)\right)\\
&+8a_L^6k^4(1-p)\left(4a_H^4k(k+2(p-qT+1))-4a_H^2(k(pqT+p-1)+p+2qT-2)\right)\\
&+4a_L^4k^2\left(8a_H^6k^4p\left(2a_H^2p+1\right)-4(1-p)qT+(p-1)^2+q^2T^2\right)\\
&-8a_H^2a_L^4k^4\left(2a_H^2(6(p-1)p+qT(4-qT)-1)+p\left(1+p-qT(2+pqT)\right)+4qT-2\right)\\
&-16a_H^4a_L^4k^5\left(4p\left(a_H^2(p+qT-2)+(p-1)(qT+1)\right)+2qT-1\right)\\
&+4a_L^4k^3\left(4a_H^2\left(1+qT(3p+qT-4)-p^2\right)-2qT+1\right)\\
&+4a_L^4k^3p(qT(3qT+4-2p(qT+1))-1),
\end{aligned}$$

$$z = 2k\left(1+2a_H^2k\right)^2\left(1+2a_L^2k\right)^2\left(1+2k(p\,a_H^2+(1-p)\,a_L^2)\right) > 0.$$

Comparative statics of the incentive rate s_{Div}^{SB}:

$$\frac{\partial s_{Div}^{SB}}{\partial p} = \frac{2\,k\,(a_H - a_L)(a_H + a_L)(1 + q\,T)}{(1 + 2\,k\,E(a^2))^2} > 0,$$

$$\frac{\partial s_{Div}^{SB}}{\partial a_i} = \frac{4\,Pr(a_i)\,a_i\,k\,(1 + qT)}{(1 + 2\,k\,E(a^2))^2} \geq 0, \qquad \frac{\partial s_{Div}^{SB}}{\partial k} = \frac{2E(a^2)\,(1 + q\,T)}{(1 + 2\,k\,E(a^2))^2} > 0,$$

$$\frac{\partial s_{Div}^{SB}}{\partial q} = -\frac{T}{1 + 2\,k\,E(a^2)} < 0, \qquad \frac{\partial s_{Div}^{SB}}{\partial T} = -\frac{q}{1 + 2\,k\,E(a^2)} \leq 0,$$

with $E(a^2) = p\,a_H^2 + (1-p)\,a_L^2$ and $a_H > a_L \geq 1$, $0 \leq p \leq 1$, $k \geq 1$, $0 < q \leq 1$, $0 < T < \hat{T}_{s_{Div}}$.

Determination of critical value for T in Equation (28) to ensure $s_{Div}^{SB} > 0$: To ensure that s_{Div}^{SB} is positive, penalty T has to be limited if $0 < q \leq 1$ to ensure a positive numerator of s_{Div}^{SB} (the denominator is positive anyway). The conditions for $s_{Div}^{SB} > 0$ are the same as for $1 \geq s_{Div}^{SB} > 0$. It must hold that

$$1 \geq s_{Div}^{SB} > 0 \text{ with } s_{Div}^{SB} = \frac{2\,k\,(p\,a_H^2 + (1-p)\,a_L^2) - q\,T}{2\,k\,(p\,a_H^2 + (1-p)\,a_L^2) + 1} = \frac{2\,k\,E(a^2) - q\,T}{2\,k\,E(a^2) + 1}$$

$$\text{if } 1 \leq a_L < a_H,\ 0 \leq p \leq 1,\ k \geq 1,\ 0 < q \leq 1$$

$$\text{and } 0 < T < \hat{T}_{s_{Div}} = \frac{2\,k\,(p\,a_H^2 + (1-p)\,a_L^2)}{q} = \frac{2\,k\,E(a^2)}{q},$$

with $E(a^2) = p\,a_H^2 + (1-p)\,a_L^2$. $\hat{T}_{s_{Div}}$ is used as a limitation for T for further calculations in the model without CoE.

Proof of Result 1: For $a_H > a_L \geq 1\,, 0 \leq p \leq 1\,, k \geq 1\,, 0 < q \leq 1\,, 0 < T < \hat{T}_{s_{Div}}$:

$$e_{ji}^{SB} = a_i\,s_{Div}^{SB} < e_{ji}^{B} = a_i, \text{ since } 0 < s_{Div}^{SB} \leq 1;\ \frac{\partial e_{ji}^{SB}}{\partial a_i} \geq 0 \text{ since } \frac{\partial s_{Div}^{SB}}{\partial a_i} \geq 0.$$

$$b^{SB} = \frac{s_{Div}^{SB}}{k} > 0, \text{ since } 0 < s_{Div}^{SB} \leq 1;\ \frac{\partial b^{SB}}{\partial a_i} \geq 0, \text{ since } \frac{\partial s_{Div}^{SB}}{\partial a_i} \geq 0.$$

$$\tau_i^B = \frac{1}{2\,a_i^2} > 0,\ \frac{\partial \tau_i^B}{\partial a_i} = -\frac{1}{a_i^3} < 0;\ \tau^{SB}(y) = \frac{y - b\,(1 + q\,T)}{y^2} \text{ with } y = x - b.$$

■

Appendix A2 - With CoE

Proof of Lemma 3:

Since the headquarters can contract upon the CoE's efforts e_2 and $\tau(y)$ paying a wage $\frac{e_2^2}{2}+\frac{(y\,\tau(y))^2}{2}$ the optimal effort for the second process and the optimal consulting activity from the headquarters' view after observing y maximizes

$$\begin{aligned} &\max_{e_2,\tau(y)}\ E(x\,(1+\tau(y))|y)+x_2-\frac{e_2^2}{2}-\frac{(y\,\tau(y))^2}{2},\\ \Leftrightarrow &\max_{e_2,\tau(y)}\ y\,(1+\tau(y))+x_2-\frac{e_2^2}{2}-\frac{(y\,\tau(y))^2}{2}.\end{aligned}$$

Applying the first-order condition leads to

$$e_2=a_C,\qquad \tau(y)=\frac{1}{y}.$$

The CoE receives the report from the division manager. By following the backward-induction procedure, we analyze the first stage by applying the first-order condition to IC 2. Then, the incentive constraint of the division manager (after observing his type) can be written as

$$\frac{\partial U^C_{Div_i}}{\partial e_{1i}}=0\Leftrightarrow a_i\,s_{Div}-e_{1i}=0\Leftrightarrow e_{1i}=a_i\,s_{Div},$$

with $i=H,L$. The optimal incentive rate of the division manager $s^{C,B}_{Div}=1$ results from maximizing the reduced optimization problem for the agency relationship which is obtained by inserting (PC 2) as a binding equation into (39) as well as the optimal efforts for e_{1i}, e_2 and $\tau(y)$,

$$\begin{aligned}&\max_{s_{Div}}\ p\left(x_{1H}\,(1+\tau_H)+x_2-\frac{e_{1H}^2}{2}-\frac{e_2^2}{2}-\frac{(y_H\,\tau_H)^2}{2}\right)\\ &+(1-p)\left(x_{1L}\,(1+\tau_L)+x_2-\frac{e_{1L}^2}{2}-\frac{e_2^2}{2}-\frac{(y_L\,\tau_L)^2}{2}\right).\end{aligned}$$

The first-order condition of the reduced optimization problem regarding s_{Div} is

$$(s_{Div}-1)\left((p-1)\,a_L^2-p\,a_H^2\right)=0.$$

Rearranging with respect to s_{Div} leads to $s^{C,B}_{Div}=1$ in (40). Inserting the incentive rate into the optimal efforts brings us equation (41) - (43) in Lemma 3. ■

Inserting the incentive rate and optimal actions from Lemma 3 into the objective function (39) leads to the expected profit of the headquarters:

$$E(G^{C,B}) = \frac{1}{2}(1 + a_C^2 + p\,a_H^2 + (1-p)\,a_L^2).$$

Proof of Lemma 4:

The proof follows the procedure of Lemma 3 but with earnings manipulation b. As before, the headquarters and the CoE can contract on the service process effort e_2 and the consulting activity $\tau(y)$ and the wage $w_{CoE}(e_2, \tau(y))$ is again chosen such that the CoE's effort costs for e_2 and $\tau(y)$ are exactly offset.

$$\begin{aligned}
&\max_{e_2,\tau(y)}\; E(x\,(1+\tau(y))|y) + x_2 - \frac{e_2^2}{2} - \frac{(y\,\tau(y))^2}{2} - q\,T\,b\,(1+\tau(y)),\\
\Leftrightarrow &\max_{e_2,\tau(y)}\; (y-b)(1+\tau(y)) + x_2 - \frac{e_2^2}{2} - \frac{(y\,\tau(y))^2}{2} - q\,T\,b\,(1+\tau(y)),
\end{aligned}$$

since $y = x + b$. Applying the first-order condition leads to

$$e_2 = a_C, \qquad \tau(y) = \frac{y - b\,(1+qT)}{y^2}.$$

The CoE receives the report from the division manager. By following the backward-induction procedure, we analyze the first stage by

$$\begin{aligned}
\frac{\partial U_{Div_i}^C}{\partial e_{1i}} &= 0 \Leftrightarrow a_i\,s_{Div} - e_{1i} = 0 \Leftrightarrow e_{1i} = a_i\,s_{Div},\\
\frac{\partial U_{Div}}{\partial b} &= 0 \Leftrightarrow s_{Div} - kb = 0 \Leftrightarrow b = \frac{s_{Div}}{k},
\end{aligned}$$

with $i = H, L$. The optimal incentive rate and induced actions are determined by conducting the optimization of (45) with a binding (PC 2.1) and the optimal efforts for e_{1i}, e_2, b and $\tau(y)$:

$$\begin{aligned}
\max_{s_{Div}}\; &p\left(x_{1H}\,(1+\tau_H) + x_2 - \frac{e_{1H}^2}{2} - \frac{k\,b^2}{2} - \frac{e_2^2}{2} - \frac{(y_H\,\tau_H)^2}{2} - q\,T\,b\,(1+\tau_H)\right)\\
&+ (1-p)\left(x_{1L}\,(1+\tau_L) + x_2 - \frac{e_{1L}^2}{2} - \frac{k\,b^2}{2} - \frac{e_2^2}{2} - \frac{(y_L\,\tau_L)^2}{2} - q\,T\,b\,(1+\tau_L)\right).
\end{aligned}$$

The first-order condition regarding s_{Div} is

$$\frac{k\,(p\,a_H^2 + (1-p)\,a_L^2) - q\,T\,(1 + k\,(p\,a_H^2 + (1-p)\,a_L^2))s_{Div}}{k} = 0.$$

Rearranging provides $s_{Div}^{C,SB}$ in (46) in Lemma 4. Inserting $s_{Div}^{C,SB}$ in the optimal effort choices, we obtain the equilibrium actions given by (47) - (50). ■

Inserting the incentive rate and optimal actions from Lemma 4 into the objective function (45) leads to the expected profit of the headquarters:

$$
\begin{aligned}
&E(G^{C,SB}) = \\
&\frac{2a_H^6k^3p^2 + a_H^4k^3p + a_H^4k^2p^2 + a_L^8k^4(p-1)^2\left(1+a_H^2k\right)^2}{z} \\
&+\frac{a_C^2k\left(1+a_H^2k\right)^2\left(1+a_L^2k\right)^2\left(a_H^2kp + a_L^2k(1-p)+1\right) + p^2k^4(a_H^8 + a_H^6)}{z} \\
&+\frac{q^2T^2(1+k) - 2a_H^6k^3pqT - 2a_H^4k^3p^2qT - 4a_H^4k^2pqT - 2a_H^2k^2pqT - 2a_H^2kpqT}{z} \\
&+\frac{q^2T^2(a_H^4k^3 + a_H^4k^2 - a_H^2k^2p + 2a_H^2k^2 + 2a_H^2k)}{z} \\
&+\frac{q^2T^2(a_H^6k^4(p-p^2) - 2a_H^4k^3p^2 + a_H^4k^3p)}{z} \\
&+\frac{a_L^6k^3\left(a_H^4k^3\left(1+2a_H^2(p-p^2)-p\right) - 2(1-p)(p+qT-1)\right)}{z} \\
&-\frac{a_L^6k^3\left(k(1-p)\left(2a_H^2(p+2qT-2) - pq^2T^2 + p - 1\right)\right)}{z} \\
&+\frac{a_L^6k^3\left(2a_H^2k^2(1-p)\left(a_H^2(p-qT+1) - p(qT+1)+1\right)\right)}{z} \\
&+\frac{a_L^4k^2\left(a_H^6k^4p\left(a_H^2p+1\right) + p^2 + 4pqT - 2p + q^2T^2 - 4qT + 1\right)}{z} \\
&-\frac{a_L^4k^3\left(2a_H^2\left(p^2 + qT(4-3p-qT) - 1\right) + 2p^2qT(qT+1)\right)}{z} \\
&-\frac{a_L^4k^3\left(p\left(1-3q^2T^2 - 4qT\right) + 2qT - 1\right)}{z} \\
&+\frac{a_H^2a_L^4k^4\left(a_H^2\left(6(p-p^2) + q^2T^2 - 4qT + 1\right) + p^2\left(q^2T^2 - 1\right) + p(2qT-1) - 4qT + 2\right)}{z} \\
&+\frac{a_H^4a_L^4k^5\left(p\left(a_H^2(4-2qT) + 4qT + 4\right) - 2p^2\left(a_H^2 + 2qT + 2\right) - 2qT + 1\right)}{z} \\
&+\frac{a_L^2k\left(2a_H^8k^4p^2 + 2a_H^6k^3p(p(k(1+qT)+1) - ((k+2)qT)+1)\right)}{z} \\
&+\frac{2a_H^2a_L^2k^2\left(p^2(2kqT(qT+1)-1) - 2kpqT(1+qT) + qT(k(qT-2)+2qT-2)+p\right)}{z} \\
&+\frac{a_L^2kqT(k(p(qT+2)+qT-2) + 2(p+qT-1))}{z} \\
&+\frac{a_H^4a_L^2k^3\left(p\left(k\left(3-2q^2T^2-2qT\right) - 6qT + 4\right) + qT(k(qT-2)+2qT-2)\right)}{z} \\
&+\frac{a_H^4a_L^2k^3\left(p^2\left(k\left(q^2T^2-1\right)-2\right)\right)}{z},
\end{aligned}
$$

with $z = 2k\left(1+a_H^2 k\right)^2\left(1+a_L^2 k\right)^2\left(1+k(p\,a_H^2+(1-p)\,a_L^2)\right) > 0.$

Comparative statics of the incentive rate $\boldsymbol{s_{Div}^{C,SB}}$:

$$\frac{\partial s_{Div}^{C,SB}}{\partial p} = \frac{k\,(a_H-a_L)\,(a_H+a_L)\,(1+q\,T)}{\left(1+k\,E(a^2)\right)^2} > 0, \qquad \frac{\partial s_{Div}^{C,SB}}{\partial a_C} = 0,$$

$$\frac{\partial s_{Div}^{C,SB}}{\partial a_i} = \frac{2\,a_i\,k\,Pr(a_i)(1+q\,T)}{\left(1+k\,E(a^2)\right)^2} \geq 0, \qquad \frac{\partial s_{Div}^{C,SB}}{\partial k} = \frac{E(a^2)\,(1+q\,T)}{\left(1+k\,E(a^2)\right)^2} > 0,$$

$$\frac{\partial s_{Div}^{C,SB}}{\partial q} = -\frac{T}{1+k\,E(a^2)} < 0, \qquad \frac{\partial s_{Div}^{C,SB}}{\partial T} = -\frac{q}{1+k\,E(a^2)} \leq 0,$$

with $E(a^2) = p\,a_H^2 + (1-p)\,a_L^2$, $i = H, L$ and $a_H > a_L \geq 1$, $0 \leq p \leq 1$, $k \geq 1$, $0 < q \leq 1$, $0 < T < \hat{T}_{s_{Div}^C}$.

Determination of critical value for $\boldsymbol{T}$ in equation (51) to ensure $\boldsymbol{s_{Div}^C > 0}$:

To ensure that $s_{Div}^{C,SB}$ is positive, penalty T has to be limited if $0 < q \leq 1$ to ensure a positive numerator of $s_{Div}^{C,SB}$ (the denominator is positive anyway). The conditions for $s_{Div}^{C,SB} > 0$ are the same as for $1 \geq s_{Div}^{C,SB} > 0$.

$$1 \geq s_{Div}^{C,SB} > 0 \text{ with } s_{Div}^{C,SB} = \frac{k\,(p\,a_H^2+(1-p)\,a_L^2) - q\,T}{k\,(p\,a_H^2+(1-p)\,a_L^2)+1} = \frac{k\,E(a^2)-q\,T}{k\,E(a^2)+1}$$
$$\text{if } 1 \leq a_L < a_H,\ 0 \leq p \leq 1,\ k \geq 1, 0 < q \leq 1$$
$$\text{and } 0 < T < \hat{T}_{s_{Div}^C} = \frac{k\,(p\,a_H^2+(1-p)\,a_L^2)}{q} = \frac{kE(a^2)}{q},$$

with $E(a^2) = p\,a_H^2 + (1-p)\,a_L^2$. $\hat{T}_{s_{Div}^C}$ is used as a limitation for T for further calculations in the model with CoE.

Since $\hat{T}_{s_{Div}} = 2\,\hat{T}_{s_{Div}^C}$ for the approved parameters, $\hat{T}_{s_{Div}^C}$ is the lower critical value. Thus, we will use it for all the following calculations.

Proof of Result 2:

See Proof of Result 1 plus $a_H > a_C > a_L \geq 1,\ 0 < T < \hat{T}_{s^C_{Div}}$:

$$e_{1i}^{C,SB} = a_i\, s_{Div}^{C,SB} < e_{1i}^{C,B} = a_i, \text{ since } 0 < s_{Div}^{C,SB} \leq 1;\ \frac{\partial e_{1i}^{C,SB}}{\partial a_i} > 0, \text{ since } \frac{\partial s_{Div}^{C,SB}}{\partial a_i} \geq 0.$$

$$b^{C,SB} = \frac{s_{Div}^{C,SB}}{k} > 0, \text{ since } 0 < s_{Div}^{C,SB} \leq 1;\ \frac{\partial b^{C,SB}}{\partial a_i} \geq 0, \text{ since } \frac{\partial s_{Div}^{C,SB}}{\partial a_i} \geq 0.$$

$$\tau_i^{C,B} = \frac{1}{a_i^2} > 0\,,\ \frac{\partial \tau^{C,B}}{\partial a_i} = -\frac{2}{a_i^3} < 0;\ \tau^{C,SB}(y) = \frac{y - b\,(1 + q\,T)}{y^2} \text{ with } y = x_1 - b.$$

■

Appendix A3 - Comparison

Determination of players' compensation payments in the second-best solutions:

Solving the binding (PC 1.1) with the optimal effort, earnings manipulation and incentive rate, the second-best fixed wage F_{Div} is

$$F_{Div} = \frac{(q\,T - 2\,k(p\,a_H^2 + (1-p)\,a_L^2))^2}{2\,k(-1 - 2\,k\,(p\,a_H^2 + (1-p)\,a_L^2))} = \frac{(q\,T - 2\,k\,E(a^2))^2}{2\,k(1 + 2\,k\,E(a^2))^2}.$$

The second-best wage of the consultant $w_{Con}(\tau_i)$ for $i = H, L$ (based on the forcing contract) is

$$w_{Con}(\tau_i) = \frac{(y_i\,\tau_i)^2}{2} = \frac{(q\,T - 2\,a_i^2\,k)^2}{2(1 + 2\,a_i^2\,k)^2}.$$

Solving the binding (PC 2.1) with the optimal effort, manipulation and incentive rate, the second-best fixed wage F_{Div}^C is

$$F_{Div}^C = \frac{(q\,T - k(p\,a_H^2 + (1-p)\,a_L^2))^2}{2\,k(-1 - k(p\,a_H^2 + (1-p)\,a_L^2))} = \frac{(q\,T - k\,E(a^2))^2}{2\,k(-1 - k\,E(a^2))}.$$

The second-best wage $w_{CoE}(e_2, \tau_i)$ for $i = H, L$ (based on the forcing contract) is

$$w_{CoE}(e_2, \tau_i) = \frac{e_2^2}{2} + \frac{(y_i\,\tau_i)^2}{2} = \frac{(a_C(1 + a_i^2\,k))^2 + (a_i^2\,k - q\,T)^2}{2(1 + a_i^2\,k)^2}.$$

Illustration of compensation differences without and with a CoE:

$$s_{Div} - s^C_{Div} = \frac{k\,(1 + q\,T)\,E(a^2)}{(k\,E(a^2) + 1)\,(2\,k\,E(a^2) + 1)} > 0.$$

$$F_{Div} - F^C_{Div} = \frac{(q\,T - k\,E(a^2))^2}{2\,k\,(1 + k\,E(a^2))} + \frac{(q\,T - 2\,k\,E(a^2))^2}{2\,k\,(1 + 2\,k\,E(a^2))} < 0.$$

$$E(w_{Div}) - E(w^C_{Div}) = \frac{E(a^2)\,(kE(a^2)\,(2\,k\,E(a^2) + 3) - q\,T\,(q\,T + 2))}{2\,(k\,E(a^2) + 1)\,(2\,k\,E(a^2) + 1)} > 0,$$

$$\text{with}\, E(w_{Div}) = F_{Div} + s_{Div}E(y)\,\text{and}\,E(w^C_{Div}) = F^C_{Div} + s^C_{Div}E(y^C).$$

$$E(w_{Con}(\tau(y))) - E(w_{CoE}(e_2, \tau(y)) < 0,$$

$$\text{with}\, E(w_{Con}(\tau(y))) = p\,w_{Con}(\tau_H) + (1 - p)\,w_{Con}(\tau_L)$$

$$\text{and}\, E(w_{CoE}(e_2, \tau(y)) = p\,w_{CoE}(e_2, \tau_H) + (1 - p)\,w_{CoE}(e_2, \tau_L)\,\text{where}$$

$$w_{Con}(\tau_i) - w_{CoE}(e_2, \tau_i) =$$

$$\frac{1}{2}\left(\frac{a_i^2\,k\,(1 + q\,T)(a_i^2\,k\,(3 + 4\,a_i^2\,k - 3\,q\,T) - 2\,q\,T)}{(q + 3\,a_i^2\,k + 2\,a_i^4\,k^2)^2} - a_C^2\right) < 0,$$

with $E(a) = p\,a_H + (1 - p)\,a_L$ and $E(a^2) = p\,a_H^2 + (1 - p)\,a_L^2$.

