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Nana Adrian, Marc Möller

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CH-3012 Bern, Switzerland
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Partnerships with Asymmetric Information: The Benefit of Sharing Equally amongst Unequals

Nana Adrian* Marc Möller†

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Abstract

This paper provides a rationale for equal sharing in heterogeneous partnerships. We introduce project choice and information sharing to a standard team production setting. A team with two agents can choose whether they want to work on a status quo project or on an alternative project. If the (expected) quality of the projects is given and common knowledge, it is optimal for team surplus to give a higher share to the more productive agent in order to optimally motivate. If agents have private information, we have to give the higher share of profits to the less productive agent if we want agents to share this information, which would allow for better adaptation. Equal revenue-sharing strikes a balance between the two objectives of adaptation and motivation and can be efficient even in the presence of considerable productivity differences across partners.

JEL *classification*: D2; D8; L2

Keywords: Team adaptation, effort motivation, information disclosure.

*Department of Economics, University of Bern. E-mail: nana.adrian@vwi.unibe.ch

†Department of Economics, University of Bern. E-mail: marc.moeller@vwi.unibe.ch

1 Introduction

Evidence shows that teams are often organized as partnerships, i.e. team members work together on a project and share the revenue. Partnerships can for example be found in service professions (Hansmann, 1996) as law firms (Leibowitz and Tollison, 1980), medical practices (Encinosa et al., 2007), architecture firms and accounting firms (Greenwood and Empson, 2003).

If the partners share the revenue, free-riding leads to inefficiently low effort provision since each partner only considers his own share of revenue. Experimental evidence for such free-riding can be found in Nalbantian and Schotter (1997) and Chao and Croson (2013). In case of heterogeneous partners, this free-riding problem can be mitigated by giving higher shares to more productive partners. This result is quite robust and also holds if partners differ in ability and self-select (McAfee and McMillan, 1991) or when production is of repeated nature (Rayo, 2007; Kobayashi et al., 2016).

However, we often observe equal revenue sharing even in partnerships in which we would expect heterogeneity.[1] Encinosa et al. (2007) find that 54% of small medical-group practices (3 to 5 members) share equally. In larger practices (16 to 24 members), equal sharing still plays an important role (24%). Farrell and Scotchmer (1988) find equal shares among partners of similar seniority in law firms and argue that for example marriage and coauthorship in economics are close to equal sharing.[2]

Such equal sharing in partnerships can be rationalized e.g. by preferences for equality (Bartling and von Siemens, 2010; Gill and Stone, 2015), concerns for sabotage (Bose et al., 2010) or market reputation and moral hazard (Jeon, 1996). Farrell and Scotchmer (1988) argue that equal sharing is a social convention and people want to satisfy some concept of justice. However, evidence suggests that it might actually be teamwork that leads to preferences for equal sharing in the first place (Hamann et al., 2011). Furthermore, discussions about how revenue should be shared, if not equally, could give rise to inefficient rent-seeking.

We show in this paper that in a standard team production setting à la Holmström (1982) with project quality and effort being complementary in-

[1] Prat (2002) provides arguments in favor of heterogeneity in a team theory setting à la Marschak and Radner (1972).

[2] Ray and Robson (2018) suggest to randomize the order of the names in economic coauthorship, which is a further step towards equal sharing.

puts, equal sharing can be optimal for heterogeneous agents if we introduce team project choice and asymmetric information about projects' qualities. The changes we incorporate in the standard model can be justified by observations in reality. In partnerships, agents do often not only work together but also decide which project they want to work on. This seems natural when considering firms or countries working together. Within organizations, the share of self-managed teams has increased in recent years (Lazear and Shaw, 2007; Osterman, 2000; Manz and Sims Jr, 1993).

Consider for example a team that is organizing an event and wants to book a newcomer band. The band's quality is uncertain but the team expects it to be better, and hence attract more people, than the alternative of a well-known local artist. However, one of the partners in the organizing team might get "bad news" about the quality, as e.g. that the last concert of the band was a flop. If he reveals this information to the team, they can adapt to the alternative, which is known to have higher quality in the presence of such "bad news".

The possibility to disclose information and the project choice introduce a trade-off between improving adaptation and motivating effort. The disclosure of information allows the team to choose a better project. However, it also demotivates the partners if the information is "bad news". In order to study this trade-off, we use a similar model of team production as Blanes i Vidal and Möller (2016). We consider a team which consists of two agents. They can jointly choose between two projects. Before they decide on a project, one of them might receive private information about the quality of the projects. Information is private but verifiable, so an informed agent can credibly disclose the news to his partner. When an informed agent decides whether to disclose, he compares the benefit from better adaptation to a potential loss of his partner's motivation. A loss of motivation can occur if the news is bad in the sense that the partner's expectation about quality was higher without information. Since the informed agent only takes into account his own share of revenue, his disclosure strategy might not be optimal for team surplus. By carefully choosing the revenue sharing rule, we do not only affect motivation but also whether agents disclose their information. While Blanes i Vidal and Möller (2016) find the optimal mechanism for homogeneous agents, we consider heterogeneous agents and restrict attention to the case in which shares are independent of revenue and disclosure strategies.

In the benchmark of project selection with symmetric information, the expected surplus of the team is maximized if the more productive agent receives a higher share. The percentage loss in surplus if shares are equal rather than optimal can be substantial, up to 25%.

If we introduce asymmetric information, we have to take into account the impact of the revenue sharing rule not only on the effort but also on whether agents disclose private information. Given the optimal sharing rule in the benchmark case, the less productive agent is less willing to disclose because the reaction of the more productive agent on changes in expected quality is stronger. Increasing the share of the less productive agent and thereby decreasing the share of the more productive agent reduces this reaction and thus makes it more likely that the less productive agent is willing to disclose. It turns out that the propensity to share information in the team is maximized if the shares are just opposite to the shares in the benchmark with symmetric information: The less productive agent needs a higher share while the more productive agent gets a lower share. Compared to the optimal sharing rule with symmetric information, giving a higher share to the less productive agent can increase surplus since better information sharing leads to better adaptation.

Our main result characterizes the optimal sharing rule in situations in which full disclosure is feasible. The optimal sharing rule balances incentives to disclose information and incentives to provide effort and thus lies between the optimal information sharing rule and the optimal sharing rule given symmetric information. Hence, the optimal sharing rule is torn towards equal shares and it turns out that there exist situations in which sharing equally amongst unequals is optimal for the partnership even in the presence of considerable heterogeneity. Where we can determine the optimal sharing rule, the percentage loss in surplus due to equal sharing is weakly lower than in the benchmark case.

The rest of the paper is structured as follows. Section 2 reviews the literature on equal sharing and information problems in teams. Section 3 sets up the model of team production with project choice. In Section 4, we consider the benchmark of symmetric information. In Section 5, we introduce asymmetric information and consider the effect of the sharing rule on disclosure strategies. In Section 6, we characterize the optimal sharing rule and discuss the optimality of equal sharing. Section 7 examines the robustness of the model and Section 8 concludes.

2 Literature

In partnerships, the problem of free-riding can be mitigated by carefully designing the sharing rule (Legros and Matthews, 1993). There are several papers providing arguments against equal sharing. If a partnership forms endogenously, equal revenue sharing leads to partnerships that are too small (Farrell and Scotchmer, 1988) and not diverse enough (Sherstyuk, 1998). Wilson (1968) shows that equal sharing is not optimal when agents are heterogeneous in risk preferences. Kräkel and Steiner (2001) adapt the LEN framework of the standard principal-agent model to partnerships. They show that equal sharing is not optimal even if agents are homogeneous. While equal sharing would induce optimal risk-sharing, optimal motivation pushes the shares towards giving each agent his own profit. Balancing risk-sharing and motivation, they find that the optimal shares lie between equal sharing and no sharing (keeping the own profits). Equal sharing would only be optimal in the extreme case of variance or risk aversion going to infinity. Similarly, Winter (2004) shows that equal sharing is typically not optimal even for homogeneous agents in the presence of complementarities in efforts and asymmetric information about efforts.