Proof of Result 3:

For $a_H > a_L \geq 1$, $0 \leq p \leq 1$, $k \geq 1$, $0 \leq q \leq 1$ and $T < \hat{T}_{s^C_{Div}}$.

$$\Delta e_1^{SB} = E(e_1) - E(e_1^C) = \frac{E(a)\,k\,(1 + q\,T)\,E(a^2)}{(1 + 2\,k\,E(a^2))\,(1 + k\,E(a^2))} > 0.$$

$$\Delta e_2^{SB} = E(e_2) - e_2^C = \frac{E(a)\,(2\,k\,E(a^2) - qT)}{2\,k\,E(a^2) + 1} - a_C \lesseqqgtr 0,$$

$$\text{When is}\, E(e_2) = e_2^C?\,\text{If}\, a_C = E(a): \frac{E(a)\,(2\,k\,E(a^2) - qT)}{2\,k\,E(a^2) + 1} = E(a)$$

$$\Leftrightarrow \frac{2\,k\,E(a^2) - qT}{2\,k\,E(a^2) + 1} < 1.$$

Even with $T = 0$, the numerator is always smaller than the denominator. Hence, the whole quotient is smaller than 1. This effect becomes stronger with increasing a_C and/or T. It also shows that the inequality sign crucially depends on the ratio of a_C and $E(a)$ as well as the value of T.

$$\begin{aligned}
&\text{If } a_C \geq E(a) : e_2^C > E(e_2). \\
&\text{If } a_C < E(a) : e_2^C < E(e_2) \quad && \text{if } a_C \leq a'_C < E(a) \text{ and } T < \hat{T}_{s^C_{Div}} \\
& && \text{or if } a'_C < a_C < 2\,a'_C < E(a) \text{ and } T < T' < \hat{T}_{s^C_{Div}}, \\
&\qquad\qquad\quad\; e_2^C > E(e_2) && \text{if } 2\,a'_C \leq a_C < E(a) \text{ and } T < \hat{T}_{s^C_{Div}} \\
& && \text{or if } a'_C < a_C < 2\,a'_C < E(a) \text{ and } T' < T < \hat{T}_{s^C_{Div}},
\end{aligned}$$

$a'_C = \frac{k\,E(a)\,E(a^2)}{1+2\,k\,E(a^2)}$ and $T' = \frac{2\,k\,E(a^2)+a_C\left(\frac{(2\,k\,a_H\,a_L-1)}{E(a)}-2\,k\,(a_H+a_L)\right)}{q}$.
With $E(a) = p\,a_H + (1-p)\,a_L$ and $E(a^2) = p\,a_H^2 + (1-p)\,a_L^2$. In order to determine the values for a'_C and T', it is possible that $a_C \leq a_L$. ■

Proof of Result 4:

$$\Delta b^{SB} = b - b^C = \frac{s_{Div}}{k} - \frac{s^C_{Div}}{k} > 0 \text{ since } s_{Div} > s^C_{Div}.$$
$$\frac{\partial \Delta b^{SB}}{\partial a_i} = \frac{2\,Pr(a_i)\,a_i(1+q\,T)\,(1-2\,k^2 E(a^2)^2)}{(1+2\,k\,E(a^2))^2\,(1+k\,E(a^2))^2} \leq 0,$$

with $E(a^2) = p\,a_H^2 + (1-p)\,a_L^2$. ■

Proof of Result 5:

For $1 \leq a_L < a_H$, $0 \leq p \leq 1$, $k \geq 1$, $0 < q \leq 1$, $0 < T < \hat{T}_{s^C_{Div}}$.

$$0 < \frac{b^C}{b} = \frac{E(e_1^C)}{E(e_1)} = \frac{(1+2\,k\,E(a^2))\,(k\,E(a^2)-q\,T)}{(1+k\,E(a^2))\,(2\,k\,E(a^2)-q\,T)} < 1,$$

with $E(a^2) = p\,a_H^2 + (1-p)\,a_L^2$. ■

Proof of Result 6:

$$E(\tau^C) = \frac{k\,(k\,E(a^2)+1)}{(k\,E(a^2)-q\,T)}\left(\frac{p\,(a_H^2\,k-q\,T)}{(1+a_H^2\,k)^2} + \frac{(1-p)\,(a_L^2\,k-q\,T)}{(1+a_L^2\,k)^2}\right),$$
$$E(\tau) = \frac{k\,(2\,k\,E(a^2)+1)}{(2\,k\,E(a^2)-q\,T)}\left(\frac{p\,(1+2\,a_L^2\,k)^2(2\,a_H^2\,k-q\,T)}{(1+2\,a_H^2\,k)^2(1+2\,a_L^2\,k)^2} + \frac{(1-p)\,(1+2\,a_H^2\,k)^2(2\,a_L^2\,k-q\,T)}{(1+2\,a_H^2\,k)^2(1+2\,a_L^2\,k)^2}\right),$$

with $E(a^2) = p\,a_H^2 + (1-p)\,a_L^2$. The CoE's ability a_C has no impact, thus, the difference $\Delta E(\tau) = E(\tau^C) - E(\tau)$ crucially depends on the manager's ability realization as well as the penalty height. Since the formula expression of the difference $\Delta E(\tau)$ is quite long, we prove it with numerical examples for the impact of penalty T which is also important for τ_L being positive or negative: With $k = 3$, $p = 0.5$, $q = 0.3$, $a_L = 4$, $a_H = 8$ and thus, $\hat{T}_{s^C_{Div}} = 400$ and $\hat{T}_{\tau^C_L} = 368.48$: In this setting, $\tau_L^{C,SB} < 0$ if $T > 160\,(\frac{a_L^2\,k}{q})$ and $\tau_L^{SB} < 0$ if $T > 320\,(\frac{2\,a_L^2\,k}{q})$:

$\Delta\tau_H = \tau_H^C - \tau_H > 0,$	$\Delta\tau_L = \tau_L^C - \tau_L \lesseqgtr 0,$	$\Delta E(\tau) = E(\tau^C) - E(\tau) \lesseqgtr 0,$
$T = 50$: $\Delta\tau_H = 0.0084 > 0,$	$T = 50$: $\Delta\tau_L = 0.0199 > 0,$	$T = 50$: $\Delta E(\tau) = 0.0141 > 0,$
$T = 300$: $\Delta\tau_H = 0.0236 > 0,$	$T = 300$: $\Delta\tau_L = -0.2147 < 0,$	$T = 300$: $\Delta E(\tau) = -0.0956 < 0.$

$\tau_L^{C,SB}$ is negative for $T = 300$ which explains the negative difference $\Delta\tau_L$ since τ_L^{SB} only becomes negative for a $T > 320$. This effect also explains the varying results in $\Delta E(\tau)$. ■

Proof of Result 7:

Target function of principal:
CoE with ability a_C: $e_2^* = a_C$.

$$E(X) - E(C_e(e_2)) = E(a_C^2) - \frac{1}{2}E(a_C^2) = \frac{1}{2}E(a_C^2)$$
$$= \frac{1}{2}[Var(a_C) + E(a_C)^2] = \frac{1}{2}[0 + a_C^2] = \frac{1}{2}a_C^2.$$

Manager with expected ability $E(a)$: $e_2^* = E(a)$.

$$E(X) - E(C_e(e_2)) = E(a^2) - \frac{1}{2}E(a^2) = \frac{1}{2}E(a^2) = \frac{1}{2}[Var(a) + E(a)^2].$$

If $a_C = E(a)$, the expected profit is higher with $\frac{1}{2}Var(a)$. The higher the variance, the higher the benefit from a firm structure without a CoE. This can be diminished by the effect of penalty T as both terms are reduced by $q\,T\,b\,(1 + E(\tau))$ whereas $E(\tau^C) < E(\tau)$ with a high penalty T and $b^C < b$. Hence, the costs with a CoE are smaller the higher penalty T, which counteracts $\frac{1}{2}Var(a)$. The higher penalty T and the smaller the variance, the more likely is a higher expected profit with a CoE than without one. These effects can be illustrated by determining a critical value $\hat{a}_C(E(G^C) = E(G))$ above which the CoE's expected profit exceeds the decentralized one. That critical value contains the manager's expected ability as well as the penalty value T and thereby, their relation to each other. The full term of $\hat{a}_C(E(G^C) = E(G))$ is very long and therefore, not part of the appendix. It can be provided on demand by the authors. ■

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Essay III

Brain Drain in Mergers: The Impact of Retention Bonuses and Behavioral Biases on Voluntary Turnover Rates*

Abstract

A frequently observed phenomenon is that an announced merger increases the voluntary turnover rates of the affected managers and thus, decreases the expected firm value of the merged firm. In this paper, we examine how a one-time retention bonus can reduce the managers' voluntary turnover rates after a merger announcement. Additionally, we analyze the impact of a CEO that is positively biased towards her own managers on the managers' turnover rates and how this bias and the retention bonus interact. In contrast to the setting without a retention bonus, we find that the voluntary turnover rate of the biased CEO's managers is higher than the one of the rational CEO's managers if a retention bonus is paid despite a higher ex ante probability to be retained for the biased CEO's managers. We show that implementing a retention bonus successfully decreases the voluntary turnover rates and generates higher benefits from merging, independent of whether a biased CEO is considered. Hence, the firm value-enhancing effect of an optimal retention bonus exceeds the firm value-decreasing effect of a bias.

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* This chapter is joint work with Carsten Sören Ruhnke (Leibniz Universität Hannover).

1 Introduction

Mergers often turn out to be less efficient than expected and sometimes even fail (Kidd in Light (2001), Tetenbaum (1999), Marks and Mirvis (2001)).[1] One reason for this is that a forthcoming merger increases the voluntary turnover rates compared to a no merger situation (Light, 2001; Walsh, 1988, 1989; Walsh and Ellwood, 1991). Frank et al. (2004) define turnover as "the unplanned loss of workers who voluntarily leave and whom employers would prefer to keep." (p. 13).[2] An announced merger causes the managers to fear the loss of their current positions in the merged firm (Deloitte, 2009; Statz, 2016). They are uncertain whether they will be retained in the merged firm due to a position scarcity caused by capacity restrictions of management positions. In addition to this uncertainty, there is a great demand for talents in the market, i.e. other firms try to headhunt top executives, e.g. by using a signing bonus (Statz, 2016). The combination of the managers' uncertainty and the competition for talent represents a high risk for merging firms: Both factors increase the probability for talented managers to enhance their search activity for a new job or at least their openness for outside offers after a merger announcement. In sum, these facts increase the voluntary turnover rates.

Merging firms especially suffer from high turnover rates because they are accompanied by large financial implications like hiring costs for new employees as well as the loss of firm-specific knowledge (Deloitte, 2009) and consequently low post merger performance (Cannella Jr. and Hambrick, 1993; Hambrick and Cannella Jr., 1993). The most talented managers, i.e. the key employees, are usually the first ones to leave. This is also known as "brain drain" and it can be value-destroying as a firm's business continuity crucially depends on its key employees (Krug, 2009). Rosenblatt and Sheaffer (2001) define brain drain "as the exit of employees who hold any skill, competency, or personal attribute that may be considered a highly needed and valuable organizational asset." (p. 409). Hence, merging firms have to ensure that especially their key employees stay at least during the merging process in order to ensure the business continuity (Bergh, 2001; Ranft and Lord, 2000; Statz, 2016).[3] The most fragile time to lose employees in a merger is directly after the merger announcement and before the regulatory approval. We call this part of a merger

[1] A very famous example for a failed merger is the one of Daimler-Benz and Chrysler to the DaimlerChrysler AG in 1998 that separated again in 2007.

[2] Turnover can be classified in voluntary or forced turnover. Our paper focuses on voluntary turnover (initiated by employees) instead of forced turnover (initiated by employer).

[3] The paper of Deloitte (2009) offers more reasons why managers may leave the firm during a merger and why it is important to retain them.

"transition process" analogous to the transition period in Kohers and Ang (2000). Many managers already start "jumping ship" (Deloitte, 2009; Statz, 2016) before the new positions in the merged firm can be staffed. Hence, counter mechanisms ought to focus here. These counter mechanisms are part of the retention management which receives a lot of attention in the companies' strategies and also in research papers, e.g. in Ellingsen and Kristiansen (2021), Bergh (2001) and Deloitte (2009). Retention management refers to an employer's effort to retain employees that are assumed to add value to the firm (Frank et al., 2004). At best, as many managers as possible stay voluntarily during the merging process so that the firm is able to staff each position with the best suitable manager. Our paper addresses this challenge. As the risk of losing top executives is highest directly after the merger announcement, According to Kidd in Light (2001), merging negotiations should include a plan to reduce the employees' anxieties through appropriate communication as well as a monetary incentive for staying, e.g. by using a one-time bonus that is paid after the completed merger. The bonus included in such a retention strategy is also called "retention bonus" (Deloitte, 2009; Statz, 2016), "which is a bonus for people who stay until after the merger is approved." (O'Sullivan in (Light, 2001, p. 44)).[4] Receiving an offer for a retention bonus directly after the merger announcement influences the managers' expected payoffs of staying and thus, possibly affects their effort to search for an outside job. Hence, a retention bonus should increase the amount of available managers in order to find the best fitting manager for each position.[5]

When making the staying decision, managers consider the probability to be retained in the new merged firm. Kidd mentions in Light (2001) that people tend to favor the people they know in a merger situation. This means that if there are two nearly symmetric managers, a biased decision-maker would prefer to retain the own manager. An explanation for this could be that decision-makers often overestimate the success of their own projects and firms which includes the performance of their managers (e.g. Foad (2010), Malmendier and Tate (2008), Brown and Sarma (2007)).[6] Then, the managers' expectations about being retained and thus, the voluntary turnover rates, depend on whether the own or the other CEO is biased. In sum, the managers' staying decisions may be influenced by a retention bonus and

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[4] Other synonyms are "stay bonus" (Statz, 2016) or "stay pay" (O'Sullivan in Light (2001)).

[5] Anvari et al. (2014) discuss additional key factors that may influence the voluntary turnover rates of employees.

[6] Several papers, e.g. Goel and v. Thakor (2008), show that overconfident decision-makers often overinvest compared to unbiased decision-makers. The example of the failed merger of Daimler-Benz and Chrysler also confirms this phenomenon, see e.g. Büschemann (2013).

a potential bias of an involved CEO. Our paper addresses these issues.

This paper aims at answering the question how to decrease the voluntary turnover rates during the merging process in order to optimize the firm value of the merged firm. We do so by determining the optimal retention bonus to incentivize the managers to decrease their search activity for an outside option. Additionally, we analyze the impact of a CEO's bias to favor the own managers on their search activity and how this bias and the retention bonus interact.

To examine this issue, we consider a one-period agency model with a merging agreement between two firms. Firstly, the CEOs can decide whether to pay a retention bonus and afterwards, the managers have to decide whether they stay voluntarily during the transition process after a merger announcement or whether they look for an outside option. Dependent on who stays voluntarily, the retention bonus is paid and the positions in the merged firm are staffed afterwards. We study the question how these decisions are influenced by one CEO which is positively biased towards the fit of the own managers within the merged firm. In our paper, several factors affect the managers' expectations to be retained and thus, the voluntary turnover rates. Besides the bias and retention bonus, another influencing factor is the CEO power in combination with the bias. The CEO power determines "who calls the shots" regarding the staffing decisions.[7] According to Demonaco in Light (2001), the power in a merger is of great significance for the success of a merger. If there is a bias, the power has a crucial impact on the managers' expectations about being retained. The direction for another factor is rather intuitive: The higher the probability that the direct competitor on the same position leaves voluntarily during the merging process, the higher the probability of being retained. Consequently, ceteris paribus, the higher the probability of being retained, the lower the voluntary turnover rate. We aim at determining how these effects interact and which effect dominates the others under which conditions.

A main finding of our paper is that the presence of a biased CEO can in fact lead to a decrease in the voluntary turnover rate from a rational perspective as the bias influences the optimal retention bonus decisions. Additionally, a retention bonus reduces the voluntary turnover rate and increases the expected merging benefit, independent of the occurrence of a bias.

In the benchmark scenario with two rational CEOs, we show that the voluntary turnover rate increases with a merger announcement and the firm value decreases with the voluntary turnover rate. We also prove that the key employees are the first

[7] The official acquirer has more than 50 percent of the power and thus, her preferences are more likely to be enforced.

ones to leave, i.e. brain drain occurs. Based on these problems, we show that the payment of a retention bonus successfully decreases the voluntary turnover rate for the benchmark scenario. In contrast, the results differ when implementing one biased CEO: Although the retention expectations of the managers increase (decrease) with the bias for the biased (rational) CEO's managers, the voluntary turnover rate of the biased CEO's managers can be higher than the one of the rational CEO's managers with an optimal retention bonus. This effect is the other way around if no retention bonus is paid. Intuitively, a biased CEO would pay a higher retention bonus to the own managers, but we show that this is in fact usually not the case: Although the biased CEO is convinced that her managers are always the better fit, she pays a lower retention bonus than her rational counterpart.

The remainder of the paper is organized as follows. Section 2 gives an overview of relevant literature and states our contribution to it. In section 3, we describe the model which is analyzed in the subsequent section 4. Section 4 also presents and compares our central findings. Section 5 concludes.

2 Contribution to Literature

The literature regarding mergers is rich, but the largest proportion uses empirical methods while theoretical literature mainly focuses on acquisitions and takeovers, e.g. Burkart and Raff (2015). Selected papers that deal with CEO overconfidence in mergers and acquisition (M&A) decisions are Malmendier and Tate (2005a), Doukas and Petmezas (2007) and Billett and Qian (2008). None of them considers voluntary turnover rates and the payment of a retention bonus as we do. In this paper, we focus on a so called "merger of equals", meaning that the merging firms are similar regarding profit, size, etc. Both firms are assumed to be equally involved in the merged firm although one of the former CEOs (the one of the official acquirer) is the new CEO.[8] Hypothetically, both CEOs should have the same negotiating power in a merger of equals, but real mergers show that this is not always the case.[9] Hence, the CEO power in our model can be seen as a negotiating power that bases on who is declared to be the official acquirer and acquiree. This power is only significant if the expectations and opinions of both CEOs differ, e.g. due to a bias.
A large amount of literature deals with a wide range of behavioral biases, such

[8] According to IFRS 3 in combination with IFRS 10, even a merger of equals has to state an official acquirer which controls the acquired firm.

[9] A famous example of a merger like this is the one of Daimler-Benz and Chrysler. They had many issues with balancing their negotiating power, see Büschemann (2013).

as optimism, overconfidence and the familiarity bias. Optimism refers to an excessive forecast in the desired direction or in general, positive expectations about the future (Dawson et al., 2014; Puri and Robinson, 2007).[10] There are several papers that consider optimism in their approach, e.g. Ben-David et al. (2013), Cooper et al. (1988), Dawson et al. (2014), Infuehr and Laux (2022), Larwood and Whittaker (1977), Laux and Stocken (2012), Malmendier and Tate (2005b). Infuehr and Laux (2022) mention that "entrepreneurial activities create ideal conditions for overoptimism." (p. 357). They refer to investment projects in "complex and unpredictable environments, where odds are difficult to assess and where decisions are not routinely repeated" (p. 357). A merger can be seen as such an investment project as they are accompanied by a huge amount of uncertainties and reference points are missing. Even Kahneman and Lovallo (1993) name M&As as "illustration(s) of optimism and of illusions of control" (p. 28) and mention these biases and the overestimated control as the main causes for failed M&As.

Apart from optimism, a lot of empirical, survey and theoretical literature supports the approach that CEOs are biased by overconfidence, see e.g. Brown and Sarma (2007), Doukas and Petmezas (2007), Ferris et al. (2013), Goel and v. Thakor (2008), Hirshleifer et al. (2012), Hribar and Yang (2016), Malmendier and Tate (2005a,b, 2008) and Twardawski and Kind (2016). In this paper, we define overconfident CEOs as individuals that overestimate the own abilities relative to others and believe themselves to be more capable than they are in fact. They overestimate the future success under their leadership and experience their beliefs as extremely precise. These definitions are collected among others from Camerer and Lovallo (1999), Hirshleifer et al. (2012), Langer (1975), Larwood and Whittaker (1977), Malmendier and Tate (2008) and Moore and Healy (2008).[11] Overconfidence is important to consider in our model as Goel and v. Thakor (2008) show that CEOs are more likely to be overconfident than other individuals. Also, overconfident behaviour is seen as one of the most robust biases in psychology (De Bondt and Thaler, 1995).

Additionally, overconfidence and the familiarity bias interact. According to Foad (2010), a familiarity bias means that investors prefer to invest in what they know, i.e. in what they are familiar with. He connects the familiarity bias with overconfidence as overconfident investors predominantly tend to invest more in familiar assets.