Nevertheless, as mentioned in the introduction, we often observe equal sharing in reality and equal shares are assumed in many papers considering partnerships (e.g. Huck and Rey-Biel, 2006; Farrell and Scotchmer, 1988; Levin and Tadelis, 2005). The authors typically argue that equal shares are a social convention or there is a social preference of agents (Farrell and Scotchmer, 1988). Theoretically, it has been shown that equal shares can be optimal in order to foreclose sabotage (Bose et al., 2010) or if there are market reputation and moral hazard (Jeon, 1996). Bose et al. (2010) show that agents would sabotage each other if the principal cannot commit to a reward structure ex-ante. Hence, the possibility to commit to equal shares could be beneficial for the principal because agents would not sabotage each other. They argue that equal sharing is the only distribution to which the principal could commit since this commitment is facilitated by legal obligations. Bevia and Corchón (2006) also find that sabotage is rational in cooperative production when revenue is shared among the agents. Even though a saboteur suffers from lower revenue, he benefits from a better relative standing. Such sabotage is more likely under meritocratic systems than under equal sharing. Jeon (1996) consider a model with two periods in which the effort in the first period signals higher ability and thus increases the wage in the second period. It turns out that when the sharing arrangement is such that revenue from abilities is shared, equal sharing is efficient. Furthermore, social preferences as inequality aversion, make equal shares more attractive. Bartling and von Siemens (2010) show that if agents are sufficiently inequality averse, equal shares are the only renegotiation proof option. We provide an argument in favor of equal sharing in a simple team setting.

In our model, we find a force driving in the direction of equal shares when introducing asymmetric information and project selection. Information is private but can be shared with the partners. We thus also relate to the literature on teams and information sharing. In this literature, information sharing would typically be optimal for surplus but teams fail to share information because of conflicting preferences (Li et al., 2001; Dessein, 2007), career concerns (Ottaviani and Sørensen, 2001; Levy, 2007; Visser and Swank, 2007) or distortions by voting rules (Feddersen and Pesendorfer, 1996). In some settings, however, restricting information about the quality of a project is beneficial because it mitigates the free-riding problem in team production. In Teoh (1997), the social planner can restrict access to information ex-ante in a public goods game. This is optimal if "bad news" decrease contributions more than "good news" would increase them. Hermalin (1998) only informs one agent who can then exert effort first. The possibility of leading by example increases the informed agent's effort above the optimal free-riding effort. Similarly, in our paper, full information sharing is not necessarily optimal. It has the positive effect of better adaptation and the negative effect of demotivating team members. Agents possibly fail to share information because it can be optimal to keep the other agent motivated, rather than realistic.

This trade-off between adaptation and motivation is considered in some other papers. Banal-Estañol and Seldeslachts (2011) study merger decisions and the incentives to free-ride on a partner's post-merger decision. Zábojník (2002), Blanes i Vidal and Möller (2007), and Landier et al. (2009) consider the trade-off in settings in which decision making and execution of effort lie at different hierarchical levels. Zábojník (2002) shows that in case of liquidity constraints and thus limited punishment possibilities, it might be optimal to delegate the decision to the worker in order to keep his motivation high. Landier et al. (2009) find that dissent in the preferences of the decision maker and the implementer can be beneficial since it implies a better use of information. This results in better adaptation and higher credibility of the decision maker but also demotivates the implementer. Blanes i Vidal and Möller (2007) ask whether a worker should get hard information given a leader has additional soft information. Giving a worker hard information might induce the leader to give a too high weight to this hard information in order to avoid demotivating the worker. These studies consider decision making and implementation at different hierarchical levels. We contribute to this literature by considering agents who take decisions and implement projects jointly.

Similarly, Guo and Roesler (2016) consider the trade-off between adaptation and motivation in a dynamic setting with two agents working together on a project. Agents' efforts increase the success probability of the project. While working on the project, an agent might receive private information about the success probability. He can then either exit the project and thereby disclose his information or he can stick to the project and shirk on the other agent's effort. However, Guo and Roesler (2016) consider homogeneous agents who share equally and focus on the effort and exit decisions in equilibrium.

Campbell et al. (2014) and Gershkov and Szentes (2009) also consider teams with private information and group members who may not share their information in order to manipulate beliefs about the marginal return of effort. Their settings differ from ours since their agents provide effort in order to acquire information rather than for the implementation of a joint project.

Our paper adds information sharing in the same way as Blanes i Vidal and Möller (2016). They introduce asymmetric information about the production technology and information sharing into a model of team production. They use a mechanism design approach and consider homogeneous agents. But team members, whether they are different firms or different workers, are often heterogeneous. Given heterogeneous agents, we restrict attention to partnerships, i.e. team members share the revenue of the project.

Gershkov et al. (2016) take a similar approach when introducing asymmetric information in a team production setting with moral hazard. However, they assume that revenue distribution can depend on a signal about the ranking of efforts. They find a simple rank-based contract which can implement first best information sharing and first best efforts given homogeneous agents in many situations. With heterogeneous agents, first best is possible if private information is given to one agent only. Without the ranking of efforts, we find that there is no revenue distribution which implements first best information sharing and effort choices. In order to minimize free-riding, we would want to give a higher share to more productive agents. However, the need to incentivize information sharing promotes giving a higher share to less productive agents.

Our result thus provides a rationale for why sometimes equal shares could be preferred given heterogeneous agents: If transfers cannot depend on the disclosure strategy, information sharing has to be incentivized by the choice of the shares. Since equal shares always lie between the optimal shares given symmetric information and the optimal shares for information sharing, trying to balance the incentives to provide effort and to share information leads us in the direction of equal shares.

3 Model

Consider a team that consists of two agents $i = L, H$, who work on a joint project X. The revenue of the project depends on whether it is successful or not. A successful project yields revenue 1 while a failed project generates no revenue. The probability of success of a project depends on the efforts of the agents, e_L and e_H, on the productivities of their effort, γ_L and γ_H, and on the quality of the project, which, with slight abuse of notation, we also denote as X:

$$R_X(e_L, e_H) = (e_L\gamma_L + e_H\gamma_H)X. \tag{1}$$

Since revenue in case of success is equal to 1, $R_X(e_L, e_H)$ is equivalent to the expected revenue of a project X. Agents are heterogeneous in the sense that the effort of agent H is more productive $\gamma_L < \gamma_H \leq 1$. If the project is successful, the revenue is shared between the two agents according to the sharing rule $\boldsymbol{\alpha} = (\alpha_L, \alpha_H)$ with $\alpha_L + \alpha_H = 1$.[3] Effort is not contractible. Effort costs $C(e_i)$ are increasing at an increasing rate for both agents $i = L, H$:

$$C(e_i) = \frac{1}{2} e_i^2. \tag{2}$$

Hence, agents differ only in their effort productivity.[4] Agents choose effort in order to maximize their expected utility, which consists of their share of the expected revenue minus their costs of effort:

$$U_i = \alpha_i R_X(e_L, e_H) - C(e_i), \qquad i = L, H. \tag{3}$$

Total expected surplus of a project with quality X is the sum of agents' expected utilities. It is thus the total expected revenue of the project, reduced by the costs of effort of the two team members:

$$S_X(e_L, e_H) = R_X(e_L, e_H) - C(e_L) - C(e_H). \tag{4}$$

Efficiency would require that marginal revenue equals marginal cost for each agent $i = L, H$:

$$R'_{e_i}(e_L, e_H) = C'(e_i). \tag{5}$$

It is, however, a standard result that team production leads to inefficient effort provision (Holmström, 1982). To see this, consider the first order condition of an agent's utility maximization problem:

$$\alpha_i R'_{e_i}(e_L, e_H) = C'(e_i). \tag{6}$$

Since $\alpha_i \leq 1$ with strict inequality for at least one of the agents, marginal cost must remain at a lower level than efficient. At least one of the agents will thus choose an inefficiently low effort. They only take into account their own share of the revenue and ignore the impact of their effort on their

[3] Since revenue is always either 0 or 1, the sharing rule cannot depend on revenue. Another argument for the sharing rule being independent of revenue would be that team revenue is not verifiable by a third party. Furthermore, the sharing rule cannot depend on the probability of success, since it cannot be observed. Such linear contracts are "particularly suitable for organizations in which individual goals coincide: partnerships, political parties, NGOs." (Blanes i Vidal and Möller, 2007)

[4] The model is equivalent to a model in which agents have equal effort productivity but differ in their costs with $C(e_i) = \frac{1}{2\gamma_i^2} e_i^2$.

partner's utility. Given the specific functions for effort costs and revenue, agents $i = L, H$ choose efforts which maximize their utility:

$$e_i^* = \alpha_i \gamma_i \hat{E}_i[X], \quad (7)$$

where $\hat{E}_i[X]$ is agent i's expectation of quality X.