[10] See Puri and Robinson (2007) or Gervais et al. (2011) for a literature overview regarding optimism.

[11] Overviews and detailed information about overconfidence and other behavioral biases can be found in Alicke et al. (1995), Camerer and Lovallo (1999), Gallagher et al. (2013), Goel and v. Thakor (2008), Infuehr and Laux (2022), Larwood and Whittaker (1977), Malmendier and Tate (2005a, 2008), Moore and Healy (2008), Twardawski and Kind (2016) and Weinstein (1980).

If we talk about a biased CEO in this paper, we refer to a mix of optimism, overconfidence and the familiarity bias: Our biased CEO is convinced that her managers (familiar) are the better fit than the managers of the other merging firm (overconfidence) in the future of the merged firm (optimism) as they have been under her leadership. Thus, a biased CEO in this paper aims at keeping the own managers despite the other ones could create a higher value from a rational perspective.

Turnover rates, especially from voluntary turnovers, receive high attention in M&A literature from business practice and in empirical papers, e.g. Krug et al. (2014), Walsh (1988, 1989) and Deloitte (2009). The reasons for voluntary turnovers are based on managerial career concerns, e.g. Holmström (1999), Holmström and Costa (1986) and Prendergast (1999). Career concerns are considered in many different theoretical settings. Auriol et al. (2002) show that these incentives can have a crucial impact on teamwork effectiveness, as they might lead to the employees sabotaging each other. Additionally, career concerns play an important role for the signal structure used by the employer (Autrey et al., 2010) and for the job design (Kaarboe and Olsen, 2006). Milbourn et al. (2001) show that career concerns also affect the employees' investment in information. Analogously, they have an impact on the search for outside options and thus, on the turnover rates of the employees. A large amount of literature contributes to the topics of M&As as well as turnover rates, incentive payments and overconfident CEOs. Most of these papers that combine at least two of these topics use empirical methods e.g. Malmendier and Tate (2008), Twardawski and Kind (2016), Brown and Sarma (2007). Analytical research only contributes to one to two of these topics: Goel and v. Thakor (2008) deal with the topic of CEO selection, whereby the managers tend to be overconfident. Inderst and Mueller (2010) analyze the role of private information in the context of CEO turnover. Burkart and Raff (2015) deal with CEO confidence in the course of corporate acquisitions. However, they do not implement the aspect of retention bonuses. This is an aspect that Ellingsen and Kristiansen (2021) examine in their theoretical model. Thereby, they analyze the implementation of retention payments into the compensation structures of the firm. The above shows that M&As and related problems are theoretically dealt with in the literature.

Despite the huge amount of literature regarding the separate topics, the theoretical papers of Inderst and Mueller (2010) and Ellingsen and Kristiansen (2021) are closest related to ours, whereas the considered topics in the empirical papers of Kohers and Ang (2000) and Malmendier and Tate (2008) are closely related to our idea. Kohers and Ang (2000) consider a disagreement on the acquisition price and a retention payment. They analyze empirically whether a retention bonus is a successful mean to retain target managers with special firm-specific knowledge. They consider payments that are divided into two parts, one which is paid with the merger and one as a deferred bonus, whereas our retention bonus is paid after the new firm is fully staffed. Malmendier and Tate (2008) empirically examine the effect of an overconfident CEO on merging decisions but they do not consider a retention bonus within the compensation contract. Inderst and Mueller (2010) use an incentive pay in a theoretical model to induce only the good CEOs to stay while the basic ones quit voluntarily. In contrast to our paper, they do not consider a merger and they disregard behavioral biases. Ellingsen and Kristiansen (2021) consider a model with a risk-averse agent that is incentivized by a retention bonus scheme under fairness considerations. They do not consider a biased principal or a merger situation in their model.

To sum up, this project aims at adding value to the literature on voluntary turnover rates in M&As, behavioral biases as well as bonus contracts in several ways. Firstly, most literature concentrates on post-merger issues, whereas this project adds value as it focuses on earlier stages. Thereby, we aim at counteracting problems before they become critical. Secondly, we expand our understanding of how biased CEOs influence the decision-making of other players by showing how the managers adjust their turnover rates during a merger dependent on whose CEO is biased and how much power this CEO possesses. To the best of our knowledge, our paper is the only one that combines the goal of decreasing voluntary turnover rates by a retention bonus in a merger with a biased CEO in a theoretical model.

3 The Model

3.1 Elements of the Model

We develop a one-period agency model with a merging agreement between two firms. At the beginning of the model, the firms have already decided to merge and make the respective announcement. The owners' role in contracting, strategic decision-making and monitoring is delegated to the board of directors, represented by the CEO.[12] Thus, the risk neutral players are the firms' managers and the respective CEOs.[13] In detail, there are two firms, thus two CEOs, and two groups of managers. We aim

[12] It is not in the focus of our paper to examine the explicit board composition. For a literature overview regarding board composition, see e.g. Boone et al. (2007), Coles et al. (2008), Linck et al. (2008), and Raheja (2005).

[13] We denote the principal (she) as CEO and the agents (he) as managers.

at examining a so called "merger of equals" which is a 50/50-merger and is based on the assumption that both firms are similar regarding their size, positions and thus, requirements concerning their employees' qualifications. As we consider a merger of equals, we assume both firms to employ the same amount of managers in the same positions. To simplify our model, we focus on one manager of each firm $i \in \{1, 2\}$. Both managers are assumed to be employed in the same position $t \in (0, \frac{2}{3}]$ which also indicates their degree of being a key employee. This means that they can be in a position up to $t = \frac{2}{3}$ meaning "the most important employee" and therefore, the highest position.[14] The higher the position, the higher the manager's contribution to the firm value. We assume that there is only one position t in the merged firm for both potential managers in the former positions t from firm 1 and firm 2 and the CEOs have to decide which of the two managers will be retained if both are available and have not left the firm during the transition process. The merged firm has to ensure that each position is staffed, either by one of the incumbent managers or by an externally hired manager. The corresponding outcomes x_n depend on the managers' positions t and their productivity factors $\rho_n \in \mathbb{R}^+$ which represent the skill to generate synergy effects via knowledge transfer,

$$x_n = \rho_n \, t, \tag{1}$$

with $n \in \{B, G\}$. In our model, we assume the initial productivity to be $\rho_B = 1$, i.e. $x_B = t$, since synergy effects are assumed to be excluded in an existing firm that does not merge. The managers' positions, initial productivities in the old firms and thus, outcomes are common knowledge and firm-invariant. Although we assume both managers to be employed in the identical position in their old firms, one of them is able to contribute more to the merged firm value by achieving synergy effects with productivity $1 < \rho_G \leq \frac{2-t}{t}$ (good fit/GF), whereas the direct competitor (manager in the same position t) is only as productive as without a merger with productivity $\rho_B = 1$ (basic fit/BF) in the merged firm.[15] The managers know their positions and thus, their degree of being a key employee in the old firm as well as their initial productivity. However, they are uncertain whether they are the better fit than their

[14] Note that we assume $t > 0$ in order to sharpen our focus and forego the analysis of the trivial case of $t = 0$ that does not provide interesting insights.

[15] The parameter t refers to the manager's position, e.g. Head of the Accounting Department. His productivity ρ_n considers the knowledge transfer and thus, synergy effects, with new colleagues. Such a knowledge transfer is excluded in existing firms. That differs in a merger: The differentiation between the basic fit and the good fit considers two former Heads of the Accounting Department, but only one of them (the good fit) is able to transfer knowledge within the merged firm and hence, generate the aimed synergy effects.

direct competitor for this position in the merged firm. The fact that one of both managers is the better fit in the merged firm does not affect the outside option. The ex ante probability to be the better fit is $\frac{1}{2}$ in each firm.

A rational CEO is always able to identify the good fit for the merged firm. Hence, the rational CEO would pick the manager from firm 1 and the manager from firm 2 with a probability of $\frac{1}{2}$ each, the pick is always a good fit. An important aspect of our theoretical approach is that CEO 1 can be biased, i.e. she is convinced that her manager is always the better fit.[16] Due to her bias, CEO 1 favors the people she knows (own managers) and only picks the manager from firm 1 as she overestimates the success of the merger when only the own manager stays in the firm. We assume that the biased CEO 1 is convinced that her manager is always the good fit which implies that she assumes the other manager from firm 2 to be the basic fit. The different fit expectations (biased (GF only in firm 1) vs. rational (GF distributed equally between firm 1 and 2)) are common knowledge. However, following the "agree-to-disagree" literature, each CEO is convinced that the own expectations are the right ones and the other CEO makes mistakes.[17]
Table 1 gives an overview of the expected probabilities to pick the good fit or basic fit both from the rational and the biased perspective if both managers are available.

		rational CEO 2 picks		biased CEO 1 picks	
		GF	BF	GF	BF
CEO's Perspective	rational CEO 2	1	0	$\frac{1}{2}$	$\frac{1}{2}$
	biased CEO 1	$\frac{1}{2}$	$\frac{1}{2}$	1	0

Table 1: Expected probabilities to pick a GF/BF if both managers are available.

[16] The approach that not all players act rationally is common in the behavioral accounting literature, e.g. in Hirshleifer and Teoh (2003) and Bagnoli and Watts (2017). Hirshleifer and Teoh (2003) consider a fraction of investors that are inattentive which means that they are not fully rational. In our model, this fraction would be $\frac{1}{2}$ as we assume only one CEO being biased. Bagnoli and Watts (2017) follow the same procedure and assume a certain fraction of individuals that use heuristics and thus, are not fully bayesian.

[17] Theoretical models that contribute to that thread of literature are e.g. Hirshleifer and Teoh (2003), Bagnoli and Watts (2017), Laux and Stocken (2012), Infuehr and Laux (2022), Friedman and Heinle (2016) and Hakenes and Katolnik (2018). Laux and Stocken (2012) and Infuehr and Laux (2022) also assume different subjective prior beliefs of ex ante unobservable states. Analogous to our model, they assume that the biased player (in their models the optimistic entrepreneur) has higher beliefs about the good state and the players' beliefs are common knowledge, they "agree to disagree". In the "agree-to-disagree" literature, each player is absolutely convinced that his beliefs are correct while the other players' beliefs are assumed to be incorrect, see e.g. Harris and Raviv (1993).

The rational CEO 2 picks the manager from firm 1 and firm 2 with a probability of $\frac{1}{2}$ each which is common knowledge. As she is able to identify the good fit, the probability to retain the good fit manager is 1 from a rational perspective. From the biased CEO's perspective, who is convinced that only the own manager from firm 1 has the potential to generate ρ_G, CEO 2 makes mistakes with 50 percent by keeping the basic fit from firm 2. In contrast, the biased CEO would only retain the own manager (common knowledge) and thus, receives only the good fit from her perspective. From the rational perspective, the biased CEO overlooks the good fit manager from firm 2 and thus, only receives a good fit manager with a probability of 50 percent.

Following experiences from real mergers, the impact of the bias is restricted by a consideration of the CEO power, which means "who calls the shots"[18] and dominates the staffing negotiations as she is the official acquirer. Since both firms are predominantly similar, the merger is considered as being a merger of equals, but according to IFRS 3 in combination with IFRS 10, even a merger of equals has to state an official aquirer who controls the acquired firm.[19] However, we assume that the power of each CEO in the merged firm is affected by who is declared to be the acquirer and acquiree. CEO 1 possesses power α whereas CEO 2 has power $1-\alpha$ with $\alpha \in [0,1]$. This distribution is common knowledge. Power $\alpha > \frac{1}{2}$ ($\alpha < \frac{1}{2}$) implies that firm 1 (2) is the acquirer, but the firm value is still planned to be equally shared among the previous shareholders since it is a merger of equals.[20] The CEO who belongs to the acquiring firm is assumed to be the CEO of the merged firm while the other CEO has to leave after the staffing decisions. The CEO who belongs to the acquired firm still has a voice regarding these staffing decisions (represented by the respective probability α or $1-\alpha$). The power only matters if there is a biased CEO since otherwise, both CEOs' fit expectations are congruent.

If both managers of the same position decide to stay during the transition process, i.e. between the merger announcement and the staffing decision, both CEOs have to negotiate whose manager should be retained. Thus, the ex ante probability to receive x_G from the well fitting manager in the merged firm bases on Table 1 and differs with $\alpha \neq \frac{1}{2}$:

[18] See Light (2001) for more details about the term "who calls the shots".

[19] Since the merging firms have to be very similar, the shareholders would decide to structure the new board balanced with members from both boards. To simplify our model, we only consider CEOs as the boards' chairpersons. This structure is common knowledge to all players. If one firm was significantly larger than the other firm, an acquisition rather than a merger of equals should be considered. This case is not displayed by our model.

[20] Power $\alpha = \frac{1}{2}$ is generally possible but represents only a hypothetical scenario which is used for additional explanations of the effects within our model.

From the biased CEO's perspective, the probability to receive x_G is

$$P(x_G)^1 = \alpha \cdot 1 + (1-\alpha) \cdot \frac{1}{2} = \frac{1}{2}(1+\alpha). \tag{2}$$

From the rational perspective, the probability to receive x_G is

$$P(x_G)^2 = (1-\alpha) \cdot 1 + \alpha \cdot \frac{1}{2} = 1 - \frac{1}{2}\alpha. \tag{3}$$

The counter-probabilities are the probabilities to receive outcome x_B, i.e. $P(x_B)^i = 1 - P(x_G)^i$. Both CEOs are convinced that they will pick the good fit with probability 1 multiplied with their decision-making power. Since they have different expectations about whether the good fit manager stems from firm 1 or 2, they assume that the other CEO follows wrong expectations and makes mistakes (picks the basic fit) with probability $\frac{1}{2}$ multiplied with the respective power of the other CEO. In sum, the higher the own power, the higher the probability to receive x_G in the merged firm from both perspectives. The expected probabilities of the rational and biased CEO equal if their power is equally shared, $\alpha = 0.5$. This is due to the symmetrical expectations of picking the good or the basic fit. If both CEOs are rational and thus use equation (3), α is set to zero which means that the bias has no impact on the retention decisions. Then, the probability to pick the good fit is always 1 from both CEOs' perspectives.

The managers' expected probabilities to be retained if both of them are available differ depending on whether they work for the rational or biased CEO. These probabilities are crucial factors in the following analysis regarding the differences of the CEO's expected firm values.
If the manager belongs to the biased CEO 1's firm, the expected probability to be retained is

$$P(\text{retained})_1 = \alpha \cdot 1 + (1-\alpha) \cdot \frac{1}{2} = \frac{1}{2}(1+\alpha). \tag{4}$$

If the manager belongs to the rational CEO 2's firm, the expected probability to be retained is

$$P(\text{retained})_2 = \alpha \cdot 0 + (1-\alpha) \cdot \frac{1}{2} = \frac{1}{2}(1-\alpha). \tag{5}$$

If a manager belongs to the biased CEO's firm 1, he will be retained in any case if the biased CEO calls the shots (with probability α). On the other side, the manager from the rational CEO's firm 2 will never be retained by the biased CEO. As long as the rational CEO has the power (with probability $1-\alpha$), both managers have equal chances of $\frac{1}{2}$ to be retained. The uncertainty whether the managers will be retained combined with the competition for talent in the job market makes it attractive to search for an outside option. Hence, the expected probabilities of being retained from (4) and (5) lead to the conclusion that managers from the rational CEO are more likely to search for outside options if the biased CEO has at least some power. Their probabilities to be retained only equal if no CEO is biased or the biased CEO has no power, i.e. $\alpha = 0$. Then the bias has no impact on the decision-making of the agents. Otherwise, the bias crucially influences the manager's probability to be retained and therefore his decision to search for an outside option. This search activity is illustrated by the manager's effort $a_i \in [0, 1]$ with convex effort costs $C(a_i) = (1 - t)\frac{a_i^2}{2}$. The effort a_i represents the probability to receive and accept an outside offer and thus, the voluntary turnover rate of firm i's manager directly after the merger announcement but before the new positions are staffed. Consequently, $1 - a_i$ is the probability that manager i's search for an outside option is not successful and thus, he stays voluntarily during the transition process. Figure 1 shows this connection between effort and probability.

Figure 1: Effort decision of managers, a_i.

Based on the above probabilities to be retained and the respective outcomes, each manager decides how much effort to exert to find another job. In order to reduce the voluntary turnover rates by reducing this effort, the merging firms can make a contract offer with a retention bonus $R \in \mathbb{R}$ directly after the merger announcement which is paid if the managers decide to stay.

The following Figure 2 illustrates the possible actions of the managers as well as their respective payoffs.

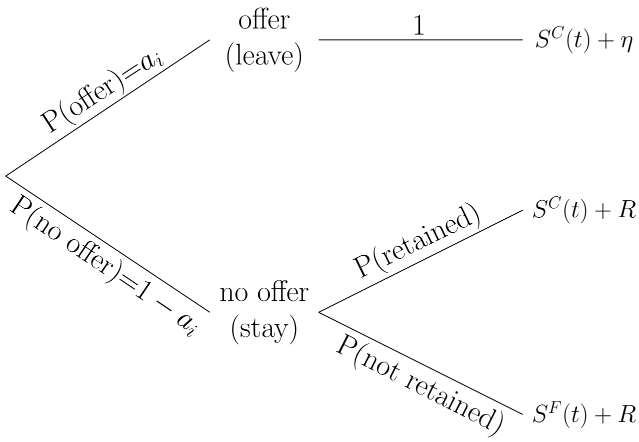


Figure 2: Illustration of the managers' outcomes.

With probability $1 - a_i$, manager i will stay during the transition process and not get an offer. He receives a usual market salary $S^C(t) = t$ if being retained and a lower salary $S^F(t) = \frac{1}{2} S^C(t)$ if he is ousted. He also receives the retention bonus $R \in \mathbb{R}$ if he stays voluntarily and the firm decides to offer one.
If manager i tries to leave and searches successfully for an outside option with effort a_i, he receives the market salary $S^C(t)$ and an additional signing bonus $0 \leq \eta \leq 1-t$ from the outside option (with probability a_i). We assume that a received offer after searching will always be accepted.[21] If both managers decide to leave, the merged firm has to hire a new manager from the market in order to staff the vacant position. The firm has to pay the manager's market salary $S^C(t)$ as well as additional hiring costs $H > \eta$. These hiring costs include a signing bonus as there is still a competition for talents in the market. Figure 3 illustrates the timeline of the whole game.

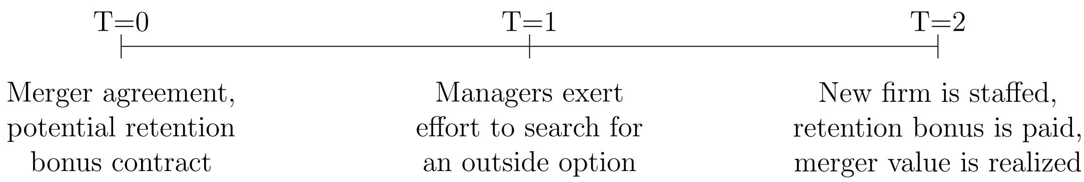


Figure 3: Timeline.

The following subsections show the considerations at date $T = 0$ (the CEOs' expected merging benefit and potential retention bonus determination) as well as date $T = 1$ (the managers' effort decisions) in more detail.

[21] Note that a manager always accepts a received offer because he has already exerted effort for it. If he plans not to accept the offer, he will not exert any search effort in the first place.

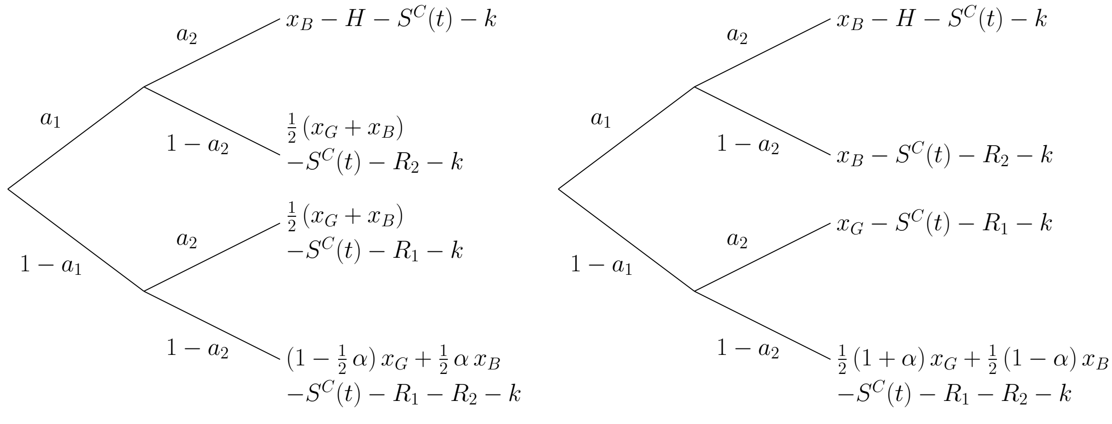
3.2 Model Setup - T=0: CEOs' Potential Retention Bonus Determination and Expected Benefit from Merging

If no merger is considered, the firm value of firm i is

$$\begin{aligned} V_i &= x_B - a_i \left(S^C(t) + H\right) - (1 - a_i)\, S^C(t) - k \\ &= t\,(\rho_B - 1) - a_i\, H - k. \end{aligned} \tag{6}$$

Note that $x_B = t$ represents the manager's contribution to the firm value (as $\rho_B = 1$) and $k > 0$ stands for the fixed costs resulting from marketing and sales (assumed to be identical in each firm). Similar to the scenario with a merger, the manager is able to search for an outside option. However, there is no uncertainty whether they will be retained in their current firm. The manager leaves with the probability of a_i and the firm has to hire a new manager for this position resulting in hiring costs $H > \eta$ and costs in form of the market salary of the manager's position $S^C(t) = t$. If the manager stays (probability $1 - a_i$), the firm only pays him his market salary. As the biased CEO is only biased regarding the managers' fits in a merged firm, the bias has no impact on the firm value without a merger.