We consider the situation of a team working on a status quo project Q which can have either low quality $Q = q$ or high quality $Q = 1 > q$. It is common knowledge that the states are equally likely ex-ante and hence the ex-ante expected quality is $E[Q] = \frac{1+q}{2}$. Conditional on the quality of the status quo project Q being low, one of the agents will receive private and verifiable information.[5] Since information is verifiable, the informed agent can choose to disclose this new information to his partner. After the decision of disclosing potential evidence, the team chooses whether to stick to the status quo project Q or whether to switch to an alternative project P with quality P.[6] We abstract from a specific voting procedure and use the rule that the team switches to alternative P if and only if evidence was disclosed. We show at the end of Section 5.3 that this rule can be rationalized as the outcome of an arbitrary voting procedure.

We assume that project Q has a higher ex-ante expected quality than project P. However, project P would be preferred to project Q if project Q is known to be of low quality.

Assumption 1 (Status quo vs. alternative project)**.** $P \in (q, E[Q])$.

This assumption brings us to the interesting case in which project Q is preferred ex-ante and project P would be preferred in case of evidence for the low quality of project Q. It would thus be beneficial for the team to adopt project P in case of receiving evidence. Note that for all relevant expectations $q \leq \hat{E}_i[X] \leq 1$, optimal efforts are such that the probability of success $R_X(e_L, e_H)$ is well defined in $[0, 1]$.

To summarize, the timing is as follows: First, nature decides whether the quality of project Q is high or low. If quality is low, there is evidence which

[5]The assumption that there is information only if the quality of project Q is low simplifies the analysis but is not crucial for the result that optimal information sharing requires giving a higher share to the less productive agent. Similarly, allowing that both or none of the agents receives information does not change this result. We will discuss this in Section 7.1.

[6]If there was uncertainty about the quality of project P, the analysis would be analogous, with P replaced by $E[P]$.

is observed by one of the agents. Second, an informed agent can decide whether to disclose the information to his partner. Third, agents jointly choose whether to switch to project P and forth, each agent contributes with effort to the success of the chosen project. Finally, nature determines whether the project is successful, in which case the revenue is shared among the agents according to the sharing rule $\boldsymbol{\alpha}$.

We assume that the sharing rule is independent of the choice of the project $X \in \{Q, P\}$ and of the disclosure history $D \in \{0, L, H\}$.

Assumption 2 (Simple revenue sharing)**.** $\boldsymbol{\alpha}(X, D)$ *is independent of* $X \in \{Q, P\}$ *and* $D \in \{0, L, H\}$.

Rewarding the disclosure of information would provide incentives to disclose information (Blanes i Vidal and Möller, 2016). However, we focus on the problem of a social planner when he has to incentivize efforts and disclosure with a simple revenue sharing rule.

We use the equilibrium concept of Perfect Bayesian Equilibrium, i.e. beliefs are consistent given strategies on the equilibrium path and strategies are sequentially rational given beliefs.

4 Benchmark: Symmetric information

As a benchmark, consider the situation of symmetric information: If the quality of project Q is low, both agents receive evidence. The disclosure strategies are thus irrelevant in this benchmark case. Agents will agree to choose the project with the higher expected quality. Therefore, they stick to the status quo project Q if there is no evidence and change to the alternative project P else. Total expected surplus in this situation is

$$E^{sym}[S(\boldsymbol{\alpha})] = \frac{1}{2}S_1(e_L^*(1), e_H^*(1)) + \frac{1}{2}S_P(e_L^*(P), e_H^*(P)). \tag{8}$$

Maximizing expected surplus (8) given individually optimal effort choices, we find the optimal shares α_L^{sym} and α_H^{sym} and characterize them in Proposition 1:

Proposition 1 (Optimal shares with symmetric information)**.** *In the symmetric information benchmark, the surplus-maximizing shares are*

$$\alpha_L^{sym} = \frac{\gamma_L^2}{\gamma_L^2 + \gamma_H^2} \quad \text{and} \quad \alpha_H^{sym} = \frac{\gamma_H^2}{\gamma_L^2 + \gamma_H^2}. \tag{9}$$

The more productive agent receives a higher share $\alpha_H^{sym} > \frac{1}{2}$.

The proof can be found in the Appendix. In the situation of moral hazard and symmetric information, it is surplus-maximizing to give a higher share to the more productive agent H than to the less productive agent L, since the team benefits more from agent H's effort. This implies that it is optimal to let the more productive agent work harder. He works harder not only because his effort is more productive but also because he gets more than half of the project's revenue.

As argued in the Introduction, we often observe equal sharing $\boldsymbol{\alpha}^{equal} \equiv (\frac{1}{2}, \frac{1}{2})$ even in the presence of different productivities. In our setting with symmetric information, equal sharing leads to a loss in surplus relative to the optimal shares $\boldsymbol{\alpha}^{sym}$:

$$\Delta E^{sym}[S] = \frac{E^{sym}[S(\boldsymbol{\alpha}^{sym})] - E^{sym}[S(\boldsymbol{\alpha}^{equal})]}{E^{sym}[S(\boldsymbol{\alpha}^{sym})]} = \frac{(\gamma_H^2 - \gamma_L^2)^2}{4(\gamma_H^4 + \gamma_H^2\gamma_L^2 + \gamma_L^4)} > 0. \tag{10}$$

The percentage loss in surplus increases in the heterogeneity of agents, i.e. it increases in γ_H and decreases in γ_L. It can amount to 25% for $\gamma_L \to 0$ and $\gamma_H \to 1$.

5 Information sharing

We now consider the case when, conditional on quality of project Q being low, only one of the agents receives evidence. Hence, the disclosure strategies of agents become relevant. In this section, we first determine the optimal revenue shares given disclosure strategies. Then, we show how the individually optimal disclosure strategies depend on the revenue sharing rule and find the sharing rule that optimizes information sharing in the sense that the propensity of full disclosure is maximized. Finally, we characterize the surplus-maximizing sharing rule under the constraint of full disclosure.

5.1 Optimal sharing given disclosure strategies

We showed before that with symmetric information, it would be optimal to reduce free-riding with the distribution $\boldsymbol{\alpha}^{sym}$. It turns out that the same distribution is optimal if there is asymmetric information and both agents choose the same disclosure strategy $d_L = d_H$.

Given project X, agents choose their efforts to maximize utility, i.e. according to (7). The effort of agent i depends on his expectation about the quality of the project. Since agents might have asymmetric information, their expectations about the quality of project Q may differ. An informed agent knows that the quality of project Q is low. Whenever an agent i remains uninformed, he updates his belief about the quality of project Q. He knows that with ex-ante probability $\frac{1}{2}$, quality is high and both agents remained uninformed. However, with ex-ante probability $\frac{1}{2}$, quality is low and the other agent was informed but conceals this information. The uninformed agent i updates his belief on whether project Q has high quality to

$$\rho_i = \frac{\frac{1}{2}}{\frac{1}{4}(1-d_j)+\frac{1}{2}} = \frac{2}{3-d_j} \geq \frac{1}{2}, \tag{11}$$

where $d_j \in [0,1]$ is the (equilibrium) probability that the other agent j discloses information given he receives evidence. Receiving no evidence and no information of the other agent increases the belief that project Q has high quality. Given the updated belief, agent i expects the quality of project Q to be

$$\hat{E}_i[Q] = \frac{1-d_j}{3-d_j}q + \frac{2}{3-d_j}. \tag{12}$$

The expected quality of project Q with updated beliefs is higher than its ex-ante expected quality since a higher weight is given to the high quality state. Since the quality of project P is not affected by the information, project Q is now even more attractive than ex-ante.

Taking the disclosure strategies d_L and d_H as given, the ex-ante expected surplus must take into account several cases. With probability $\frac{1}{4}$ the quality of project Q is low and agent i gets information. If agent i receives information, he discloses it with probability d_i to his uninformed partner j. Project P is then chosen and both agents know the quality of the project. With probability $(1-d_i)$, the informed agent does not disclose, so project Q is chosen. While the informed agent i knows that the quality of the project is low, the uninformed agent j updates beliefs to $\hat{E}_j[Q]$. Finally, with probability $\frac{1}{2}$, the quality of project Q is high, agents are not informed and will both update beliefs. The choice of project Q is optimal in this case. Considering all these cases, the ex-ante expected surplus is

$$\begin{aligned} E[S(\boldsymbol{\alpha}, d_L, d_H)] = & \\ & \frac{1}{4}[d_L S_P(e_L^*(P), e_H^*(P)) + (1-d_L)S_q(e_L^*(q), e_H^*(\hat{E}_H[Q]))] \\ & + \frac{1}{4}[d_H S_P(e_L^*(P), e_H^*(P)) + (1-d_H)S_q(e_L^*(\hat{E}_L[Q]), e_H^*(q))] \\ & + \frac{1}{2} S_1(e_L^*(\hat{E}_L[Q]), e_H^*(\hat{E}_H[Q])). \end{aligned} \tag{13}$$

This surplus is maximized by the sharing rule $\boldsymbol{\alpha}^*(d_L, d_H)$, characterized in Proposition 2.

Proposition 2 (Optimal sharing given disclosure strategies)**.** *The surplus-maximizing sharing rule given disclosure strategies d_L and d_H is*

$$\alpha_L^*(d_L, d_H) = \frac{\gamma_L^2 \hat{q}_L}{\gamma_L^2 \hat{q}_L + \gamma_H^2 \hat{q}_H} \quad \textit{and} \quad \alpha_H^*(d_L, d_H) = \frac{\gamma_H^2 \hat{q}_H}{\gamma_H^2 \hat{q}_H + \gamma_L^2 \hat{q}_L}, \tag{14}$$

with

$$\hat{q}_i = \frac{1}{4}\left\{(d_i + d_{-i})P^2 + (1-d_i)q^2 + [(1-d_{-i})q + 2]\hat{E}_i[Q]\right\}, \quad i = L, H. \tag{15}$$

The less productive agent receives a higher share if and only if heterogeneity is not too strong $\gamma_L^2 \geq \gamma_H^2 \frac{\hat{q}_H}{\hat{q}_L}$.

The proof is in the Appendix. For given disclosure strategies d_H and d_L, we can determine the optimal distribution of revenue. Whenever both agents choose the same disclosure strategy $d_H = d_L$, the same sharing rule $\boldsymbol{\alpha}^{sym}$ as in the case of symmetric information is optimal. The reason is that even though agents do not have symmetric expectations in every situation, they have ex-ante the same expectation about what situations can arise. It is then surplus-maximizing to give a higher share to the more productive agent. Whenever agents differ in their disclosure strategies, the sharing rule $\boldsymbol{\alpha}^{sym}$ is not optimal anymore. The optimal share for an agent decreases in his own probability of disclosing and increases in the probability of disclosing of the other agent. Hence, the optimal share of the less productive agent

$\alpha_L^*(d_L, d_H)$ is higher than α_L^{sym} whenever $d_L < d_H$. The less productive agent might even get a higher share than the more productive agent if his effort productivity is high enough.

If we want to find the overall optimal shares, however, we have to take into account that disclosure strategies depend on the sharing rule and are chosen by the agents to maximize their expected utility. Therefore, we will now look at the individually rational disclosure strategies of the agents.

5.2 Disclosure strategies

When an agent decides whether to disclose information or not, he has to anticipate which project will be chosen and which efforts will be provided by himself and his partner.

Project P is chosen if and only if information was disclosed. Therefore, agent i discloses information if he expects a higher utility from project P than if he conceals and the team sticks to the status quo project Q:

$$E_i[U_i^d] \geq E_i[U_i^c] \tag{16}$$

$$\Leftrightarrow \alpha_i[e_i^*(P)\gamma_i + e_j^*(q)\gamma_j]P - \frac{1}{2}e_i^*(P)^2 \geq \alpha_i[e_i^*(q)\gamma_i + e_j^*(\hat{E}_j[Q])\gamma_j]q - \frac{1}{2}e_i^*(q)^2.$$

If agent i discloses, the team will choose project P and efforts will be individually optimal given quality P. After concealing, project Q is chosen. While agent i then knows that the quality of project Q is low, agent j has to form expectations. As shown before, his expectation $\hat{E}_j[Q]$, given by (12), is higher than the quality of project P, so the uninformed agent would be more motivated when the informed agent did not disclose and they work on project Q.

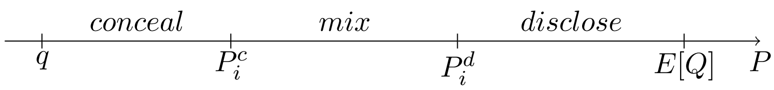
Agent i discloses information if and only if the gain in project's quality due to switching to project P dominates the loss from lower effort. Hence, the quality of project P must be high enough to make an agent willing to disclose. From condition (16), we get two thresholds for P, which depend on the sharing rule $\boldsymbol{\alpha}$. If the quality of P is high enough,

$$P \geq P_i^d(\boldsymbol{\alpha}) \equiv \left[\frac{q(\alpha_i\gamma_i^2 q + 2\alpha_j\gamma_j^2)}{\alpha_i\gamma_i^2 + 2\alpha_j\gamma_j^2}\right]^{1/2}, \tag{17}$$

agent i is willing to disclose his information. If the quality of P is low,

$$P \leq P_i^c(\boldsymbol{\alpha}) \equiv \left[\frac{3\alpha_i\gamma_i^2 q^2 + 2\alpha_j\gamma_j^2 q(2+q)}{3(\alpha_i\gamma_i^2 + 2\alpha_j\gamma_j^2)}\right]^{1/2}, \tag{18}$$

agent i would conceal any information he gets. The disclosure decisions, and hence the thresholds, are independent of the disclosure strategy of the other agent since an informed agent knows that the other agent did not receive information. For an agent i the thresholds are thus unique. Furthermore, $P_i^c < P_i^d$ because the expectation of the uninformed agent $\hat{E}_j[Q]$ increases in the probability of disclosing d_i and thus incentives to disclose decrease in d_i. Therefore, full disclosure $d_i = 1$ with $\hat{E}_j[Q] = 1$, requires a higher P to induce disclosure than full concealment $d_i = 0$ with $\hat{E}_j[Q] = \frac{2+q}{3}$. The following graph shows the thresholds and the optimal disclosure strategy of agent i on the P-line:



The two thresholds lie in the range $[q, E[Q]]$. If $P = q$, agents will always conceal since adaptation has no benefit and discourages the partner. If $P = E[Q]$, the benefit of adaptation is always high enough to induce full disclosure. Between his two thresholds, an agent is not willing to fully disclose or to fully conceal. If the agent fully discloses, the other agent has high motivation whenever he does not get any information, since he is then rather sure that the quality of project Q is high. This makes concealing more attractive for the informed agent. If the agent fully conceals, the effect on the other agent's motivation is weak. Full disclosure would then be better for the informed agent. Between the thresholds, an equilibrium thus only exists when the agent partially discloses with probability $\delta_i(\boldsymbol{\alpha}) \in (0, 1)$ that makes him just indifferent between disclosing and concealing. Being indifferent, he is then also willing to disclose with this probability

$$\delta_i(\boldsymbol{\alpha}) = \frac{3\alpha_i\gamma_i^2 + 2\alpha_j\gamma_j^2}{\alpha_i\gamma_i^2 + 2\alpha_j\gamma_j^2} + \frac{4\alpha_j\gamma_j^2}{\alpha_i\gamma_i^2 + 2\alpha_j\gamma_j^2}\frac{P^2 - q}{P^2 - q^2}. \tag{19}$$

Hence, agent i's unique optimal disclosure strategy given P is

$$d_i^* = \begin{cases} 1 & \text{if } P \geq P_i^d \\ \delta_i(\boldsymbol{\alpha}) & \text{if } P \in (P_i^c, P_i^d) \\ 0 & \text{if } P \leq P_i^c. \end{cases} \tag{20}$$

Since there is a unique optimal disclosure strategy for each agent (which is independent of the disclosure strategy of the other agent), there is always a unique equilibrium. An equilibrium in which both agents fully disclose arises whenever adaptation is important enough, i.e. if and only if P is high and lies above the disclosure thresholds of both agents $P \geq \max[P_L^d, P_H^d]$. Full concealment is the equilibrium when adaptation is not important, i.e. if and only if P lies below the concealment thresholds of both agents $P \leq \min[P_L^c, P_H^c]$. For intermediate values of P, asymmetric equilibria arise in which agents adapt different disclosure strategies.

Whether agents want to disclose or conceal depends on the share of revenue they receive. An increase in the own share (which implies a decrease in the other's share) has three effects on the disclosure strategy of an agent. First, he benefits more from a better adaptation to the state of the world. Second, the effect on the other agent's motivation is weaker, since the other agent reacts less to changes in expected quality. And finally, the agent benefits more from the difference in motivation of the other agent. While the first two effects are in favor of disclosure, the third effect is in favor of concealing. It turns out that the first and second effect always dominate and an agent is more likely to disclose if he gets a higher share.

Lemma 1. *The propensity of an agent to disclose private information increases in his own share of revenue and decreases in the other agent's share of revenue.*

The thresholds P_i^d and P_i^c decrease in the own share of revenue. If the own share increases, budget balance implies that the other's share decreases, which lowers P_i^d and P_i^c even more. The probability of disclosing $\delta_i(\boldsymbol{\alpha})$ in the range of P between the thresholds increases in the own share and decreases in the partner's share. The proofs can be found in the Appendix.

5.3 Full information sharing

Since the disclosure of information leads to the choice of the project with higher quality, one question we can ask is which sharing rule is optimal for information sharing in the sense that it maximizes the probability that agents fully share their information. The two agents fully disclose if P lies above their thresholds P_L^d and P_H^d. Hence, we want to find the sharing rule $\boldsymbol{\alpha}$ that minimizes the maximum of the thresholds. As stated in Lemma 1, any change in the sharing rule $\boldsymbol{\alpha}$ moves the thresholds in opposite directions. Therefore, the maximum is minimized when the thresholds are equalized, i.e. when $\boldsymbol{\alpha}$ is such that $P_L^d(\boldsymbol{\alpha}) = P_H^d(\boldsymbol{\alpha})$. This equation gives us the optimal shares for information sharing α_L^{dis} and $\alpha_H^{dis} = 1 - \alpha_L^{dis}$:

Proposition 3 (Full Information Sharing)**.** *If agents receive private information, the partnership's ability to share information is optimized (i.e. the range of parameters for which $d_L^* = d_H^* = 1$ is maximized) with the shares:*

$$\alpha_L^{dis} = \frac{\gamma_H^2}{\gamma_L^2 + \gamma_H^2} \quad \textit{and} \quad \alpha_H^{dis} = \frac{\gamma_L^2}{\gamma_L^2 + \gamma_H^2}. \tag{21}$$

The less productive agent receives a higher share $\alpha_L^{dis} > \frac{1}{2}$.

The intuition for this result is as follows. The incentives to conceal are higher if the other agent reacts strongly to changes in expected quality of the project. Given equal shares, the more productive agent would react more strongly than the less productive agent, since his effort has a higher effect on revenue. The less productive agent thus has a higher incentive to conceal when sharing equally. Increasing the share of the less productive agent (and thereby decreasing the share of the more productive agent) balances the effort reactions to changes in expected quality and thereby the incentives to disclose.

This result is in contrast to the result from our benchmark case, where the more productive agent should get a higher share and provide higher effort in order to maximize surplus. If we want to induce full information sharing, the less productive agent should get a higher share and will potentially even provide higher effort. Corollary 1 follows directly from Propositions 1 and 3.

Corollary 1. *The revenue allocation that optimizes information sharing is diametrically opposed to the revenue allocation that maximizes surplus in the absence of informational asymmetries, i.e. $\alpha_L^{dis} = 1 - \alpha_L^{sym}$.*

Since $\boldsymbol{\alpha}^{dis}$ equalizes the thresholds, both agents will fully disclose if $P \geq \underline{P} \equiv P_L^d(\boldsymbol{\alpha}^{dis}) = \left[\frac{1}{3}q(2+q)\right]^{1/2}$. If the quality of project P is high enough $P \geq \bar{P} \equiv P_L^d(\boldsymbol{\alpha}^{sym}) = \left[\frac{q(q\gamma_L^4 + 2\gamma_H^4)}{\gamma_L^4 + 2\gamma_H^4}\right]^{1/2}$, agents would disclose also with the shares $\boldsymbol{\alpha}^{sym}$. Figure 1 depicts total expected surplus (13) given optimal disclosure strategies as a function of P, once with $\boldsymbol{\alpha}^{dis}$ and once with $\boldsymbol{\alpha}^{sym}$.

In this example with $q = 0.1$, $\gamma_L = 0.8$ and $\gamma_H = 1$, we find that for values of P close to $\bar{P}$, $\boldsymbol{\alpha}^{sym}$ is preferred to $\boldsymbol{\alpha}^{dis}$. However, given $\boldsymbol{\alpha}^{sym}$,

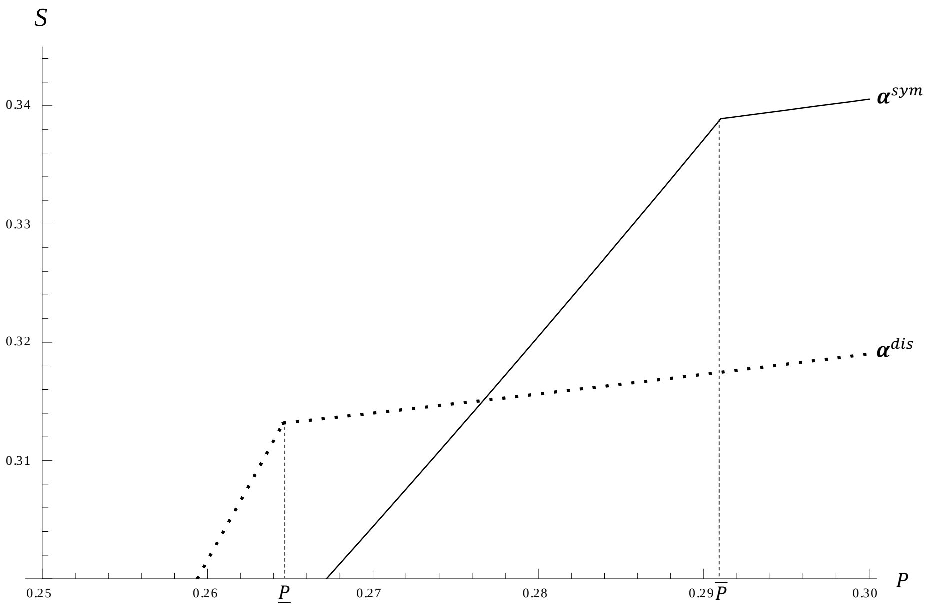


Figure 1: **Surplus with optimal symmetric and optimal disclosure shares.** Surplus as a function of the alternative project's quality P, given $\boldsymbol{\alpha}^{sym}$ (solid) and $\boldsymbol{\alpha}^{dis}$ (dotted) when $q = 0.1$, $\gamma_L = 0.8$ and $\gamma_H = 1$.