Our main focus lies on the case with the merger of the two firms. Then, the firm value expectations differ dependent on the CEO's perspective. If CEO 1 is biased, Figure 4 illustrates the payoffs from the rational CEO 2's perspective in the left graph (4a) and from the biased CEO 1's perspective in the right one (4b).



(a) Rational perspective (CEO 2) **(b)** Biased perspective (CEO 1)

Figure 4: CEOs' expected merger values.

The merger values consist of the expected managers' contributions $E(x)$ to the firm value subtracted by their market salary $S^C(t)$ which is paid to every retained or hired manager, fixed costs k and a potential retention bonus R_i. The fixed costs

k occur once for the merged firm and each firm i can potentially pay a retention bonus R_i to all the managers who stay voluntarily. R_i is a liability and thus part of the merged firm value $V_{i,M}$.

If both managers of the same position decide to leave (probability $\boldsymbol{a_1\, a_2}$), the merging firm has to hire a manager for this position for his market salary $S^C(t)$ and additional hiring costs H, but no retention bonus has to be paid. This payoff is equal in both perspectives and we assume that a new manager contributes the same to the firm value as a basic fit manager as he has no firm specific knowledge and thus, is not able to generate synergy effects.

If only one of the two potential managers stays voluntarily during the transition process (probability $\boldsymbol{a_1(1-a_2)}$ or $\boldsymbol{a_2(1-a_1)}$), the rational CEO correctly expects that the probability that the good fit stays is $\frac{1}{2}$. Thus, her expected contribution in both cases is $E(x) = \frac{1}{2}(x_G + x_B)$. The biased CEO is convinced that if the own manager stays ($a_2(1-a_1)$), the contribution to the merged firm's output will be x_G and consequently x_B if the other manager (from firm 2) stays ($a_1(1-a_2)$). These different beliefs mainly shape the different firm value expectations since they are independent of power α but still different. Dependent on whose manager stays, the respective retention bonus has to be paid.

If both managers of the same position are available (probability $\boldsymbol{(1-a_1)(1-a_2)}$), the expected probabilities to receive x_G in the merged firm are given by (3) for the rational CEO and (2) for the biased CEO. The counter-probabilities are determined accordingly. As both managers stay during the transition process, both retention bonuses reduce the firm's profit.

Based on these explanations and Figure 4, the firm value of the merged firm from the biased CEO 1's perspective (Figure 4b) is

$$\begin{aligned} V_{1,M} =& a_1\,(1-a_2)\,\big(x_B - S^C(t)\big) + a_2\,(1-a_1)\,\big(x_G - S^C(t)\big) \\ &+ (1-a_1)\,(1-a_2)\left(\frac{1}{2}\,(1+\alpha)\,x_G + \frac{1}{2}\,(1-\alpha)\,x_B - S^C(t)\right) \\ &+ a_1\,a_2\,\big(x - S^C(t) - H\big) - k - (1-a_1)\,R_1 - (1-a_2)\,R_2, \end{aligned} \tag{7}$$

and from the rational CEO 2's perspective (Figure 4a) is

$$\begin{aligned} V_{2,M} =& (a_1\,(1-a_2) + a_2\,(1-a_1))\left(\frac{1}{2}\,(x_G + x_B) - S^C(t)\right) \\ &+ (1-a_1)\,(1-a_2)\left((1-\frac{1}{2}\,\alpha)\,x_G + \frac{1}{2}\,\alpha\,x_B - S^C(t)\right) \\ &+ a_1\,a_2\,(x - S^C(t) - H) - k - (1-a_1)\,R_1 - (1-a_2)\,R_2. \end{aligned} \tag{8}$$

If both CEOs are rational, α can be set to zero. Then both managers aim at maximizing $V_{2,M}$ as in (8) with $\alpha = 0$ and solely Figure 4a has to be used. In this scenario, both CEOs are able to identify the good fit so that the payoff can be simplified to $x_G - S^C(t)$ if both managers are available $((1-a_1)(1-a_2))$.

Each original firm expects to receive half of the merged firm value $V_{i,M}$, as we consider a merger of equals. Thus, the expected benefit from merging is

$$\Delta V_i = \frac{1}{2} V_{i,M} - V_i, \quad i = 1, 2. \tag{9}$$

For a better understanding, the merger of equals can also be seen as an acquisition. Therefore, we assume one firm to be the acquirer and the other firm to be the acquiree. Thereby, the acquirer receives the complete value of the merged firm but has to pay half of it to the acquiree as a price for the acquisition.[22] The firms also need to determine the optimal retention bonus R that maximizes the merger value. This decision has to be made directly after the merging announcement by each firm but without observing any additional information,

$$\max_{R_i} \frac{1}{2} V_{i,M}, \quad i = 1, 2. \tag{10}$$

3.3 Model Setup - T=1: Managers' Effort Decisions

At $T = 1$, directly after the merger announcement and the potential retention bonus offer, the managers decide about their search activity a_i and thus, whether to stay or quit the firm voluntarily during the merging process before the CEOs decide about the new positions. All managers have the opportunity to leave the firm voluntarily.

[22] According to IFRS 3 "Business Combinations" (see Deloitte (2008)), the accounting method for business combinations like mergers ("two entities are legally merged into one entity" (Deloitte, 2008, p. 17) is called "Acquisition method" and the following steps have to be applied: *1. Identification of the "acquirer".* In our model, this determination has to be done but it does not change anything mathematically as both firms are involved on equal shares. Note that the acquirer is indicated by the higher power. According to IFRS 3 (Appendix A) (Zülch and Hendler, 2021), "true mergers" or "mergers of equals" are also stated as business combinations. *2. Determination of the acquisition date.* In our model, the official acquisition date is after the managers' search activity decisions. *3. Recognition and measurement of the identifiable assets acquired, the liabilities assumed and any non-controlling interest in the acquiree.* As both firms are assumed to be symmetrical ex ante, the values only differ regarding the liabilities, here regarding the retention bonus payment, and the different firm value expectations based on the divergence of the fit expectations. *4. Recognition and measurement of goodwill or a gain from a bargain purchase.*

Thus, each manager of firm i has a linear utility function that drives this decision,

$$U_i = a_i \cdot (S^C(t) + \eta) + (1 - a_i) \cdot (S(t) + R_i) - (1 - t)\frac{a_i^2}{2}, \quad i = 1, 2. \tag{11}$$

If they search (a_i), they will receive and accept the offer from the outside option and receive their market salary $S^C(t)$ and a signing bonus η. If they stay $(1 - a_i)$, they receive a payment $S(t)$ which depends on whether they will be retained ($S^C(t) = t$) or not ($S^F(t) = \frac{1}{2}t$). Additionally, they receive a retention bonus R_i if they stay and if their firm decides to pay one. If a manager decides to stay, he will be retained if either the direct competitor leaves (a_j) or if he is picked in case both managers of the same position are available ($(1 - a_i)(1 - a_j)$). The managers anticipate the probability of receiving the position t in the new firm based on their retention bonus, the search activity of the direct competitor and the CEO power. The tree diagram with the potential payoffs can be seen in Figure 5.

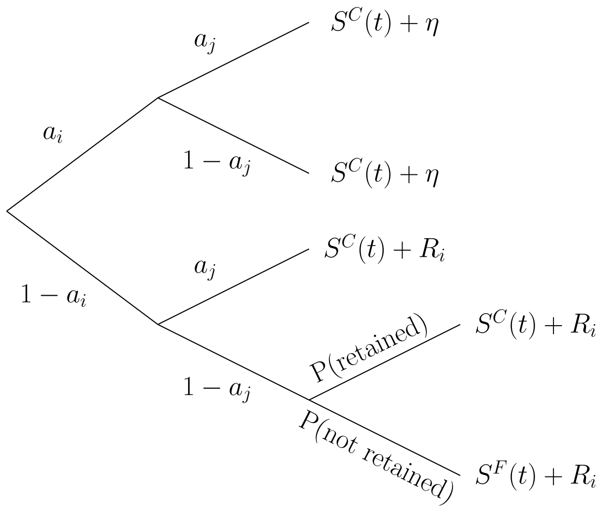


Figure 5: Manager i's expected payoffs.

P(retained) is the probability to be retained in the merged firm if both managers decide to stay voluntarily, as shown in equations (4) and (5). This probability and its counter-probability crucially depend on the potentially biased CEO and her power α. The managers are able to anticipate perfectly their direct competitor's effort a_j in order to determine their expected retention probabilities. They decide about a_i based on their expected utility. Therefore, manager i's expected utility function dependent on the direct competitor j's search activity a_j can be written as

$$
\begin{aligned}
E(U_i) =&(1-a_i)\Big\{R_i + a_j \cdot S^C(t) \\
&+ (1-a_j)\Big[P\,(\text{retained}) \cdot S^C(t) + P\,(\text{not retained}) \cdot S^F(t)\Big]\Big\} \\
&+ a_i \cdot \big(S^C(t) + \eta\big) - (1-t)\frac{a_i^2}{2},
\end{aligned}
\tag{12}
$$

with $i, j = 1, 2,\ i \neq j$. As already explained regarding P(retained) and P(not retained) in equation (4) and (5), these probabilities always differ from the rational and biased perspective with a non-zero power α. Hence, even if $\alpha = 0.5$, both managers optimize a different expected utility function to determine their search activity. After both managers have made their search activity decisions, the merged firm has to pay the retention bonuses and has to staff the available positions ($T = 2$). This happens based on the outlined processes.

4 Analysis

The following subsections analyze the described model and present as well as compare our findings.

4.1 No Merger

In this subsection, we determine the expected firm value without a merger in order to be able to compare it to the merger situations in the following subsections. Since the bias in our model only refers to the manager's fit in the merged firm, both CEOs and thus managers have symmetric optimization problems without a merger, i.e. they are the same for $i = 1, 2$. As we consider a sequential game, we solve it by backward induction and thus, start in $T = 1$ with the maximization of the manager's expected utility function,

$$\max_a E(U) = \max_a a\ \big(S^C(t) + \eta\big) + (1-a)\, S^C(t) - (1-t)\frac{a^2}{2}. \tag{13}$$

The managers search for an outside option with effort a. Solving (13) leads to the optimal search activity

$$a^*_{nM} = \frac{\eta}{1-t}. \tag{14}$$

In order to keep this search activity positive and as the manager's effort is equivalent to the probability to receive an outside offer, we limit η to $\eta \in [0, 1-t]$ with $t \in (0, \frac{2}{3}]$. With this assumption we ensure that $a^*_{nM} \in [0, 1]$. This limitation will be used in all subsequent analyses.
Inserting the activity from (14) into the corresponding firm value V_i from equation (6) leads to

$$V_i^* = V^* = t\,(\rho_B - 1) - \frac{H\,\eta}{1-t} - k. \tag{15}$$

This firm value will be used in further calculations in $T = 0$ for the comparison of the firm values and expected benefits from merging.

4.2 Rational CEOs in a Merger

In this subsection, we examine the case of two rational CEOs. Thus, the bias does not have any impact and the power α is set to zero.

4.2.1 Rational CEOs without Retention Bonus - Benchmark

In the benchmark solution, we examine the case of two rational CEOs, which can be illustrated by $\alpha = 0$ and $R_i = 0$ with regard to the introduced model from section 3. We solve the sequential game again by using backward induction.

T=1 (Managers): Determination of search activity a_1 and a_2:
The managers maximize their expected utilities with regard to their search activity a_i,

$$\begin{aligned} \underset{a_i}{max}\ E(U_i) = \underset{a_i}{max}\ (1-a_i)\Big\{a_j \cdot S^C(t) + (1-a_j)\Big[\frac{1}{2}\cdot S^C(t) + \frac{1}{2}\cdot S^F(t)\Big]\Big\} \\ + a_i \cdot \big(S^C(t) + \eta\big) - (1-t)\frac{a_i^2}{2}. \end{aligned} \tag{16}$$

With two rational CEOs, both managers expect a probability of being retained of $\frac{1}{2}$ if both stay voluntarily as the rational CEOs are able to pick the better fitting manager, but the managers do not know whether they are the good or the basic fit. Solving the optimization problem leads to manager i's reaction function depending on manager j's search activity,

$$a_i(a_j) = \frac{t(1-a_j)}{4(1-t)} + \frac{\eta}{1-t}. \tag{17}$$

The derivative of this reaction function with respect to the direct competitor's effort a_j is negative, $\frac{\partial a_i(a_j)}{\partial a_j} = -\frac{t}{4(1-t)} < 0$. This shows that each manager's voluntary turnover rate decreases in the search activity of the direct competitor as they are strategic substitutes.
Simultaneously solving for the optimal efforts, we obtain the following result:

$$a^* = a_1^* = a_2^* = \frac{t + 4\,\eta}{4 - 3\,t}. \tag{18}$$

With a symmetric position distribution and no biased CEO, this effort becomes firm-invariant in the equilibrium solution, i.e. $a^* = a_1^* = a_2^*$.[23] With $t \in (0, \frac{2}{3}]$ and $\eta \in [0, 1-t]$, it follows that $0 \leq a^* \leq 1$. The managers, independent of their positions t, will leave the firm voluntarily if the signing bonus reaches the limit of $1 - t$. The highest position and the most important key employee ($t = \frac{2}{3}$), has the strongest incentive to leave after a merger announcement, independent of the height of the signing bonus as long as it is positive. These findings are confirmed by the following Lemma.

Lemma 1 *An announced merger increases the voluntary turnover rates compared to the managers' voluntary turnover rates without a merger ($a^* \geq a_{nM}^*$).*
The managers in the highest positions and thus, the key employees, are the first ones to leave the firm voluntarily (Brain drain). Comparative statics show

$$\frac{\partial a^*}{\partial t} = \frac{4(1 + 3\,\eta)}{(4 - 3t)^2} > 0, \tag{19}$$

with $t \in (0, \frac{2}{3}]$ and $\eta \in [0, 1-t]$.

Proof: See the Appendix A1.

As hypothesized in the beginning of this paper, we can confirm that the key employees (highest positions) have the highest voluntary turnover rates (brain drain). This is driven by the fact that the managers in high positions have lower effort costs as they will receive an offer more easily from the market. Additionally and intuitively, the higher the signing bonus in the outside option, the higher the voluntary turnover rate for each manager position, $\frac{\partial a^*}{\partial \eta} = \frac{4}{4-3\,t} > 0$ for $t \in (0, \frac{2}{3}]$. For all positions and signing bonuses, there is at least a positive probability that they decide to search, even if the signing bonus is zero. This is caused by the uncertainty in the merged firm: They do not know whether they will be retained. If they are

[23] If both position distributions are not considered as symmetric or similar, a merger of equals will not take place. Instead, an acquisition would result.

not retained, they will only receive the lower salary $S^F(t)$ instead of receiving their market salary $S^C(t) = 2\,S^F(t)$ and the signing bonus η in the outside option.

T=0 (CEOs): Determination of the expected merging benefit:
The expected merging benefit is given by

$$\Delta V = \frac{1}{2} V_M^* - V^*, \tag{20}$$

with $V^* = t\,(\rho_B - 1) - \frac{H\,\eta}{1-t} - k$ from (15). By setting $\alpha = 0$, $R_1 = 0$ and $R_2 = 0$ in (8), we receive

$$\begin{aligned} V_M =& - a_1 a_2\, H + (a_1(1-a_2) + a_2(1-a_1)) \left(\frac{1}{2}(x_G + x_B) - S^C(t)\right) \\ &+ (1-a_1)(1-a_2)\left(x_G - S^C(t)\right) - k. \end{aligned} \tag{21}$$

As we assume $\rho_B = 1$ for the externally hired manager so that $x_B = \rho_B\, t$ and $S^C(t) = t$, $a_1\, a_2(x - S^C(t) - H)$ can be summarized to $-a_1\, a_2\, H$. Both rational CEOs have the same perspective on the expected merger value. If only one manager stays voluntarily, there is a chance of $\frac{1}{2}$ that this manager is the good fit. If both managers stay voluntarily, both CEOs agree to retain the good fit. The following derivative of (21) shows that the firm value decreases with an increasing voluntary turnover rate,

$$\frac{\partial V_M}{\partial a_i} = -\frac{1}{2}\Big(t\,(\rho_G - 1) + 2\,a_j\,H\Big) < 0, \tag{22}$$

with $\rho_G > 1$, $t \in (0, \frac{2}{3}]$, $a_j \in [0,1]$ and $H > \eta > 0$. Hence, decreasing the voluntary turnover rates is part of the firms' strategy to increase the firm value. Inserting the optimal values for a^* from (18) in (21), the following merging value results for symmetric firms:

$$\begin{aligned} V_M^* =& \frac{4\,t\,(\rho_G - 1)(1-\eta-t)(4\,\eta + t) - H\,(4\,\eta + t)^2}{(4-3\,t)^2} \\ &+ \frac{16\,t\,(\rho_G - 1)(1-\eta-t)^2 - k(4-3\,t)^2}{(4-3\,t)^2}. \end{aligned} \tag{23}$$

4.2.2 Rational CEO with Retention Bonus

In this setting, we still assume both CEOs to be rational, but now a retention bonus payment is an option to decrease the voluntary turnover rates. The potential impact of a retention bonus on the search activity is examined in the following.

T=1 (Managers): Determination of a_1 and a_2:

The managers maximize the same expected utility as in (16) but with an option for a retention bonus R_i for $(1 - a_i)$,

$$
\begin{aligned}
\underset{a_i}{max}\ E(U_i) = \underset{a_i}{max}\ a_i \cdot \big(S^C(t) + \eta\big) \\
&+ (1 - a_i)\Big\{R_i + a_j \cdot S^C(t) + (1 - a_j)\Big[\frac{1}{2} \cdot S^C(t) + \frac{1}{2} \cdot S^F(t)\Big]\Big\} \\
&- (1 - t)\frac{a_i^2}{2}.
\end{aligned}
\tag{24}
$$

Solving the previous expression leads to manager i's reaction function depending on manager j's search activity,

$$
a_i^R(a_j^R) = \frac{t(1 - a_j^R)}{4(1 - t)} + \frac{\eta - R_i}{1 - t}. \tag{25}
$$

The derivative of this reaction function with respect to the direct competitor's effort a_j is negative, $\frac{\partial a_i^R(a_j^R)}{\partial a_j^R} = -\frac{t}{4\,(1-t)} < 0$. Under symmetry assumptions in equilibrium due to both CEOs being rational, we obtain the following optimal effort:

$$
\begin{aligned}
a^R &= \frac{t + 4\,\eta}{4 - 3\,t} - \frac{4\,R}{4 - 3\,t} \\
&= a^* - \frac{4\,R}{4 - 3\,t}.
\end{aligned}
\tag{26}
$$

With a symmetric position distribution, the resulting effort reaction function becomes independent of the firm in the equilibrium solution, $a^R = a_1^R = a_2^R$. This optimal effort shows that the retention bonus $R > 0$ decreases the search activities and thus, the voluntary turnover rates compared to the previous setting without a retention bonus. The derivative of equation (26) leads to the corresponding proposition.

Proposition 1 *With rational CEOs, a positive retention bonus strictly decreases the voluntary turnover rates,* $\frac{\partial\, a^R}{\partial\, R} = -\frac{4}{4-3\,t} < 0$.

Proof: See the Appendix A1.

T=0 (CEOs): Determination of retention bonus and expected merging benefit:
In order to determine the optimal retention bonus with the purpose of decreasing the voluntary turnover rates, the CEOs maximize the following expression under anticipation of a^R from (26),

$$\begin{aligned} &\max_R \frac{1}{2} V_M^R \\ &= \max_R \frac{1}{2}\Big[- a_1^R a_2^R H + (a_1^R(1-a_2^R) + a_2^R(1-a_1^R)) \left(\frac{1}{2}(x_G + x_B) - S^C(t)\right) \\ &\qquad + (1-a_1^R)(1-a_2^R)\left(x_G - S^C(t)\right) - k - (1-a_1^R)R - (1-a_2^R)R\Big]. \end{aligned} \tag{27}$$

The next Lemma presents the optimal retention bonus and induced actions by solving the maximization problem with the optimal efforts from (26) in equation (27).

Lemma 2 *When both CEOs are rational, the managers' optimal retention bonuses and their equilibrium efforts are given by:*

$$R^* = \frac{2\,t\,(2\,\rho_G - 3\,\eta + H + 5) - 3\,(1+\rho_G)\,t^2 + 8\,(\eta\,(1+H) - 1)}{4\,(2\,H - 3\,t + 4)}, \tag{28}$$

leading to

$$a^{R^*} = \frac{2\,(1+\eta) - \rho_G\,t}{4 + 2\,H - 3\,t}. \tag{29}$$

Proof: See the Appendix A1.

The assumption $1 < \rho_G \leq \frac{2-t}{t}$ ensures that $0 \leq a^{R^*} \leq 1$. The retention bonus R^* is usually positive, but it can in fact be non-positive, if $0 < t \leq \frac{2}{3}$, $1 < \rho_G < \frac{2-t}{t}$ and $0 < \eta < H < H^{crit} \leq 1 - t$ or $H^{crit} < H < H^{crit'}$ and $0 < \eta \leq \eta^{crit}$ with $H^{crit} = \frac{1}{4}\left(t - 2 + \sqrt{20 - 8(3+\rho_G)t + (7+6\rho_G)t^2}\right)$, $H^{crit'} = \frac{(3\,t-4)(t\,(1+\rho_G)-2)}{2\,t}$ and $\eta^{crit} = \frac{8-2\,(5+2\,\rho_G+H)\,t+3\,(1+\rho_G)\,t^2}{8\,(1+H)-6\,t}$.

Figure 6 illustrates the critical values of H and the dependence of R^* on H and η.

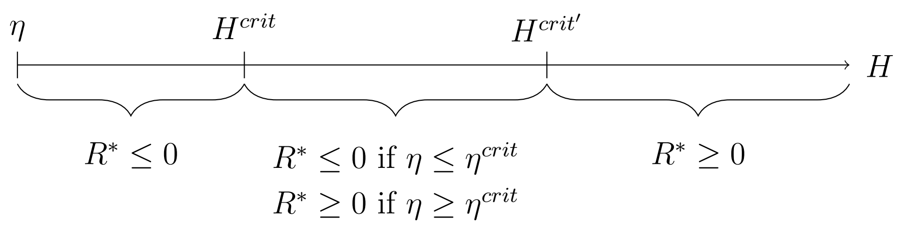


Figure 6: Sign of retention bonus dependent on hiring costs H and signing bonus η.

The occurrence of a negative retention bonus can be explained as follows: If the signing bonus η and the additional hiring costs H are below the critical values, the payment of a (positive) retention bonus is too expensive from the principal's view as it is relatively cheap to hire a new manager from the market (low H) and the incentive for the incumbent managers to leave the firm is relatively low (low η). Indeed, it is even beneficial for the principal to persuade the managers to leave the firm by requesting a payment from the managers for staying due to the low hiring costs. From the managers' view, the incentive to leave the firm is rather low as the expected low signing bonus does not fully balance the effort costs from searching for an outside option. The negative retention bonus can also be interpreted as the managers' decision to waive the possibility to receive a severance pay (by not paying R^* when leaving the firm). They prefer to stay in the current firm and even pay R^* instead of "spending" effort costs for searching for an outside option.

Considering a comparative statics analysis of R^*, we can show that the optimal retention bonus R^* is strictly increasing in the manager's position t, the signing bonus η, the productivity of the good fit ρ_G as well as the additional hiring costs H under the allowed parameter restrictions from the model setup. These effects are intuitive as we already showed that the higher positions t have a higher voluntary turnover rate. Hence, their retention bonus has to be higher than for lower positions in order to decrease their turnover rate. The same effect is achieved by a higher retention bonus if the signing bonus, and thereby the incentive to go to the outside market, η, increases. The signing bonus η enhances the retention bonus R^*, i.e. $\frac{\partial R^*}{\partial \eta} = \frac{1}{2} + \frac{H}{4+2H-3t} > 0$. In contrast to H, η also directly influences the outside option and thereby, a^{R^*}. Although a^{R^*} decreases with R^* (which increases with η), η has a strict positive overall effect on a^{R^*}, i.e. $\frac{\partial a^{R^*}}{\partial \eta} = \frac{2}{2(2+H)-3t} > 0$.
Additionally, if the synergy effects are expected to be rather high (by a high ρ_G), the retention bonus also increases to retain these value-enhancing managers. Finally, if the hiring costs H for a new manager increase, it becomes more attractive to keep the incumbent manager by paying him a higher retention bonus instead of spending much for a basic fit from the market. The higher the hiring costs H, the lower the turnover rate, i.e. $\frac{\partial a^{R^*}}{\partial H} = \frac{2(\rho_G t-2(1+\eta))}{(4+2H-3)^2} < 0$, as the retention bonus R^* strictly increases with H, i.e. $\frac{\partial R^*}{\partial H} = \frac{(3t-4)(\rho_G t-2(1+\eta))}{2(4+2H-3t)^2} > 0$, and a^R from (26) decreases with the increasing retention bonus.

Figure 7 illustrates the comparison between the managers' optimal search activities without and with a retention bonus if both CEOs are rational.

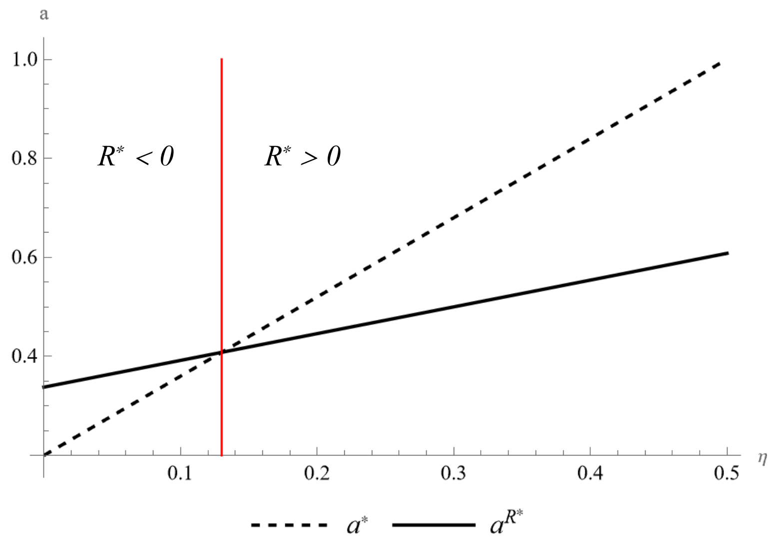


Figure 7: Comparison of search activities dependent on signing bonus η with $t = 0.5$, $H^{crit'} = 1.875 > H = 0.6 > H^{crit} = 0.2374$, $0 \leq \eta \leq 1 - t$ and $1 < \rho_G = 1.5 < \frac{2-t}{t} = 3$. Red line: η^{crit} for $R^* = 0$, i.e. $a^* = a^{R^*}$.

Figure 7 shows clearly that a retention bonus decreases the search activity after passing the critical value η^{crit} for $R^* = 0$, i.e. $a^* > a^{R^*}$. The red line marks $\eta^{crit} = 0.1301$ if $H^{crit'} = 1.875 > H = 0.6 > H^{crit} = 0.2374$ for $R^* = 0$, i.e. $a_i^* = a_i^{R^*}$, see Figure 6.
For a negative R^*, the voluntary turnover rate with a retention bonus is higher than the one without a retention bonus. Thus, the principal's aim to let some agents go by requiring a payment from them seems to be successful. Figure 7 confirms this effect. The lower the signing bonus η, the tougher the situation on the job market for the managers. Thus, they consider the outside option as less rewarding and decrease their voluntary turnover rate. Due to the negative retention bonus on the left side of the red line ($\eta < 0.130102$), the managers have to pay the retention bonus in contrast to the situation without a retention bonus. Hence, they exert a higher effort to find an outside job, as shown in Figure 7.

Considering the optimal values for effort a^{R^*} and retention bonus R^* from Lemma 2, the expected benefit from merging is given by

$$\Delta V^R = \frac{1}{2} V_M^{R^*} - V^*, \tag{30}$$

with $V^* = t\,(\rho_B - 1) - \frac{H\,\eta}{1-t} - k$ from (15). Analogously to the rational setting in section 4.2.1, the following merger value results by inserting a_R^* from (29) and R^*

from (28) into (8) with $\alpha = 0$:

$$V_M^{R*} = \frac{H\,t\,(4\,\rho_G - 6) + 4\,t\,(\rho_G - 3) - k\,(4\,H - 6\,t + 8) + 4}{8 + 4\,H - 6\,t} + \frac{(t\,(\rho_G - 3)2\,\eta)^2 - 8\,\eta\,(1 + H)}{8 + 4\,H - 6\,t}. \tag{31}$$

The comparison of the expected benefits from merging between the scenarios of two rational CEOs who either pay a retention bonus or not shows that the payment of a retention bonus strictly increases the expected benefit from merging,

$$\Delta V^R - \Delta V = \frac{\left(2\,t\,(2\,\rho_G - 3\,\eta + H + 5) - 3\,(1 + \rho_G)t^2 + 8(\eta(1 + H) - 1)\right)^2}{4\,(4 - 3\,t)^2(4 + 2\,H - 3\,t)}. \tag{32}$$

In sum, the fact that (32) is strictly positive in our model setup leads to the corresponding proposition.

Proposition 2 *With two rational CEOs, a retention bonus strictly increases the expected benefit from merging,* $\Delta V^R - \Delta V > 0$.

Figure 8 underlines this result by illustrating the expected benefits from merging without and with a retention bonus.

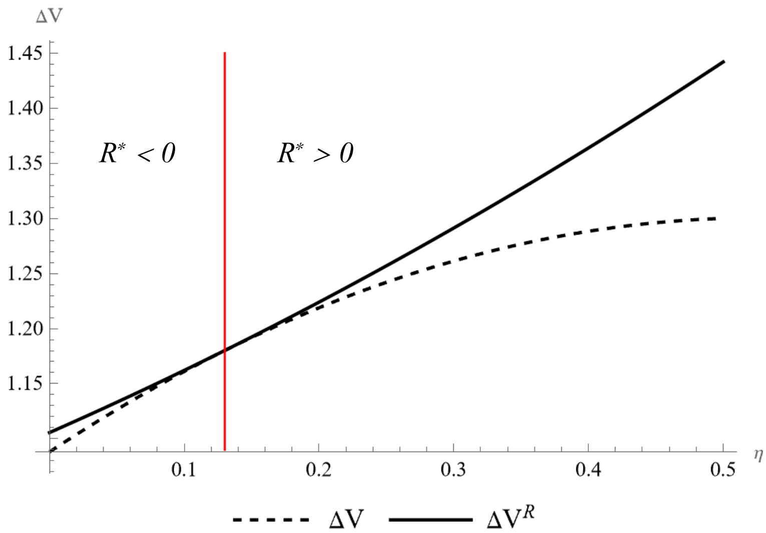


Figure 8: Comparison of expected benefits from merging dependent on signing bonus η with $t = 0.5$, $H = 0.6 > \eta$, $0 \leq \eta \leq 1 - t$, $k = 2$ and $1 < \rho_G = 1.5 < \frac{2-t}{t}$. Red line: η^{crit} for $R^* = 0$ if $H^{crit} > H > H^{crit'}$, i.e. $\Delta V = \Delta V^R$.

As before, the red line marks the point at which the retention bonus becomes positive, i.e. $\eta^{crit} = 0.1301$, as we consider the same hiring costs as in Figure 7,

$H^{crit} > H = 0.6 > H^{crit'}$. Independent of the sign of the retention bonus R^*, the expected benefit from merging is higher with a retention bonus.

4.3 One Biased CEO in a Merger

In this setting, we examine the case of a biased CEO 1, which means that the power of the biased CEO is non-zero, i.e. $0 < \alpha \leq 1$.

4.3.1 Biased CEO without Retention Bonus

We solve the sequential game again by using backward induction and setting $R_i = 0$.

T=1 (Managers): Determination of a_1 and a_2:
The following two expressions illustrate the crucial impact of the biased conviction that the managers from firm 1 are the only ones that can generate x_G and the corresponding decision to pick solely managers from firm 1 with decision-making power α if both managers are still available, i.e. with $(1 - a_1)(1 - a_2)$.
Effort determination of manager who belongs to the biased CEO's firm:

$$\begin{aligned} &\underset{a_1}{max}\ E(U_1) = \underset{a_1}{max}\ a_1 \cdot \left(S^C(t) + \eta\right) \\ &+ (1 - a_1)\Big\{a_2 \cdot S^C(t) + (1 - a_2)\left[\frac{1}{2}(1 + \alpha) \cdot S^C(t) + \frac{1}{2}(1 - \alpha) \cdot S^F(t)\right]\Big\} \\ &- (1 - t)\frac{a_1^2}{2}. \end{aligned} \tag{33}$$

Effort determination of manager who belongs to the rational CEO's firm:

$$\begin{aligned} &\underset{a_2}{max}\ E(U_2) = \underset{a_2}{max}\ a_2 \cdot \left(S^C(t) + \eta\right) \\ &+ (1 - a_2)\Big\{a_1 \cdot S^C(t) + (1 - a_1)\left[\frac{1}{2}(1 - \alpha) \cdot S^C(t) + \frac{1}{2}(1 + \alpha) \cdot S^F(t)\right]\Big\} \\ &- (1 - t)\frac{a_2^2}{2}. \end{aligned} \tag{34}$$

Solving these optimization problems leads to the optimal effort reaction functions,

$$a_1^B(a_2^B) = \frac{t\,(1 - a_2^B)(1 - \alpha)}{4\,(1 - t)} + \frac{\eta}{1 - t}, \tag{35a}$$

$$a_2^B(a_1^B) = \frac{t\,(1 - a_1^B)(1 + \alpha)}{4\,(1 - t)} + \frac{\eta}{1 - t}. \tag{35b}$$

Also, the comparative statics analysis of the managers' reaction functions shows that the optimal search activities of both managers decrease with an increasing search activity of their direct competitor, $\frac{\partial a_1^B(a_2^B)}{a_2^B} = \frac{t\,(1-\alpha)}{4\,(t-1)} < 0$, $\frac{\partial a_2^B(a_1^B)}{a_1^B} = \frac{t\,(1+\alpha)}{4\,(t-1)} < 0$ for $t \in (0, \frac{2}{3}]$ and $\alpha \in (0, 1]$.

Simultaneously solving for the optimal efforts leads to

$$\begin{aligned} a_1^{B*} &= \frac{t\,(4 - t\,(5+\alpha))(1-\alpha) + 4\,(4 - t\,(5-\alpha))\eta}{16 - t\,(32 - t\,(15+\alpha^2))} \\ &= a^* - \frac{4\,t\,\alpha\,(4 - t\,(3+\alpha))(1-t-\eta)}{(4-3\,t)(16 - t\,(32 - t\,(15+\alpha^2)))}, \end{aligned} \tag{36a}$$

$$\begin{aligned} a_2^{B*} &= \frac{t\,(4 - t\,(5-\alpha))(1+\alpha) + 4\,(4 - t\,(5+\alpha))\eta}{16 - t\,(32 - t\,(15+\alpha^2))} \\ &= a^* + \frac{4\,t\,\alpha\,(4 - t\,(3-\alpha))(1-t-\eta)}{(4-3\,t)(16 - t\,(32 - t\,(15+\alpha^2)))}. \end{aligned} \tag{36b}$$

It is possible to determine parameter restrictions for which the search activities a_i^{B*} lie within the allowed range. Hence, $0 \leq a_1^{B*} \leq 1$ and $0 < a_2^{B*} \leq 1$, if $0 < \alpha \leq 1, 0 < t \leq \frac{2}{3}, 0 \leq \eta \leq 1-t$. In order to analyze the impact of the bias, we start with comparing the activities in the benchmark case with the activities with one biased CEO, both without a retention bonus. Examining (36a) and (36b) leads us to the next Proposition.

Proposition 3 *When introducing a biased CEO 1, the voluntary turnover rate of the manager that works for the rational CEO is higher than in the setting with two rational CEOs. In contrast, the voluntary turnover rate of the manager that works for the biased CEO is strictly lower. Formally,* $1 \geq a_2^{B*} \geq a^* \geq a_1^{B*} \geq 0$.

Proof: See the Appendix A2.

Figure 9 underlines Proposition 3 by illustrating the optimal search activities if both CEOs are rational in comparison to the search activies from both perspectives if CEO 1 is biased.

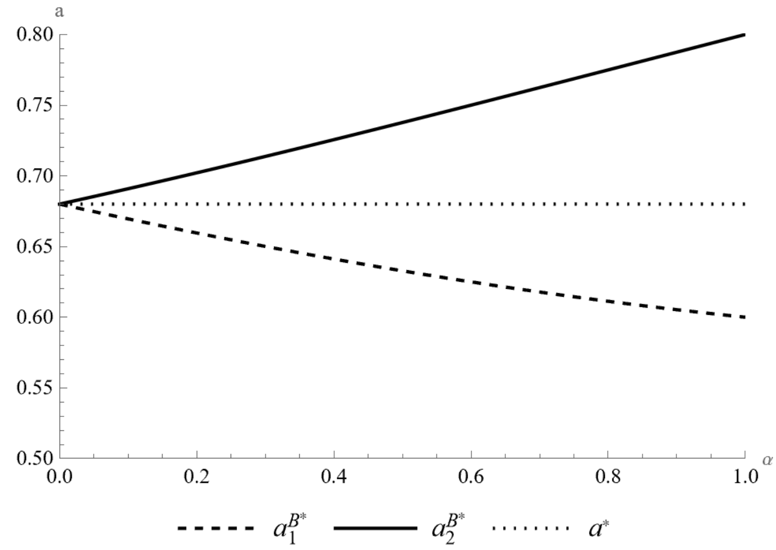


Figure 9: Comparison of optimal search activities dependent on power α with $t = 0.5$ and $\eta = 0.3 \leq 1 - t$.

With increasing power α of the biased CEO, the voluntary turnover rate of the biased (rational) CEO's manager decreases (increases). This can be explained by the fact, that both managers are aware that the biased CEO aims at retaining the manager from her firm 1. Hence, the probability to be retained (equation (4) and (5)) if both managers are available increases (decreases) with α for the biased (rational) CEO's manager. Even if the power of both CEOs is equally shared ($\alpha = 0.5$), the voluntary turnover rate of the rational CEO's manager is higher than the biased one's, see equations (36a) and (36b) as well as Figure 9 with $\alpha = 0.5$. This can be explained by the fact that the managers' probabilities to be retained (equations (4) and (5)) differ even with $\alpha = 0.5$. Thus, with a non-zero power α, the rational CEO's manager decides to increase the search activity while the biased CEO's manager decreases this activity. As already shown in the comparative statics analysis of the managers' reaction functions, each manager's turnover rate decreases with the turnover rate of the direct competitor. Thus, an enhancement of the rational CEO's manager's search activity automatically leads to a decrease of the biased CEO's manager's search activity and vice versa. The respective effects of power α on a_1^{B*} and a_2^{B*} are underlined by their comparative statics,

$$\frac{\partial a_1^{B*}}{\partial \alpha} = -\frac{4t\left(((10-\alpha)\alpha+15)t^2+8(2-(4+\alpha)t)\right)(1-\eta-t)}{\left(t\left((\alpha^2+15)\,t-32\right)+16\right)^2} \leq 0, \tag{37a}$$

$$\frac{\partial a_2^{B*}}{\partial \alpha} = \frac{4t\left((15-\alpha(\alpha+10))t^2+8(2-(4-\alpha)t)\right)(1-\eta-t)}{\left(t\left((\alpha^2+15)\,t-32\right)+16\right)^2} \geq 0, \tag{37b}$$

with $0 < \alpha \leq 1$, $0 < t \leq \frac{2}{3}$ and $0 < \eta \leq 1 - t$. In contrast, a^* is unaffected by the power α as it considers the benchmark voluntary turnover rate.
As we do not consider the option to pay a retention bonus here, we continue by determining the expected benefit from merging.

T=0 (CEOs): Determination of expected merging benefit:

$$\Delta V_i^B = \frac{1}{2} V_{i,M}^{B*} - V^*,$$

with $V^* = t\,(\rho_B - 1) - \frac{H\,\eta}{1-t} - k$ from (15). $V_{i,M}^{B*}$ differs dependent on the perspective of the CEO, according to (7) and (8) with $R_1 = 0$ and $R_2 = 0$. Then, the expected merger value from the rational CEO's perspective is

$$\begin{aligned} V_{2,M}^B =& (a_1\,(1-a_2) + a_2\,(1-a_1)) \left(\frac{1}{2}\,(x_G + x_B) - S^C(t)\right) \\ &+ (1-a_1)\,(1-a_2) \left((1 - \frac{1}{2}\,\alpha)\,x_G + \frac{1}{2}\,\alpha\,x_B - S^C(t)\right) \\ &- a_1\,a_2\,H - k. \end{aligned} \tag{38}$$

From the biased CEO's perspective, the expected merger value is

$$\begin{aligned} V_{1,M}^B =& a_1\,(1-a_2)\,\big(x_B - S^C(t)\big) + a_2\,(1-a_1)\,\big(x_G - S^C(t)\big) \\ &+ (1-a_1)\,(1-a_2) \left(\frac{1}{2}\,(1+\alpha)\,x_G + \frac{1}{2}\,(1-\alpha)\,x_B - S^C(t)\right) \\ &- a_1\,a_2\,H - k. \end{aligned} \tag{39}$$

By inserting $a_1^{B^*}$ and $a_2^{B^*}$ into (38) and (39), we receive $V_{1,M}^{B^*}$ and $V_{2,M}^{B^*}$ and hence, ΔV_1^B and ΔV_2^B.[24] Usually, the biased CEO 1 expects higher benefits from merging than the rational CEO 2, but with a low level of power α, it is even possible that the rational CEO 2 expects higher benefits.

Figure 10 shows these effects for a numerical example by illustrating the expected benefits from merging.

[24] We forego illustrating $V_{1,M}^{B^*}$ and $V_{2,M}^{B^*}$ at this point as our focus is on the expected benefits from merging $\Delta V_{1,M}^{B^*}$ and $\Delta V_{2,M}^{B^*}$. See the Appendix for an illustration of $\Delta V_{1,M}^{B^*}$ and $\Delta V_{2,M}^{B^*}$.