agent L starts to conceal when P decreases, which leads to a loss in surplus. We find a range of P in which inducing full disclosure with $\boldsymbol{\alpha}^{dis}$ is preferred to $\boldsymbol{\alpha}^{sym}$.

This observation, Corollary 1 and the fact that $\alpha_L^{equal} = \frac{1}{2} = \frac{\alpha_L^{sym} + \alpha_L^{dis}}{2} \in (\alpha_L^{sym}, \alpha_L^{dis})$, suggest that equal sharing could optimally balance the incentives between information sharing and effort provision.

5.4 Inducing full disclosure

Instead of choosing optimal disclosure shares $\boldsymbol{\alpha}^{dis}$, a smaller distortion of the sharing rule $\boldsymbol{\alpha}^{sym}$ might be enough to keep agents disclosing when P falls below $\bar{P}$. In other words, when full disclosure is possible, i.e. $P \geq \underline{P}$, we can maximize surplus subject to the constraint that both agents are willing to disclose. Since incentives to disclose increase in the agent's own share and decrease in the other's share, agent L is willing to disclose if his share is high enough:

$$\alpha_L \geq \underline{\alpha} \equiv \frac{2\gamma_H^2(P^2 - q)}{2\gamma_H^2(P^2 - q) - \gamma_L^2(P^2 - q^2)}. \tag{22}$$

For values of P below the threshold $\bar{P}$, agent L needs a higher share than α_L^{sym} in order to be willing to disclose. Therefore, we know that $\underline{\alpha} > \alpha_L^{sym}$ if $P \in [\underline{P}, \bar{P})$. Agent H is willing to disclose if the share of agent L is not too high:

$$\alpha_L \leq \bar{\alpha} \equiv \frac{\gamma_H^2(P^2 - q^2)}{\gamma_H^2(P^2 - q^2) - 2\gamma_L^2(P^2 - q)}. \tag{23}$$

Inducing full disclosure requires choosing a sharing rule for which $\underline{\alpha} \leq \alpha_L \leq \bar{\alpha}$. This is possible if $\underline{\alpha} \leq \bar{\alpha}$ which is true for all $P \geq \underline{P}$.

As shown in Section 5.1, surplus given full disclosure is strictly concave in α_L and maximized at α_L^{sym}. In order to maximize surplus under the constraint of full disclosure, we thus need to get as close as possible to α_L^{sym}. Taking into account that $\alpha_L^{sym} < \underline{\alpha} \leq \bar{\alpha}$ if $P \in [\underline{P}, \bar{P})$ and $\alpha_L^{sym} \in [\underline{\alpha}, \bar{\alpha}]$ if $P \geq \bar{P}$, we find the optimal constraint sharing rule $\boldsymbol{\alpha}^f = (\alpha_L^f, \alpha_H^f)$:

Proposition 4 (Optimal sharing rule under the constraint of full disclosure)**.** *If it is possible to induce full disclosure with $\boldsymbol{\alpha}^{sym}$, i.e. $P \geq \bar{P}$, the optimal shares of revenue under the restriction that we induce full disclosure are*

$$\alpha_L^f = \alpha_L^{sym} \quad \text{and} \quad \alpha_H^f = \alpha_H^{sym}. \tag{24}$$

If it is not possible to induce full disclosure with $\boldsymbol{\alpha}^{sym}$ but full disclosure is feasible, i.e. $P \in [\underline{P}, \bar{P})$, the optimal constraint shares are

$$\alpha_L^f = \underline{\alpha} \quad \text{and} \quad \alpha_H^f = 1 - \underline{\alpha}. \tag{25}$$

The less productive agent gets a higher share, i.e. $\alpha_L^f > \frac{1}{2}$, if $P \in [\underline{P}, P^e)$ with $P^e \equiv \left[\frac{q(q\gamma_L^2 + 2\gamma_H^2)}{\gamma_L^2 + 2\gamma_H^2}\right]^{1/2}$.

In contrast to $\boldsymbol{\alpha}^{sym}$ and $\boldsymbol{\alpha}^{dis}$, the optimal constraint distribution of revenue depends on P. When P falls below $\bar{P}$, the share for the less productive agent has to increase compared to α_L^{sym} in order to keep him disclosing. For decreasing P, his share increases from α_L^{sym} at $\bar{P}$ until it reaches α_L^{dis} at $\underline{P}$. Equal sharing is constraint optimal at P^e, which is defined by $\alpha_L^f(P^e) = \frac{1}{2}$ and always lies in $[\underline{P}, \bar{P})$. Hence, the less productive agent receives a higher share than the more productive agent whenever $P \in [\underline{P}, P^e)$.

Figure 2 depicts the total expected surplus (13) given optimal disclosure strategies and given $\boldsymbol{\alpha}^f(P)$, $\boldsymbol{\alpha}^{sym}$ and $\boldsymbol{\alpha}^{dis}$. Whenever it is possible to

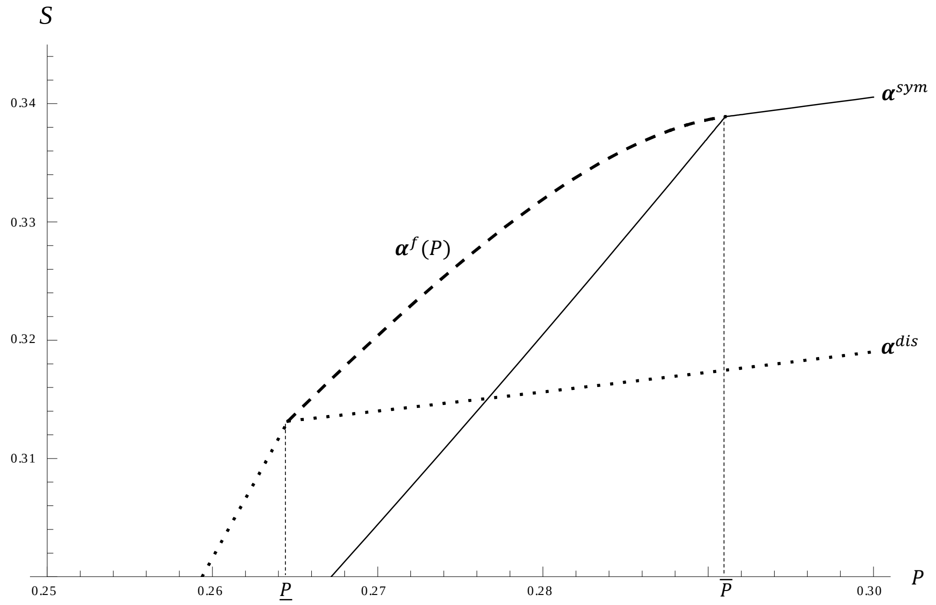


Figure 2: **Surplus under the constraint of full disclosure.** Surplus as a function of the alternative project's quality P, given $\boldsymbol{\alpha}^{sym}$ (solid), $\boldsymbol{\alpha}^{dis}$ (dotted) and $\boldsymbol{\alpha}^{f}(P)$ (dashed) when $q = 0.1$, $\gamma_L = 0.8$ and $\gamma_H = 1$.

induce full disclosure, i.e. $P \geq \underline{P}$, the sharing rule $\boldsymbol{\alpha}^{f}(P)$ is preferred to $\boldsymbol{\alpha}^{dis}$, since both induce full disclosure but $\boldsymbol{\alpha}^{f}(P)$ is closer to the optimal sharing rule given full disclosure $\boldsymbol{\alpha}^{sym}$. In our example, $\boldsymbol{\alpha}^{f}(P)$ is also weakly preferred to $\boldsymbol{\alpha}^{sym}$. However, this is not necessarily general, since it might be surplus increasing to allow for some concealment. This is true if the loss of motivation dominates the gain due to better adaptation.