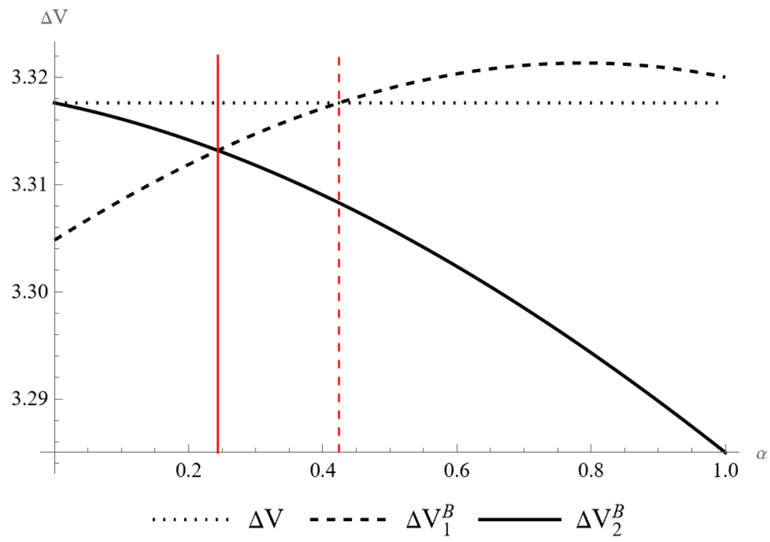


Figure 10: Comparison of expected benefits from merging dependent on power α with $t = 0.5$, $\eta = 0.3 < 1 - t$, $\rho_G = 2 < \frac{2-t}{t}$, $H = 2 > \eta$ and $k = 5$.
Red line: $\alpha' = 0.2436$ for $\Delta V_1^B = \Delta V_2^B$. Dashed red line: $\alpha = 0.4241$ for $\Delta V = \Delta V_1^B$.

This graph shows that the biased CEO 1's expectations about the expected benefit from merging increase with her power α until a maximum point is reached. In contrast, the rational CEO 2 expects lower benefits the higher the power of the biased CEO 1. Both results are rather intuitive as both players know that the biased CEO will only retain the own managers with her power α and the turnover rates develop accordingly. From the biased perspective, the own managers are always the good fit which increases the expected benefit from merging with increasing power α. From the rational perspective, the biased decision to stick with the own managers reduces the chance to retain the good fit managers in contrast to a rational decision. The rational CEO always expects lower benefits from merging if the other CEO is biased compared to the expected benefit in the benchmark solution. On the other hand, the biased CEO 1 can in fact expect higher benefits from merging than in the benchmark solution if her power is sufficiently high. In this setting, the named expected benefits are equal if $\alpha = 0.4241$ (dashed red line). Thus, if $0 < \alpha < 0.4241$, $\Delta V_i > \Delta V_1^B$ whereas $\Delta V_i < \Delta V_1^B$ for $0.4241 < \alpha < 1$.
Additionally, below a critical value $\alpha'(t, \rho_G, \eta)$ (here $\alpha' = 0.2436$, red line) of the biased CEO's power, the rational CEO 2 expects higher benefits from merging than the biased CEO. At this α', the biased and the rational CEO's expectations coincide and with an increasing α, they diverge so that the biased CEO expects higher benefits from merging. Thus, the biased CEO is willing to accept higher hiring costs H than the rational CEO as soon as α exceeds this critical value. As long as α stays below this critical value, the rational CEO is willing to accept higher

costs because she expects a higher merging benefit than her biased counterpart. This result is driven by the fact that the rational CEO expects a probability to pick the good fit manager of $(1 - \frac{1}{2}\alpha)$ while the biased CEO expects a probability of $\frac{1}{2}(1+\alpha)$ if both managers are available. If α is below $\frac{1}{2}$, the rational CEO's expectation to retain the good fit is higher than the one of the biased CEO. Among others, this effect drives the mentioned results and is affected by the CEOs' different expectations about the managers' fits if only one of them stays voluntarily.

4.3.2 Interaction between Bias and Retention Bonus

Now, we consider a biased CEO and a potential retention bonus. We analyze the interaction of both as well as their impact on the search activity and on the expected merging benefit. We solve the sequential game again by using backward induction.

T=1 (Managers): Determination of a_1 and a_2:
Both managers determine their optimal effort (search activity) analogously to (33) and (34) but with the opportunity to receive a retention bonus R_i if they stay.
Effort determination of the manager that belongs to the biased CEO's firm:

$$\begin{aligned}&\underset{a_1}{max}\ E(U_1) = \underset{a_1}{max}\ a_1 \cdot \big(S^C(t) + \eta\big)\\&+ (1-a_1)\Big\{R_1^B + a_2 \cdot S^C(t) + (1-a_2)\left[\frac{1}{2}(1+\alpha)\cdot S^C(t) + \frac{1}{2}(1-\alpha)\cdot S^F(t)\right]\Big\}\\&- (1-t)\frac{a_1^2}{2}.\end{aligned} \tag{40}$$

Effort determination of the manager that belongs to the rational CEO's firm:

$$\begin{aligned}&\underset{a_2}{max}\ E(U_2) = \underset{a_2}{max}\ a_2 \cdot \big(S^C(t) + \eta\big)\\&+ (1-a_2)\Big\{R_2^B + a_1 \cdot S^C(t) + (1-a_1)\left[\frac{1}{2}(1-\alpha)\cdot S^C(t) + \frac{1}{2}(1+\alpha)\cdot S^F(t)\right]\Big\}\\&- (1-t)\frac{a_2^2}{2}.\end{aligned} \tag{41}$$

Solving the previous expressions leads to the reaction functions,

$$a_1^{BR}(a_2^{BR}) = \frac{t\,(1-a_2^{BR})(1-\alpha)}{4\,(1-t)} + \frac{\eta - R_1^B}{1-t}, \tag{42a}$$

$$a_2^{BR}(a_1^{BR}) = \frac{t\,(1-a_1^{BR})(1+\alpha)}{4\,(1-t)} + \frac{\eta - R_2^B}{1-t}. \tag{42b}$$

The comparative statics analysis of the managers' reaction functions shows that the optimal search activities of both managers also decrease with an increasing search activity of their direct competitor. As the retention bonus is independent of a_i^{BR} within this reaction function, the comparative static is the same as in section 4.3.1 without a retention bonus, $\frac{\partial a_1^{BR}(a_2^{BR})}{a_2^{BR}} = -\frac{t\,(1-\alpha)}{4\,(1-t)} < 0$, $\frac{\partial a_2^{BR}(a_1^{BR})}{a_1^{BR}} = -\frac{t\,(1+\alpha)}{4\,(1-t)} < 0$ for $t \in [0, \frac{2}{3}]$ and $\alpha \in (0, 1]$. Simultaneously solving for the optimal efforts leads to

$$\begin{aligned} a_1^{BR} =& \frac{t\,(4-t\,(5+\alpha))(1-\alpha)+4\,(4-t\,(5-\alpha))\eta}{16+t\,(t\,(15+\alpha^2)-32)} \\ &+ \frac{4\left(t(1-\alpha)R_2^B - 4(1-t)R_1^B\right)}{16+t\,(t\,(15+\alpha^2)-32)}, \end{aligned} \tag{43a}$$

$$\begin{aligned} a_2^{BR} =& \frac{t\,(4-t\,(5-\alpha))(1+\alpha)+4\,(4-t\,(5+\alpha))\eta}{16+t\,(t\,(15+\alpha^2)-32)} \\ &+ \frac{4\left(t(1+\alpha)R_1^B - 4(1-t)R_2^B\right)}{16+t\,(t\,(15+\alpha^2)-32)}. \end{aligned} \tag{43b}$$

T=0 (CEOs): Determination of retention bonus and merging benefit:

In order to determine the optimal retention bonus with the purpose of decreasing the voluntary turnover rates, the CEOs maximize the expected merger value of the new firm. As in the previous subsection, both CEOs have different perspectives on these merger values. Thus, we distinguish between the perspectives. Both CEOs anticipate a_1^{BR} and a_2^{BR} from (43a) and (43b). We start with the biased CEO 1 followed by the rational CEO 2.

$$\begin{aligned} &\max_{R_1^B} \frac{1}{2} V_{1,M}^{BR} \\ =& \max_{R_1^B} \frac{1}{2}\Big[a_1^{BR}\,(1-a_2^{BR})\left(x_B - S^C(t)\right) + a_2^{BR}\,(1-a_1^{BR})\left(x_G - S^C(t)\right) \\ &+ (1-a_1^{BR})\,(1-a_2^{BR})\left(\frac{1}{2}\,(1+\alpha)\,x_G + \frac{1}{2}\,(1-\alpha)\,x_B - S^C(t)\right) \\ &- a_1^{BR}\,a_2^{BR}\,H - k - (1-a_1^{BR})\,R_1^B - (1-a_2^{BR})\,R_2^B\Big], \end{aligned} \tag{44}$$

$$\begin{aligned} &\max_{R_2^B} \frac{1}{2} V_{2,M}^{BR} \\ =& \max_{R_2^B} \frac{1}{2}\Big[(a_1^{BR}\,(1-a_2^{BR}) + a_2^{BR}\,(1-a_1^{BR}))\left(\frac{1}{2}\,(x_G + x_B) - S^C(t)\right) \\ &+ (1-a_1^{BR})\,(1-a_2^{BR})\left((1-\frac{1}{2}\,\alpha)\,x_G + \frac{1}{2}\,\alpha\,x_B - S^C(t)\right) \\ &- a_1^{BR}\,a_2^{BR}\,H - k - (1-a_1^{BR})\,R_1^B - (1-a_2^{BR})\,R_2^B\Big]. \end{aligned} \tag{45}$$

The next Lemma presents the optimal retention bonus and induced actions by maximizing equations (44) and (45) with the optimal efforts from (43a) and (43b).

Lemma 3 *When CEO 1 is biased towards the own managers, the managers' optimal retention bonuses and their equilibrium efforts are given by:*[25]

$$R_1^{B*} = R_1^{B*}(t, \alpha, \rho_G, \eta, H), \tag{46a}$$

$$R_2^{B*} = R_2^{B*}(t, \alpha, \rho_G, \eta, H), \tag{46b}$$

leading to

$$a_1^{BR*} = a_1^{B*} + \frac{4\left(t(1-\alpha)R_2^{B*} - 4(1-t)R_1^{B*}\right)}{16 + t\left(t\left(15+\alpha^2\right) - 32\right)}, \tag{47a}$$

$$a_2^{BR*} = a_2^{B*} + \frac{4\left(t(1+\alpha)R_1^{B*} - 4(1-t)R_2^{B*}\right)}{16 + t\left(t\left(15+\alpha^2\right) - 32\right)}. \tag{47b}$$

Proof: See the Appendix A2.

As in the rational scenario with a retention bonus, we can determine restrictions under which the retention bonus can become negative. The turning points are $R_1^{B*} = 0$ for $H = H'$ and $R_2^{B*} = 0$ for $H = H''$ whereas $H' > H''$. The retention bonus R_i^{B*} becomes positive as soon as H exceeds the respective critical value. The bonus R_2^{B*} is already positive for a lower value of hiring costs H than R_1^{B*} which means that the rational CEO already considers the payment of a positive retention bonus for lower hiring costs than the biased CEO.
Based on the optimal search activities, we derive the following proposition.

Proposition 4 *Counterintuitively, although the ex ante probability to be retained is higher for the biased CEO's manager, the biased CEO's manager's voluntary turnover rate with a retention bonus is higher than the rational CEO's manager's voluntary turnover rate with a retention bonus. Formally,* $1 \geq a_1^{BR*} > a_2^{BR*} \geq 0$.

Proof: See the Appendix A2.

Although we have already determined critical values for H to ensure a positive retention bonus, we have to refine these critical values to make sure that the optimal turnover rates still function as a probability, i.e. $0 \leq a_i^{BR*} \leq 1$. Since $a_1^{BR*} > a_2^{BR*}$, a_2^{BR*} is the turnover rate that can become negative earliest. The corresponding

[25] Note that we postpone the complete illustration of the optimal retention bonuses to the Appendix A2 due to their complexity.

critical value for H is H''', whereas $H''' \lesseqgtr H' > H''$.[26] Thus, dependent on the actual parameter values of t, η, ρ_G and α, H has to exceed $\max\{H'; H'''\}$ to ensure that $0 \leq a_2^{BR*} \leq 1$ and $R_i^{B*} > 0$. Figure 11 underlines Proposition 4 by illustrating the optimal search activities for positive retention bonuses for a numerical example with $H(=2) > H'''(=1.647731) > H'(=1.37797) > H''(=0.355231) > \eta(=0.3) > 0$.

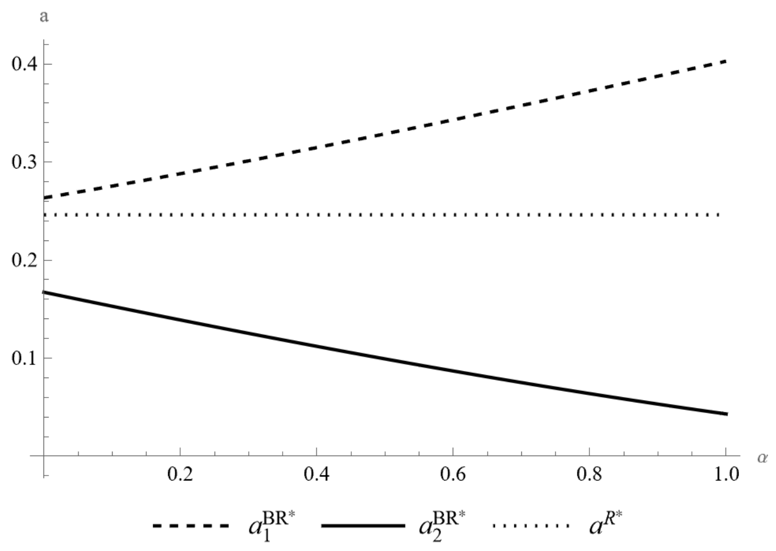


Figure 11: Comparison of optimal search activities dependent on power α with $t = 0.5$, $\eta = 0.3$, $\rho_G = 2$ and $H = 2$.

The voluntary turnover rate in this setting is higher for the biased CEO's manager than for the rational one for each $\alpha \in (0, 1]$. At first glance, Proposition 4 is surprising since ex ante, the bias increases the probability of being retained for the biased CEO's manager and decreases the probability of being retained for the rational CEO's manager which would consequently lead to a lower voluntary turnover rate of the biased CEO's manager, see Proposition 3 and Figure 9. Figure 11 also shows that the biased CEO's power α has a strong impact on the gradient of a_1^{BR*} and a_2^{BR*}: In contrast to Figure 9, where the voluntary turnover rate of the biased (rational) CEO's manager decreases (increases) with α, here it is the other way around: With increasing power α of the biased CEO, the voluntary turnover rate of the biased (rational) CEO's manager increases (decreases).

The result of Proposition 4 mainly stems from the fact that the biased CEO pays a lower retention bonus than her rational counterpart to the respective own manager and even a lower one than the in the benchmark setting although she is convinced

[26] The critical value for $0 \leq a_1^{BR*} \leq 1$ is smaller than H' and H'' and thus, not subject of further discussion. See the Appendix for a detailed illustration of H', H'' and H'''.

that her managers are always the better fit. Figure 12 shows this divergence of the retention bonuses for the same parameter assumptions as in Figure 11.[27]

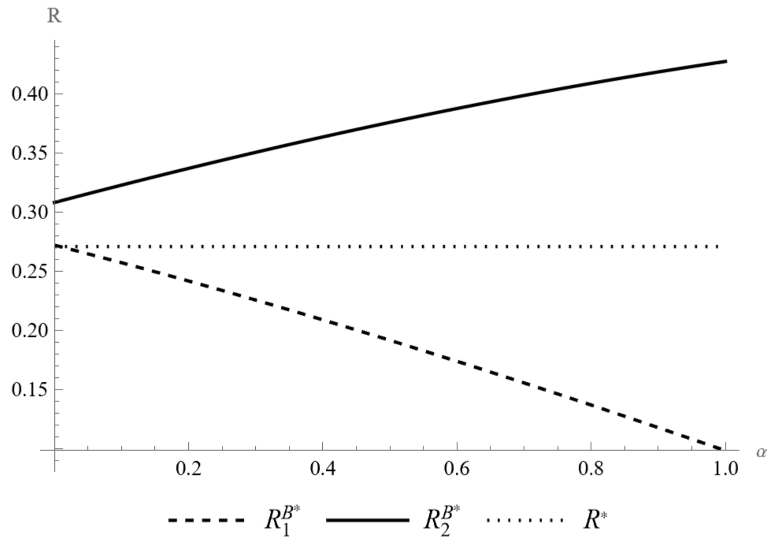


Figure 12: Comparison of optimal retention bonuses dependent on power α with $t = 0.5$, $\eta = 0.3$, $\rho_G = 2$ and $H = 2$.

In this Figure, it can be seen that the biased CEO's retention bonus $R_1^{B^*}$ decreases with the own power α while the rational CEO tries to counteract the turnover rate increasing-effect of α on the own managers with an increasing retention bonus $R_2^{B^*}$. Compared to the retention bonus R^* without consideration of a bias, the rational CEO has to increase the bonus as with a biased CEO, the managers tend to search more intensively for an outside option as has been shown in Proposition 3. In contrast, the biased CEO decides to pay them a lower retention bonus.

Consequently, the rational CEO's retention bonus $R_2^{B^*}$ is strictly higher than $R_1^{B^*}$ so that it surpasses the effect of the bias on the rational CEO's manager's voluntary turnover rate. Since the retention bonus of CEO 1 even decreases with her bias, $R_2^{B^*}$ and α counteract to such an extent that $a_2^{BR^*} < a_1^{BR^*}$ results. The biased CEO's manager is aware of the too low retention bonus compared to the rational scenario and thus, increases his search activity and hence, turnover rate.

The expected benefit from merging is

$$\Delta V_i^{BR} = \frac{1}{2} V_{i,M}^{BR^*} - V^*.$$

with $V^* = t\,(\rho_B - 1) - \frac{H\,\eta}{1-t} - k$ from (15). Analogously to the setting in section 4.3.1,

[27] In this setting, $H^{crit'}$ for $R^* \geq 0$ is also satisfied with $H(=2) > H'''(= 1.647731) > H'(= 1.37797) > H^{crit'} = 1.25 > H''(= 0.355231) > \eta(= 0.3) > 0$.

we receive $V_{1,M}^{BR^*}$ and $V_{2,M}^{BR^*}$ and hence, ΔV_1^{BR} and ΔV_2^{BR} by inserting $a_1^{BR^*}$ and $a_2^{BR^*}$ from (47a) and (47b), $R_1^{B^*}$ and $R_2^{B^*}$ from (46a) and (46b) into (7) and (8).[28] In the following, we again consider settings in which positive retention bonuses are paid, $R_i^* \geq 0$, $R_i^{B^*} \geq 0$, and all turnover rates a_i function as a probability, i.e. are between zero and one. Figure 13 illustrates the expected benefits from merging with a retention bonus and a biased CEO as well as two rational CEOs in one graph.

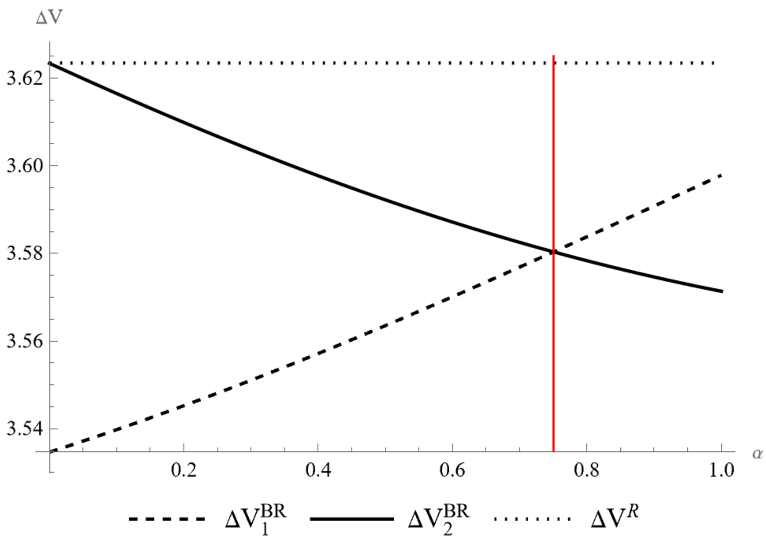


Figure 13: Comparison of expected benefits from merging dependent on power α with $t = 0.5$, $\eta = 0.3$, $\rho_G = 2$, $H = 2$ and $k = 5$.
Red line: $\alpha'' = 0.750254$ for $\Delta V_1^{BR} = \Delta V_2^{BR}$.

The graphs of ΔV_i^{BR} are similar to the ones for the scenario without a retention bonus, except for the determination of the critical value for power α. Analogously to Figure 10, we use the same parameter values in order to show the relation with a biased CEO and a retention bonus contract. Figure 13 shows that, as already known from section 4.3.1, the expected benefit from merging increases with α from a biased perspective and decreases with α from a rational perspective. Although the voluntary turnover rate $a_2^{BR^*}$ decreases with power α, the expected merging benefit also decreases from the rational CEO's perspective as the effect of the increasing retention bonus dominates the effect of the decreasing voluntary turnover rate. Compared to the critical value for α in section 4.3.1, the retention bonus increases this critical value. A reason for that is the increasing (decreasing) voluntary turnover rate with increasing power α from the biased (rational) perspective. As already known from equation (22), the firm value decreases with the voluntary turnover

[28] We forego illustrating both expected benefits from merging as these values are rather long and do not add any value neither here nor in the Appendix.

rate, thus a decreasing turnover rate increases the expected benefit from merging. In the setting of Figure 13, $\alpha''(t, \rho_G, \eta) = 0.750254$ for $\Delta V_1^{BR} = \Delta V_2^{BR}$ (red line), which is nearly three times as high in this numerical example as without a retention bonus in the biased model setup in Figure 10. Additionally, the expected benefit from merging of the rational scenario with the retention bonus, ΔV^R, is higher than both perspectives with a biased CEO and a retention bonus. Regarding the different perspectives, we determine the following proposition:

Proposition 5 *The merging firms are willing to pay a retention bonus if the hiring costs for an external manager exceed the critical values H' for R_1^{B*} and H'' for R_2^{B*}. For $\frac{t(1-\alpha)}{4(1-t)} R_2^{B*} < R_1^{B*} < \frac{4(1-t)}{t(1+\alpha)} R_2^{B*}$, the retention bonuses successfully decrease the voluntary turnover rates and consequently increase the expected benefit from merging from a rational perspective, even with a biased CEO.*

Proof: See the Appendix.

In order to draw a bigger picture of the expected benefits from merging and Proposition 5, Figure 14 combines all of them.[29]

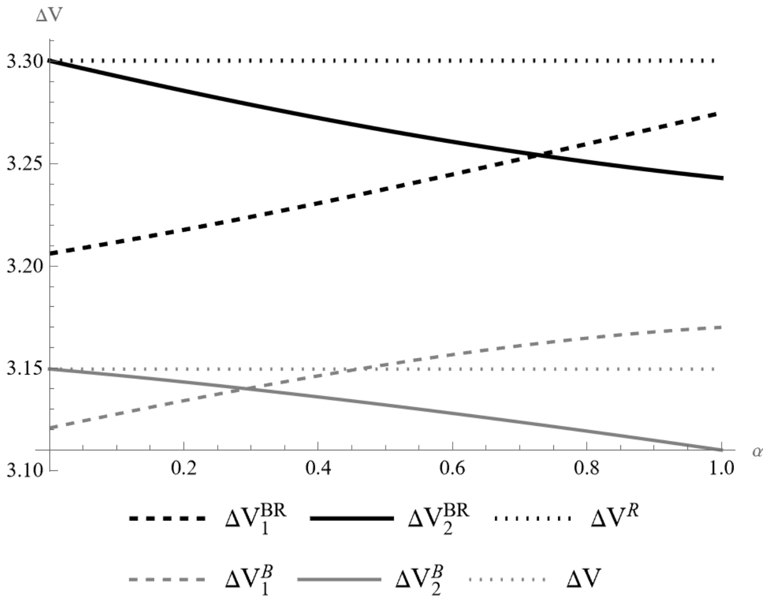


Figure 14: Comparison of all expected benefits from merging dependent on power α with $t = 0.5$, $\eta = 0.2$, $\rho_G = 2$, $H = 2$ and $k = 5$.

[29] As before, we only consider parameter settings which ensure positive retention bonuses and search activities that act as a probability. This is ensured in this setting with $H = 2 > H' = 1.875 = H''' > \eta = 0.2$.

It becomes obvious that the expected benefit from merging of the rational scenario with the retention bonus, ΔV^R, is higher than all other scenarios. But even if a bias is considered, a retention bonus always improves the expected benefit from merging from the biased and the rational perspective ($\Delta V_i^{BR} > V_i^B$). Thus, a positive retention bonus can in fact maximize the expected benefit from merging. The effects and orderings of the expected benefits without a retention bonus (grey and lower graphs) have already been explained in Figure 10. Counterintuitively, the expected benefit from merging with one biased CEO and a retention bonus (both from a rational and biased perspective) is higher than from merging with two rational CEOs but without a retention bonus, $\Delta V_i^{BR} > \Delta V_i$. Hence, if it is not avoidable that one of the merging firms is led by a biased CEO, the expected benefit from merging (rational perspective) can be increased by paying a retention bonus instead of suffering from a lower merging benefit if one CEO is biased. This is in fact more advantageous than merging with two rational CEOs and no retention bonus. Hence, from a rational point of view, the value-enhancing effect of an optimal retention bonus exceeds the value-decreasing effect of a bias.

5 Conclusion

We analyze the voluntary turnover rates and the expected merging benefit of a merger of equals in a principal-agent model. As a starting point, we show that the announcement of a merger increases the voluntary turnover rates of the managers and that especially the key employees tend to leave the firm. This underlines the relevance of finding ways to reduce the voluntary turnover rates in order to ensure that the key employees stay with the firm and thereby increase the expected merging benefit. Our results show that a retention bonus that is paid once to each manager who stays during the transition process of the merger helps to decrease the voluntary turnover rates of the managers. The retention bonus also increases both the expected overall merging benefit from the rational and the biased CEO's perspective. Hence, it can be seen as a valuable option in case of an upcoming merger (of equals).

A lot of literature suggests that the decision-makers in firms, i.e. the CEOs, tend to be biased. This is why we consider one CEO to be biased towards her own employees, as she always prefers to retain them after the merger (instead of the other firm's managers). Implementing such a biased CEO has an effect on our results regarding the voluntary turnover rates and the expected merging benefits. Without consideration of a retention bonus, the bias of the CEO leads to a lower turnover rate for her own employees, whereas the turnover rate of the other firm's employees increases. This is also reflected by a higher expected merging benefit from the biased CEO's point of view compared to the rational CEO if the biased CEO's power is sufficiently high. Interestingly, considering the retention bonus changes the results. Then, the voluntary turnover rate of the biased CEO's employees increases compared to the rational scenario, because the retention bonus paid by the biased CEO is not high enough. Thus, the expected merging benefit from the biased CEO's point of view is only higher than the benefit from the rational CEO's point of view, if she has enough (negotiation) power to signal her employees that they are likely to be retained in the merged firm. Overall, we show that a retention bonus successfully decreases the voluntary turnover rates and thus, increases the expected merging benefit in each scenario we consider.

Our results show that the payment of retention bonuses or a well structured retention management can be seen as a key aspect for the success of a merger (of equals). Even the potential bias of a decision-maker that is involved does not change the direction of this result. Nevertheless, the bias of a CEO has important implications for the actions of the employees that need to be considered in the context of the retention management. For future research it would be interesting to consider a second period in a merger in order to examine whether a paid retention bonus can have a long-term effect or whether a proportion of employees leaves the firm after the retention period ends. Furthermore, the analysis of scenarios in which the merging firms cannot be considered as equal could also be of interest. Additionally, the analysis of the impact of biases in mergers and potentially takeover situations could be further deepened.

Appendix

Appendix A0 - No Merger

Proof of a^*_{nM} in (14) and V^*_i in (15) in section 4.1:

The manager faces the optimization problem as in (13). Thus, he considers the following derivative:

$$\frac{\partial E(U)}{\partial a} = \eta - (1-t)\,a.$$

With the first-order condition $\frac{\partial E(U)}{\partial a} = 0$, it follows that $a = a^*_{nM}$.
Inserting $a^*_{nM} = \frac{\eta}{1-t}$ into equation (6), V_i becomes V^*_i as in (15). ■

Appendix A1 - Two rational CEOs

Proof of Lemma 1:

Proof of $a_i(a_j)$ *in* (17):
The manager faces the optimization problem as in (16). Thus, he considers the following derivation:

$$\frac{\partial E(U_i)}{\partial a_i} = \frac{1}{4}t(1-a_j) + \eta - (1-t)a_i.$$

With the first-order condition $\frac{\partial E(U_i)}{\partial a_i} = 0$, it follows that $a_i = a_i(a_j)$ as in (17).

Proof of a^* *in* (18)*:*
Symmetry leads to $a_i = a_j = a$. Thus, (17) becomes:

$$a = \frac{t(1-a)}{4(1-t)} + \frac{\eta}{1-t}.$$

Solving for a leads to $a = a^*$ as in (18).
The comparison of a^* and a^*_{nM} is as follows:

$$\begin{aligned}
a^*_{nM} = a^* \; &\leftrightarrow \frac{\eta}{1-t} &= \frac{t+4\,\eta}{4-3\,t}, \text{ if } 0 < t \leq \frac{2}{3} \text{ and } \eta = 1-t,\\
a^*_{nM} < a^* \; &\leftrightarrow \frac{\eta}{1-t} &< \frac{t+4\,\eta}{4-3\,t}, \text{ if } 0 < t \leq \frac{2}{3} \text{ and } 0 \leq \eta < 1-t.
\end{aligned}$$

The optimal search effort a^* is given by (18). The derivative with respect to t is as follows:

$$\begin{aligned}
\frac{\partial\, a^*}{\partial\, t} &= \frac{(4-3\,t)\cdot 1 - (t+4\,\eta)\cdot(-3)}{(4-3\,t)^2}\\
&= \frac{4-3\,t+3\,t+12\,\eta}{(4-3\,t)^2}\\
&= \frac{4\,(1+3\,\eta)}{(4-3\,t)^2} > 0.
\end{aligned}$$

As the denominator is always positive and the nominator is positive with $0 \leq \eta \leq 1-t$, the whole term is also positive. ■

Proof of Proposition 1:

Proof of $a_i^R(a_j^R)$ in (25):
The manager faces the optimization problem as in (24). Thus, he considers the following derivative:

$$\frac{\partial E(U_i)}{\partial a_i} = \frac{1}{4}t(1-a_j) + \eta - R_i - (1-t)a_i.$$

With the first-order condition $\frac{\partial E(U_i)}{\partial a_i} = 0$, it follows that $a_i^R = a_i^R(a_j^R)$ as in (25).

Proof of a^R in (26):
Symmetry leads to $R_i = R_j = R$ and $a_i^R = a_j^R = a$. Thus, (25) becomes:

$$a = \frac{t(1-a)}{4(1-t)} + \frac{\eta - R}{1-t}.$$

Solving for a leads to $a = a^R$ as in (26). The derivative with respect to R is calculated as follows:

$$\frac{\partial\, a^R}{\partial\, R} = -\frac{4}{4-3t} < 0 \text{ with } 0 < t \leq \frac{2}{3}.$$

■

Proof of Lemma 2:

The principal faces the optimization problem given by (27). With $a_1^R = a_2^R = a^R$, the first-order condition with respect to R is given by:

$$-2a^R H\frac{\partial a^R}{\partial R} + 2(\frac{\partial a^R}{\partial R}(1-2a^R))(\frac{1}{2}(x_G + x_B) - S^C(t)) - 2(1-a^R)^3 + 2\frac{\partial a^R}{\partial R}R(1-a^R)^2$$
$$-2(1-a^R)\frac{\partial a^R}{\partial R}(x_G - S^C(t) - k - 2(1-a^R)R) = 0.$$

Using the derivative as given in Proposition 1 and then solving for R leads to R^* as stated in Lemma 2. Inserting R^* from (28) into a^R from (26) leads to a^{R^*} as given by (29). ■

Appendix A2 - One Biased CEO

Proof of Proposition 3:

Proof of $a_1^B(a_2^B)$ *and* $a_2^B(a_1^B)$ *in* (35a) *and* (35b)*:*
The manager of firm 1 faces the optimization problem as in (33). Thus, he considers the following derivative:

$$\frac{\partial E(U_1)}{\partial a_1} = \frac{1}{4}t(1-a_2)(1-\alpha)+\eta-(1-t)a_1.$$

With the first-order condition $\frac{\partial E(U_1)}{\partial a_1}=0$, it follows that $a_1 = a_1^B(a_2^B)$ as in (35a).
The manager of firm 2 faces the optimization problem as in (34). Thus, he considers the following derivative:

$$\frac{\partial E(U_2)}{\partial a_2} = \frac{1}{4}t(1-a_2)(1+\alpha)+\eta-(1-t)a_1.$$

With the first-order condition $\frac{\partial E(U_2)}{\partial a_2}=0$, it follows that $a_2 = a_2^B(a_1^B)$ as in (35b).

Proof of $a_1^{B^*}$ *and* $a_2^{B^*}$ *in* (36a) *and* (36b)*:*
Solving the system of linear equations given by (35a) and (35b) leads to a_1^{B*} as in (36a) and a_2^{B*} as in (36b).

In order to understand the ranking of the search efforts as given in Proposition 3, a look at (36a) and (36b) helps. The equations show that a_1^{B*} is calculated by subtracting a term from a^*, whereas a_2^{B*} is calculated by adding a term to a^*. Thus, the ranking holds if these terms are non-negative. The following holds for the term that is subtracted from a^* in order to calculate a_1^{B*}:

$$\frac{4\,t\,\alpha\,(4-t\,(3+\alpha))(1-t-\eta)}{(4-3\,t)(16-t\,(32-t\,(15+\alpha^2)))} \geq 0,$$

if $0 < \alpha \leq 1$, $0 < t \leq \frac{2}{3}$, $0 \leq \eta \leq 1-t$. Analogously, the following holds for the term that is added to a^* in order to calculate a_2^{B*}:

$$\frac{4\,t\,\alpha\,(4-t\,(3-\alpha))(1-t-\eta)}{(4-3\,t)(16-t\,(32-t\,(15+\alpha^2)))} \geq 0,$$

if $0 < \alpha \leq 1$, $0 < t \leq \frac{2}{3}$, $0 \leq \eta \leq 1-t$. The conditions always hold true, as they are equivalent to our assumptions for the parameters. Hence, the ranking from Proposition 3 also holds true. ■

Illustration of $\boldsymbol{\Delta V_{1,M}^{B^*}}$ and $\boldsymbol{\Delta V_{2,M}^{B^*}}$:

$$\Delta V_{1,M}^{B^*} = \frac{1}{2}V_{1,M}^{B^*} - V^* =$$
$$\frac{1}{2}(k + \frac{2H\eta}{1-t}) + \frac{4(\alpha+1)(g-1)t((5-\alpha)t-4)((\alpha+5)t-4)(1-\eta-t)^2}{\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)^2}$$
$$+\frac{2(g-1)t((\alpha-5)t+4)(1-\eta-t)(4\eta(4-(\alpha+5)t)+(\alpha+1)t((\alpha-5)t+4))}{\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)^2}$$
$$+\frac{H(4\eta((5-\alpha)t-4)+(1-\alpha)t((\alpha+5)t-4))(4\eta(4-(\alpha+5)t)+(\alpha+1)t(4-(5-\alpha)t))}{2\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)^2},$$

$$\Delta V_{2,M}^{B^*} = \frac{1}{2}V_{2,M}^{B^*} - V^* =$$
$$\frac{1}{2}(k + \frac{2H\eta}{1-t}) + \frac{4(2-\alpha)(g-1)t((5-\alpha)t-4)((\alpha+5)t-4)(1-\eta-t)^2}{\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)^2}$$
$$+\frac{2(g-1)t(1-\eta-t)\left(t\left(\alpha^2(8-9t)t+(4-5t)^2\right)+4\eta((\alpha-5)t+4)(4-(\alpha+5)t)\right)}{\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)^2}$$
$$+\frac{H(4\eta((5-\alpha)t-4)+(1-\alpha)t((\alpha+5)t-4))(4\eta(4-(\alpha+5)t)+(\alpha+1)t(4-(5-\alpha)t))}{2\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)^2}.$$

Proof of Lemma 3:

Proof of $a_1^{BR}(a_2^{BR})$ and $a_2^{BR}(a_1^{BR})$ in (42a) *and* (42b)*:*
The manager of firm 1 faces the optimization problem as in (40). Thus, he considers the following derivative:

$$\frac{\partial E(U_1)}{\partial a_1} = \frac{1}{4}t(1-a_2)(1-\alpha) + \eta - R_1^B - (1-t)a_1.$$

With the first-order condition $\frac{\partial E(U_1)}{\partial a_1} = 0$, it follows that $a_1 = a_1^{BR}(a_2^{BR})$ as in (42a). The manager of firm 2 faces the optimization problem as in (41). Thus, he considers the following derivative:

$$\frac{\partial E(U_2)}{\partial a_2} = \frac{1}{4}t(1-a_2)(1+\alpha) + \eta - R_2^B - (1-t)a_1.$$

With the first-order condition $\frac{\partial E(U_2)}{\partial a_2} = 0$, it follows that $a_2 = a_2^{BR}(a_1^{BR})$ as in (42b).

Proof of a_1^{BR} and a_2^{BR} in (43a) *and* (43b)*:*
Solving the system of linear equations given by (42a) and (42b) leads to a_1^{BR} and a_2^{BR} as in (43a) and (43b).

The principal of firm 1 faces the optimization problem given by (44). The first-order condition with respect to R_1^B is given by:

$$
\begin{aligned}
(\frac{\partial a_1^{BR}}{\partial R_1^B}(1-a_2^{BR}) - \frac{\partial a_2^{BR}}{\partial R_1^B}a_1^{BR}))(x_B - S^C(t)) + (\frac{\partial a_2^{BR}}{\partial R_1^B}(1-a_1^{BR}) - \frac{\partial a_1^{BR}}{\partial R_1^B}a_2^{BR}))(x_G - S^C(t)) \\
-(\frac{\partial a_1^{BR}}{\partial R_1^B}(1-a_2^{BR}) + \frac{\partial a_2^{BR}}{\partial R_1^B}(1-a_1^{BR}))(\frac{1}{2}(1+\alpha)x_G + \frac{1}{2}(1-\alpha)x_B - S^C(t)) \\
-H(\frac{\partial a_1^{BR}}{\partial R_1^B}a_2^{BR} + \frac{\partial a_1^{BR}}{\partial R_1^B}a_1^{BR}) + \frac{\partial a_1^{BR}}{\partial R_1^B}R_1^B - (1-a_1^{BR}) + \frac{\partial a_2^{BR}}{\partial R_1^B}R_2^B = 0,
\end{aligned}
$$

with the following derivatives

$$
\begin{aligned}
\frac{\partial a_1^{BR}}{\partial R_1^B} &= -\frac{16(1-t)}{16+t\,(t\,(15+\alpha^2)-32)}, \\
\frac{\partial a_2^{BR}}{\partial R_1^B} &= \frac{4t(1+\alpha)}{16+t\,(t\,(15+\alpha^2)-32)}.
\end{aligned}
$$

The principal of firm 2 faces the optimization problem given by (45). The first-order condition with respect to R_2^B is given by:

$$
\begin{aligned}
(\frac{\partial a_1^{BR}}{\partial R_2^B} + \frac{\partial a_2^{BR}}{\partial R_2^B} - 2(\frac{\partial a_1^{BR}}{\partial R_2^B}a_2^{BR} + \frac{\partial a_2^{BR}}{\partial R_2^B}a_1^{BR}))(\frac{1}{2}(x_G + x_B) - S^C(t)) \\
-(\frac{\partial a_1^{BR}}{\partial R_2^B}(1-a_2^{BR}) + \frac{\partial a_2^{BR}}{\partial R_2^B}(1-a_1^{BR}))((1-\frac{1}{2}\alpha)x_G + \frac{1}{2}\alpha x_B - S^C(t)) \\
-H(\frac{\partial a_1^{BR}}{\partial R_2^B}a_2^{BR} + \frac{\partial a_1^{BR}}{\partial R_2^B}a_1^{BR}) + \frac{\partial a_1^{BR}}{\partial R_2^B}R_1^B + \frac{\partial a_2^{BR}}{\partial R_2^B}R_2^B - (1-a_2^{BR}) = 0,
\end{aligned}
$$

with the following derivatives

$$
\begin{aligned}
\frac{\partial a_1^{BR}}{\partial R_2^B} &= \frac{4t(1-\alpha)}{16+t\,(t\,(15+\alpha^2)-32)}, \\
\frac{\partial a_2^{BR}}{\partial R_2^B} &= -\frac{16(1-t)}{16+t\,(t\,(15+\alpha^2)-32)}.
\end{aligned}
$$