Before considering the overall optimal sharing rule in Section 6, we show that our assumption with respect to the project selection rule comes without loss of generality.

Project selection. Take any voting rule such that if an agent votes for project X, the probability that this project is chosen increases. Furthermore, if agents both vote for the same project, that project is chosen. This implies that both agents would always vote for the project from which they expect a higher utility.

If one of the agents was informed and discloses this information, both agents vote in favor of project P. This is implied by Assumption 1 and the fact that once evidence is disclosed, project Q is known to have low quality for sure. If an agent does not receive any evidence, it is not immediately clear which project he would vote for. On the one hand, no evidence strengthens the belief that project Q is of good quality. On the other hand, given the quality is low, the other agent is expected to have evidence and to provide low effort. An uninformed agent i expects that if project Q is chosen, he gets utility

$$\begin{aligned} U_i^Q = \; & \frac{1-d_j}{3-d_j}\alpha_i[\gamma_i e_i^*(\hat{E}_i[Q]) + \gamma_j e_j^*(q)]q \\ & + \frac{2}{3-d_j}\alpha_i[\gamma_i e_i^*(\hat{E}_i[Q]) + \gamma_j e_j^*(\hat{E}_j[Q])] - \frac{1}{2}e_i^*(\hat{E}_i[Q])^2 \end{aligned} \quad (26)$$

with $\hat{E}_i[Q] = \frac{(1-d_j)q+2}{3-d_j}$ and $\hat{E}_j[Q] = \frac{(1-d_i)q+2}{3-d_i}$. Given individually optimal effort choices and our assumption that $P < E[Q]$, we show in the Appendix that surplus from project P is strictly lower in this situation. Hence, the uninformed agent would vote for project Q. An informed agent who did not disclose will also vote for project Q. Otherwise, he would have made sure that project P is chosen by disclosing his evidence in the first place. Consequently, agents will agree on the status quo project Q whenever no evidence was disclosed.

6 Optimal allocation of revenue

In this section, we first determine the sharing rule $\boldsymbol{\alpha}^*$ that maximizes total expected surplus, taking into account that disclosure strategies are chosen by the agents. Then, we discuss the optimality of equal sharing.

6.1 Optimal sharing rule

Total expected surplus of the two agents takes into account the same cases as in (13) but now considers the optimal disclosure strategies of the agents:

$$\begin{aligned} E[S] = & \frac{1}{4}[d_L^* S_P(e_L^*(P), e_H^*(P)) + (1-d_L^*)S_q(e_L^*(q), e_H^*(\hat{E}_H[Q]))] \\ & + \frac{1}{4}[d_H^* S_P(e_L^*(P), e_H^*(P)) + (1-d_H^*)S_q(e_L^*(\hat{E}_L[Q]), e_H^*(q))] \\ & + \frac{1}{2}S_1(e_L^*(\hat{E}_L[Q]), e_H^*(\hat{E}_H[Q])). \end{aligned} \quad (27)$$

Figure 3 shows the thresholds P for full disclosure and full concealment of the two agents as a function of α_L. As long as $P \geq \underline{P}$, adaptation is important enough such that at least one of the agents will fully disclose and

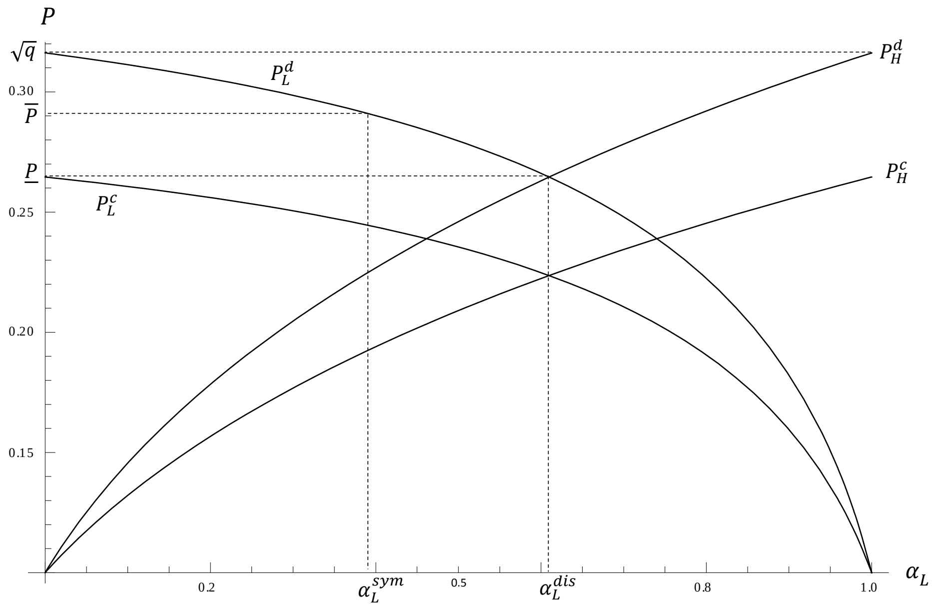


Figure 3: **Disclosure and concealment thresholds.** Thresholds P_i^d and P_i^c for agents $i = L, H$ as a function of the less productive agent's share α_L given $q = 0.1$, $\gamma_L = 0.8$ and $\gamma_H = 1$.

none of the agents would ever fully conceal. For $P \geq \sqrt{q}$, both agents fully disclose independent of the revenue sharing rule $\boldsymbol{\alpha}$.

Lemma 2. *Suppose $P \in [\underline{P}, E[Q])$. For any $\alpha_L \in [0, 1]$, at least one agent fully discloses and none of the agents fully conceals.*

You find the proof in the Appendix. Lemma 2 implies that in the range of P in which full disclosure is possible to induce, we can restrict attention to three types of equilibria: both agents fully disclose, agent L partially discloses while agent H fully discloses and agent H partially discloses while agent L fully discloses.

In the following, we normalize $\gamma_L = \gamma < 1$ and $\gamma_H = 1$. Proposition 5 characterizes the surplus-maximizing sharing rule $\boldsymbol{\alpha}^* = (\alpha_L^*, 1 - \alpha_L^*)$ when inducing full disclosure is possible. A question of particular interest is whether the optimal sharing rule $\boldsymbol{\alpha}^*$ induces full adaptation, i.e. the certain adoption of the project with the higher (expected) quality.

Proposition 5. *Suppose that $P \in [\underline{P}, E[Q])$. The revenue allocation that maximizes total expected surplus can be characterized as follows:*

- *If $P \in [\bar{P}, E[Q])$ then $\alpha_L^* = \alpha_L^{sym}$ is optimal. The project with the* *higher (expected) quality is always adopted, i.e.* $d^*_L = d^*_H = 1$.

- *If* $P \in [\hat{P}, \bar{P})$ *then* $\alpha^*_L = \alpha^f_L$ *is optimal. The project with the higher (expected) quality is always adopted, i.e.* $d^*_L = d^*_H = 1$.
- *If* $P \in [\underline{P}, \hat{P})$ *then* $\alpha^*_L \in (\alpha^{sym}_L, \alpha^f_L)$ *is optimal. The project with the higher (expected) quality fails to be adopted with positive probability, i.e.* $d^*_L < d^*_H = 1$.