Solving the above system of linear equations for R_1^{BR} and R_2^{BR} leads to the following solutions for $R_1^{B*} = \frac{S_1}{r_1}$ and $R_2^{B*} = \frac{S_2}{r_2}$ with:

$$
\begin{aligned}
S_1 = & -512(\eta-1) - 4H^2\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)((\alpha-1)t-4\eta) \\
& + 128t\left((\alpha(\eta-1)-\eta-3)\rho_G-(2\alpha-17)(\eta-1)\right) \\
& + -t^5\left((\alpha-5)(\alpha(\alpha+5)(\alpha+19)-72)+(5-\alpha(\alpha(\alpha(4\alpha+31)+81)-623))\rho_G\right) \\
& + (\alpha-1)(\alpha(\alpha(3\alpha+5)+141)-85)\left(-t^5\right)\rho_G^2 \\
& + 32t^2\left(\alpha(2\alpha(\eta-1)+27\eta-37)+(\alpha(-(\alpha+16)\eta+\alpha+24)+15\eta+39)\rho_G\right) \\
& + 32t^2\left(-109\eta-2(\alpha-1)(\alpha(\eta-1)+1)\rho_G^2+117\right) \\
& + 2t^4(\alpha(\alpha(\alpha(-(\alpha+7)\eta+\alpha+17)+37\eta-57)+183\eta-881)-340\eta+824) \\
& + 2t^4(\alpha(\alpha(\alpha(3\alpha(\eta-1)+10\eta-26)-22\eta-68)-138\eta+874)+115\eta+247)\rho_G \\
& + -4(\alpha-1)t^4\left(\alpha\left(\alpha^2+15\right)\eta-\alpha\left(\alpha^2+\alpha+87\right)+57\right)\rho_G^2 \\
& + 8t^3(\alpha(\alpha(2\alpha(\eta-1)-17\eta+19)-122\eta+268)-421) \\
& + 8t^3\left(313\eta+(\alpha(3\alpha(\alpha(-\eta)+\alpha+3\eta+1)+83\eta-221)-73\eta-169)\rho_G\right) \\
& + 16(\alpha-1)t^3(\alpha(8\eta-17)+13)\rho_G^2 \\
& - 2H\left(128(\eta+1)+\left(((\alpha-16)\alpha+31)(\alpha(\alpha+4)-1)t^4\right)\right)+1024H(1+\eta) \\
& + 2H\left(2t^3\left((\alpha+5)\left(\alpha^2+15\right)\eta-5\alpha^3+-37\alpha^2+181\alpha+21\right)-128(\eta+1)\right) \\
& + 2H\left(t\left(32(\alpha(\eta+3)+13\eta+11)-8t\left(\alpha^2(\eta-5)+8\alpha(\eta+5)+55\eta+37\right)\right)-128(\eta+1)\right) \\
& + 2H\left((\alpha-1)t\rho_G(t(t(12\alpha(\alpha+8)+\alpha((\alpha-14)\alpha-49)t+46t-140)+160-48\alpha)-64)\right) \\
& + 2H\left(4\eta t\rho_G\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)-256(\eta+1)\right),
\end{aligned}
$$

$$
\begin{aligned}
r_1 = & \; 4\left(\alpha^3t^4\left(\rho_G-1\right)^2-\alpha^4t^4\left(\rho_G-1\right)^2\right) \\
& + 4(3t-4)(5t-4)\left(t\rho_G(2H+t)+2\left(2H^2+Ht-8(t-1)^2\right)\right) \\
& + 4\alpha t^2\left(\rho_G-1\right)\left(\left(15t^2-32t+16\right)\rho_G+17t^2-32t+16\right) \\
& + 4\alpha^2t^2\left(4\left(-4\rho_G\left(\rho_G+2\right)+H^2+8\right)-3t^2\left(\rho_G\left(5\rho_G+11\right)-11\right)\right) \\
& + 8\alpha^2t^3\left(\rho_G\left(16\rho_G+H+32\right)+H-32\right),
\end{aligned}
$$

$$
\begin{aligned}
r_2 = & \; 2\left(\alpha^3t^4\left(\rho_G-1\right)^2-\alpha^4t^4\left(\rho_G-1\right)^2\right) \\
& + 2(3t-4)(5t-4)\left(t\rho_G(2H+t)+2\left(2H^2+Ht-8(t-1)^2\right)\right) \\
& + 2\alpha t^2\left(\rho_G-1\right)\left(\left(15t^2-32t+16\right)\rho_G+17t^2-32t+16\right) \\
& + 2\alpha^2t^2\left(4\left(H^2+8-4\rho_G\left(\rho_G+2\right)\right)-3t^2\left(\rho_G\left(5\rho_G+11\right)-11\right)\right) \\
& + 4\alpha^2t^3\left(\rho_G\left(16\rho_G+H+32\right)+H-32\right).
\end{aligned}
$$

$$
\begin{aligned}
S_2 &= 2H^2\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)(4\eta+\alpha t+t)-256(\eta-1)\\
&-t\left((\alpha-5)(\alpha((\alpha-11)\alpha-65)-21)t^4-32t(\alpha(\alpha(\eta-1)-14\eta+21)-47\eta+64)\right)\\
&-t\left(128(\alpha-(\alpha+8)\eta+9)+8t^2(\alpha(\alpha(\alpha+7)\eta-\alpha(\alpha+10)-65\eta+157)-119\eta+222)\right)\\
&-t^4\left(\alpha\left(\alpha\left((\alpha-12)(\alpha+2)\eta+24\alpha-\alpha^2+58\right)+202\eta-1016\right)+215\eta-729\right)\\
&-t\rho_G(t(4(\alpha(\alpha(3\alpha+4)-231)+176)t-16((\alpha-27)\alpha+30))-64(\alpha-2))\\
&-t^2\rho_G\left((140-\alpha(\alpha(\alpha(3\alpha-31)+25)+271))t^3+(\alpha(\alpha(\alpha(3\alpha-43)+25)+827)-492)t^2\right)\\
&-t\eta\rho_G((5-\alpha)t-4)\left((\alpha(\alpha(3\alpha-2)-19)+2)t^2-16\alpha+32\alpha t\right)\\
&+2(1+\alpha)(1-t)t^2\rho_G^2(16\alpha+t(-40\alpha+(\alpha((\alpha-6)\alpha+31)-10)t+8))\\
&+2(1-\alpha)\alpha\eta t^2\rho_G^2\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)\\
&+H\left(t\left(352-(\alpha(\alpha(\alpha(\alpha+10)-52)-106)+19)t^3\right)-128(\eta+1)\right)\\
&+Ht\left(416\eta-32\alpha(\eta+3)-2t^2\left((\alpha-5)\left(\alpha^2+15\right)\eta-5\alpha^3+45\alpha^2+149\alpha-61\right)\right)\\
&-8Ht^2(\alpha((\alpha-8)\eta-5\alpha-36)+55\eta+41)\\
&+(1+\alpha)Ht\rho_G((\alpha-4)t+4)\left((\alpha(\alpha+16)-1)t^2-16(\alpha+1)t+16\right)\\
&+4\eta Ht\rho_G\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right).
\end{aligned}
$$

Inserting these solutions into a_1^{BR} and a_2^{BR} leads to a_1^{BR*} and a_2^{BR*}. ■

Illustration of a_1^{BR*} and a_2^{BR*} in (47a) and (47b):

$$
a_1^{BR*}=\frac{y_1}{z},\qquad a_2^{BR*}=\frac{y_2}{z},\qquad \text{with}
$$

$$
\begin{aligned}
y_1 &= 2H\left(32(\eta+1)+\left(\alpha^3+6\alpha^2-25\alpha+2\right)t^3-16t(\alpha+4\eta+4)\right)\\
&+4Ht^2\left(\alpha^2(\eta-3)+20\alpha+15(\eta+1)\right)\\
&+((5-\alpha)t-4)\left(32(\eta+1)+\left(\alpha^3+6\alpha^2+11\alpha-6\right)t^3-8t((2\alpha+7)\eta+7)\right)\\
&+2t^2\left(\alpha^2(\eta-3)+\alpha(8\eta-6)+11\eta+15\right)((5-\alpha)t-4)\\
&+t\rho_G\left(32(\alpha(1-\eta)+\eta+3)+\left(2\alpha^4+3\alpha^2-108\alpha-25\right)t^3\right)\\
&+2(1-\alpha)Ht\rho_G\left(\left(\alpha^2+8\alpha-17\right)t^2-8(\alpha-4)t-16\right)\\
&-8t^2\left(2\alpha^2(\eta+1)+\alpha(17-11\eta)+9\eta+29\right)\rho_G\\
&+2t^3\left(\alpha^3(\eta-1)+\alpha^2(8\eta+6)+\alpha(107-29\eta)+20(\eta+4)\right)\rho_G\\
&+(1-\alpha)t^2\rho_G^2\left(\left(\alpha^3+27\alpha-20\right)t^2-16(1-\alpha)+(36-44\alpha)t\right),
\end{aligned}
$$

$$
\begin{aligned}
y_2 = &\left(64+4t^2\left(56-\alpha^2-9\alpha\right)\right)(\alpha t-2(1+\eta))\\
&-\left(t^3\left(80-4\alpha^2+\alpha^3-21\alpha\right)+16t(13-\alpha)\right)(\alpha t-2(1+\eta))\\
&+2H\left(32(1+\eta)-\left(8(1-\alpha^2)+\alpha^3-17\alpha\right)t^3\right)\\
&+2H\left(2t^2\left(19-\alpha^2(3-\eta)-16\alpha+15\eta\right)+16t(\alpha-4(1+\eta))\right)\\
&+2t\rho_G\left((1+\alpha)H\left(\left(\alpha^2-10\alpha-7\right)t^2+8(\alpha+3)t-16\right)\right)\\
&+2t\rho_G\left(\left(\alpha^4-3(\alpha^2+\alpha^3)+49\alpha-40\right)t^3\right)\\
&+2t\rho_G\left(16\alpha(\eta-1)+32-4t\left(2\alpha^2(1+\eta)+\alpha(9\eta-19)-\eta+25\right)\right)\\
&+2t^3\rho_G\left(\alpha^3(1-\eta)+\alpha^2(9\eta+11)+\alpha(21\eta-107)-5\eta+107\right)\\
&-(1+\alpha)t^2\rho_G^2\left(16\alpha+\left(\alpha^3-3\alpha^2+23\alpha-5\right)t^2+(4-36\alpha)t\right),
\end{aligned}
$$

$$
\begin{aligned}
z = &\left(32\alpha-64\alpha^2+992\right)t^3-\left(16\alpha-32\alpha^2+1520\right)t^2+1024t-256\\
&+4H^2\left(\left(\alpha^2+15\right)t^2-32t+16\right)+2Ht\left(\left(\alpha^2+15\right)t^2-32t+16\right)\\
&+\left(33\alpha^2+\alpha^3-\alpha^4-17\alpha-240\right)t^4+t^2\rho_G\left(32t\left(2\alpha^2-1\right)+16\right)\\
&+t\rho_G\left(2H\left(\left(\alpha^2+15\right)t^2-32t+16\right)+t\left(\left(2\alpha^4-2\alpha^3-33\alpha^2+2\alpha+15\right)t^2-32\alpha^2\right)\right)\\
&+(1-\alpha)\alpha t^2\rho_G^2\left(\left(\alpha^2+15\right)t^2-32t+16\right).
\end{aligned}
$$

Illustration of H' for $R_1^{B^*}=0$, H'' for $R_2^{B^*}=0$ and H''' for $a_2^{RB^*}=0$:

$$
H' = \frac{-\sqrt{a}+b}{c}, \text{ with}
$$

$$
a = a_1^2-4\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)((\alpha-1)t-4\eta)a_2,
$$

$$
\begin{aligned}
a_1 = &t\left(32((\alpha+13)\eta+3\alpha+11)+4g\eta\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)\right)\\
&+t\left((\alpha-1)g(t(-48\alpha+t(12\alpha(\alpha+8)+\alpha((\alpha-14)\alpha-49)t+46t-140)+160)-64)\right)\\
&-t\left((((\alpha-16)\alpha+31)(\alpha(\alpha+4)-1)t^3)\right)\\
&+t\left(2t^2\left(-5\alpha^3+(\alpha+5)\left(\alpha^2+15\right)\eta-37\alpha^2+181\alpha+21\right)\right)\\
&-t\left(8t(\alpha(\alpha(\eta-5)+8(\eta+5))+55\eta+37)\right)-128(\eta+1),
\end{aligned}
$$

$$
\begin{aligned}
a_2 =& t\left(128(2\alpha-17)(\eta-1)\right)\\
&+t\left((\alpha-1)g^2t\left(64(\alpha(\eta-1)+1)+(\alpha(\alpha(3\alpha+5)+141)-85)t^3\right)\right)\\
&+t\left((\alpha-1)g^2t\left(4t^2\left(\alpha\left(\alpha^2+15\right)\eta-\alpha\left(\alpha^2+\alpha+87\right)+57\right)-16t(8\alpha\eta-17\alpha+13)\right)\right)\\
&+tg\left(128(\alpha(-\eta)+\alpha+\eta+3)+(5-\alpha(\alpha(\alpha(4\alpha+31)+81)-623))t^4\right)\\
&+tg\left(2t^3(\alpha(\alpha(\alpha(-3\alpha\eta+3\alpha-10\eta+26)+22\eta+68)+46(3\eta-19))-115\eta-247)\right)\\
&+tg\left(8t^2(\alpha(3(\alpha-3)\alpha\eta-3\alpha(\alpha+1)-83\eta+221)+73\eta+169)\right)\\
&+tg\left(32t((\alpha(\alpha+16)-15)\eta-\alpha(\alpha+24)-39)\right)\\
&+t\left((\alpha-5)(\alpha(\alpha+5)(\alpha+19)-72)t^4\right)\\
&+t\left(2t^3(\alpha(\alpha(\alpha(\alpha+7)\eta-\alpha(\alpha+17)-37\eta+57)-183\eta+881)+340\eta-824)\right)\\
&-t\left(8t^2(\alpha(\alpha(2\alpha(\eta-1)-17\eta+19)-122\eta+268)+313\eta-421)\right)\\
&-t\left(32t(\alpha(2\alpha(\eta-1)+27\eta-37)-109\eta+117)\right)+512(\eta-1),
\end{aligned}
$$

$$
\begin{aligned}
b =& t^4((\alpha-1)(\alpha((\alpha-14)\alpha-49)+46)g-((\alpha-16)\alpha+31)(\alpha(\alpha+4)-1))\\
&+2t^3\left(-5\alpha^3+(\alpha+5)\left(\alpha^2+15\right)\eta-37\alpha^2+181\alpha\right)\\
&+2t^3\left(2g(\alpha(\alpha(3\alpha+\eta+21)-59)+5(3\eta+7))+21\right)\\
&-8t^2\left(\alpha^2(\eta-5)+8\alpha(\eta+5)+2g(\alpha(3\alpha-13)+8\eta+10)+55\eta+37\right)\\
&+32t(\alpha(\eta+3)+2g(-\alpha+\eta+1)+13\eta+11)-128(\eta+1),
\end{aligned}
$$

$$
c = 4\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)((\alpha-1)t-4\eta).
$$

$$
H'' = \frac{\sqrt{d}+e}{f}, \text{ with}
$$

$$
f = 4\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)(4\eta+\alpha t+t),
$$

$$
d = 8\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)(4\eta+\alpha t+t)d_1+d_2^2,
$$

$$
\begin{aligned}
d_1 =& t\left(128(-(\alpha+8)\eta+\alpha+9)\right)\\
&+2g^2t^2\left((\alpha-1)\alpha\eta\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)\right)\\
&+2g^2t^2\left((\alpha+1)(t-1)(16\alpha+t(-40\alpha+(\alpha((\alpha-6)\alpha+31)-10)t+8))\right)\\
&+gt\left(-64(\alpha-2)-\eta((\alpha-5)t+4)\left(-16\alpha+(\alpha(\alpha(3\alpha-2)-19)+2)t^2+32\alpha t\right)\right)\\
&+gt^2\left(-16((\alpha-27)\alpha+30)+(140-\alpha(\alpha(\alpha(3\alpha-31)+25)+271))t^3\right)\\
&+gt^2\left((\alpha(\alpha(\alpha(3\alpha-43)+25)+827)-492)t^2+4(\alpha(\alpha(3\alpha+4)-231)+176)t\right)\\
&+t\left((\alpha-5)(\alpha((\alpha-11)\alpha-65)-21)t^4\right)\\
&+t\left(t^3\left(\alpha\left(\alpha\left(-\alpha^2+(\alpha-12)(\alpha+2)\eta+24\alpha+58\right)+202\eta-1016\right)+215\eta-729\right)\right)\\
&+t\left(8t^2(\alpha(\alpha(\alpha+7)\eta-\alpha(\alpha+10)-65\eta+157)-119\eta+222)\right)\\
&+t\left(-32t(\alpha((\alpha-14)\eta-\alpha+21)-47\eta+64)\right)+256(\eta-1),
\end{aligned}
$$

$$
\begin{aligned}
d_2 =& t\left(-32\alpha(\eta+3)+(\alpha+1)g((\alpha-4)t+4)\left((\alpha(\alpha+16)-1)t^2-16(\alpha+1)t+16\right)\right)\\
&+t\left(4g\eta\left(t\left(\left(\alpha^2+15\right)t-32\right)+16\right)+416\eta\right)\\
&+t\left(-\left((\alpha(\alpha(\alpha(\alpha+10)-52)-106)+19)t^3\right)\right)\\
&+t\left(-2t^2\left(-5\alpha^3+(\alpha-5)\left(\alpha^2+15\right)\eta+45\alpha^2+149\alpha-61\right)\right)\\
&+t\left(-8t(\alpha((\alpha-8)\eta-5\alpha-36)+55\eta+41)+352\right)-128(\eta+1),
\end{aligned}
$$

$$
\begin{aligned}
e =& t^4(\alpha(\alpha(\alpha(\alpha+10)-52)-106)+(\alpha-4)(\alpha+1)(\alpha(\alpha+16)-1)(-g)+19)\\
&+2t^3\left(-5\alpha^3+45\alpha^2+149\alpha+6\alpha^3g+\left(\alpha^2+15\right)\eta(\alpha-2g-5)\right)\\
&+2t^3\left(-50\alpha^2g-86\alpha g-30g-61\right)\\
&+8t^2\left(\alpha((\alpha-8)\eta-5\alpha-36)+2g\left(3\alpha^2+11\alpha+8\eta+8\right)+55\eta+41\right)\\
&-32t(-\alpha(\eta+3)+2g(\alpha+\eta+1)+13\eta+11)+128(\eta+1).
\end{aligned}
$$

$$
\begin{aligned}
H''' =& \frac{t^4\left((\alpha-5)\alpha\left(\alpha^2+\alpha-16\right)+(\alpha+1)(\alpha((\alpha-3)\alpha+23)-5)g^2\right)}{b}\\
&+\frac{t^4\left((80-2\alpha(\alpha((\alpha-3)\alpha-3)+49))g\right)}{b}\\
&+\frac{2t^3\left(\alpha(\alpha(\alpha(-\eta)+\alpha+4\eta+22)+21\eta-91)-2(\alpha+1)(9\alpha-1)g^2\right)}{b}\\
&+\frac{2t^3\left(g(\alpha((\alpha-9)\alpha\eta-\alpha(\alpha+11)-21\eta+107)+5\eta-107)-80(\eta+1)\right)}{b}\\
&+\frac{8t^2\left(-\alpha((\alpha+9)\eta+3\alpha-17)+2\alpha(\alpha+1)g^2\right)}{b}\\
&+\frac{8t^2\left(g(\alpha(2\alpha(\eta+1)+9\eta-19)-\eta+25)+56(\eta+1)\right)}{b}\\
&-\frac{32t(\alpha(-\eta)+\alpha+g(\alpha(\eta-1)+2)+13\eta+13)}{b}+\frac{128(\eta+1)}{b},
\end{aligned}
$$

with $b = 2t\left(16(\alpha-4(\eta+1))+(\alpha+1)g\left(((\alpha-10)\alpha-7)t^2+8(\alpha+3)t-16\right)\right)$
$+ 2t\left(t(2\alpha(\alpha(\eta-3)-16)+30\eta+(\alpha((\alpha-8)\alpha-17)+8)(-t)+38)\right)+64(\eta+1).$

Proof of Proposition 4:

Since both voluntary turnover rates a_1^{BR*} and a_2^{BR} have the same denominator, we just consider their numerators y_1 and y_2 in this proof. If the difference $y_1 - y_2$ is positive, the numerator of a_1^{BR*} exceeds the one of a_2^{BR*}, and thus, the whole term of a_1^{BR*} exceeds the one of a_2^{BR*}.

$$\begin{aligned} y_1 - y_2 =& t\,(\rho_G - 1)\,(t\,(5-\alpha)-4)\cdot \\ &\Big(t^2\,(6-\alpha\,(27+5\,\alpha)) - 8\,(1+2\,\alpha\,(1+H-\eta)+\eta) \\ &+ 2\,t\,\big(1+2\,H\,(\alpha\,(4+\alpha)-1)+5\,\eta+\alpha\,(21+2\,\alpha\,(1-\eta)-9\,\eta)\big) \\ &+ t\,(4-12\,\alpha+t\,\rho_G\,(\alpha\,(12+\alpha)-5))\Big), \end{aligned}$$

$\Delta y = y_1 - y_2 > 0$ with our usual parameter assumptions, i.e. $0 < \alpha \leq 1$, $0 < t \leq \frac{2}{3}\,, 0 \leq \eta \leq 1-t\,, H > \eta\,, 1 < \rho_G \leq \frac{2-t}{t}$. By using these assumptions (which as necessary to ensure turnover rates between zero and one), $\Delta y = 0$ or $\Delta y < 0$ and thus, $a_1^{BR*} = a_2^{BR}$ or $a_1^{BR*} < a_2^{BR}$ cannot result. This confirms our result in Proposition 4, i.e. $a_1^{BR*} > a_2^{BR}$. ■

Proof of Proposition 5:

The critical values H' and H'' are illustrated above and ensure that $R_1^{B^*}$ and $R_2^{B^*}$ that are also illustrated above are positive for $H > H'$ and $H > H''$.

For the proof of the second part of the proposition, we focus on equations (47a) and (47b). If the terms added to the optimal efforts without retention bonus are both negative, the optimal efforts with retention bonus are lower than the ones without a retention bonus. The denominators of both terms are the same and positive for our parameter restrictions. The nominator of the term in (47a) is positive if the following condition holds:

$$\begin{aligned} & t(1-\alpha)R_2^{B^*} - 4(1-t)R_1^{B^*} > 0 \\ \leftrightarrow\ & \frac{t(1-\alpha)}{4(1-t)}R_2^{B^*} < R_1^{B^*}. \end{aligned}$$

The nominator of the term in (47b) is positive if the following condition holds:

$$t(1+\alpha)R_1^{B^*} - 4(1-t)R_2^{B^*} > 0$$
$$\leftrightarrow \; R_1^{B^*} < \frac{4(1-t)}{t(1+\alpha)} R_2^{B^*}.$$

Hence, overall the proposition holds for

$$\frac{t(1-\alpha)}{4(1-t)} R_2^{B^*} < R_1^{B^*} < \frac{4(1-t)}{t(1+\alpha)} R_2^{B^*}.$$

■

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