If $\gamma > \underline{\gamma}(q) \equiv \sqrt{\frac{2(2+3q+q^2)}{7+4q+q^2}}$, *then* $\hat{P} = \underline{P}$, *i.e. inducing full adaptation is optimal whenever feasible.*

If $P \geq \sqrt{q}$, agents fully disclose independent of the sharing rule. It is thus straightforward that $\boldsymbol{\alpha}^{sym}$ is optimal. For $P < \sqrt{q}$, we have to consider that different sharing rules imply different disclosure strategies. Agents fully disclose if $\alpha_L \in [\underline{\alpha}, \bar{\alpha}]$. We argued in Section 5.4 that within this range of α_L, $\underline{\alpha}$ would be the optimal choice for total surplus if $P \in [\underline{P}, \bar{P})$ and α^{sym}_L is optimal if $P \geq \bar{P}$. However, it might be surplus increasing to choose a sharing rule that does not lie in this range, i.e. such that one of the agents starts concealing, since this could mitigate the free-riding problem of the team. If $\alpha_L > \bar{\alpha}$, agent H starts concealing partially. The surplus is then decreasing in α_L for all $P \in [\underline{P}, \sqrt{q})$. Hence, the highest surplus we can get in $[\bar{\alpha}, 1]$ is at $\bar{\alpha}$. This brings us back to full disclosure. If $\alpha_L < \underline{\alpha}$, agent L starts concealing partially. We can show that the surplus when agent L is disclosing and agent H partially conceals is concave in α_L. Furthermore, it is strictly increasing at $\underline{\alpha}$ for $P \in [\hat{P}, \sqrt{q})$, with $\hat{P} \in [\underline{P}, \bar{P})$. Hence, for such P, all $\alpha_L < \underline{\alpha}$ would yield lower surplus than $\underline{\alpha}$. $\underline{\alpha}$ maximizes surplus and again brings us back to full disclosure. For $P \in [\underline{P}, \hat{P})$, allowing for some concealment increases the surplus. The proofs can be found in the Appendix.

Figure 4 emphasizes the consequences of optimal sharing for adaptation.

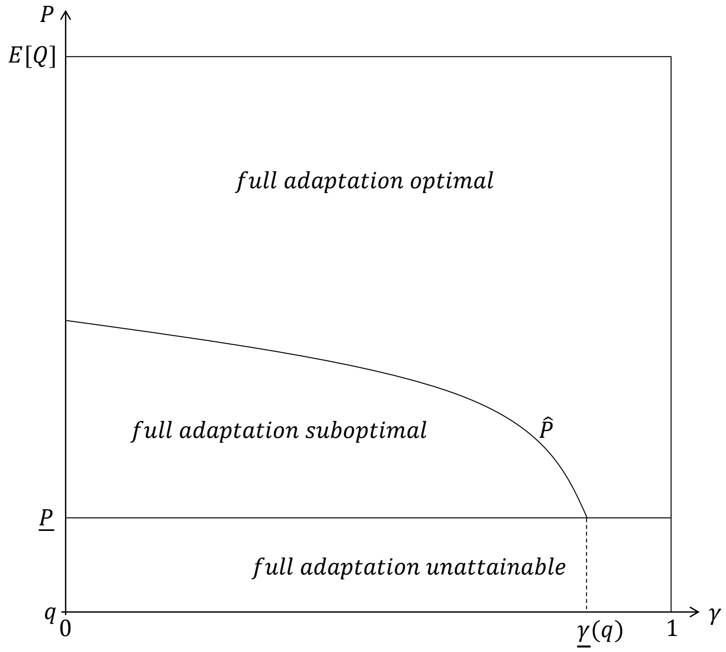


Figure 4: **Adaptation.** Characterization of the degree of adaptation under the surplus-maximizing sharing rule $\boldsymbol{\alpha}^*$ in dependence of the partners' heterogeneity and the alternative project's quality P for given q.

Whether full adaptation is optimal whenever feasible, i.e. for the whole range $[\underline{P}, E[Q])$, depends on the heterogeneity of agents γ and on the low quality of project Q. If agents are rather heterogeneous, i.e. $\gamma < \underline{\gamma}(q)$, it is not optimal to always adopt the project with the higher (expected) quality. The cost of inducing full adaptation is suboptimal motivation and this cost is higher if agents are heterogeneous. The threshold $\underline{\gamma}(q)$ is increasing in q. Hence, a higher low quality of project Q implies that full adaptation is less likely to be optimal. This is intuitive since a higher low quality of project Q makes disclosure and adaptation less important for surplus. Moreover, the size of the range in which full adaptation is feasible is decreasing in q and thus smaller for high q's.

6.2 On the optimality of equal sharing

Compared to the optimal shares given symmetric information $\boldsymbol{\alpha}^{sym}$ with $\alpha_L^{sym} < \frac{1}{2}$, equal shares have the advantage that the less productive agent is rather willing to disclose: From Lemma 1 we know that an increase in the own share increases the incentives to disclose. On the other hand, equal shares have the disadvantage that they do not optimally motivate given full disclosure. The benefit from improved information sharing potentially outweighs the loss from sub-optimal motivation. In our example with $q = 0.1$ and $\gamma = 0.8$, equal shares are indeed preferred to $\boldsymbol{\alpha}^{sym}$ for a range of values of P, as we see in Figure 5.

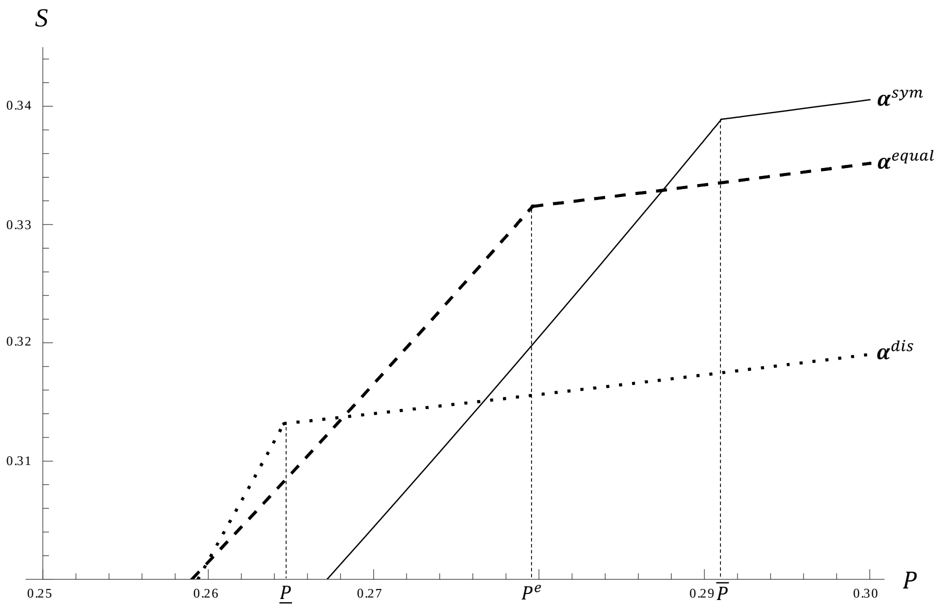


Figure 5: **Surplus with equal sharing rule.** Surplus as a function of the alternative project's quality P, given $\boldsymbol{\alpha}^{sym}$ (solid), $\boldsymbol{\alpha}^{dis}$ (dotted) and $\boldsymbol{\alpha}^{equal}$ (dashed) when $q = 0.1$ and $\gamma = 0.8$.

Given the distribution $\boldsymbol{\alpha}^{sym}$, both agents fully disclose for $P \geq 0.291$ while they disclose for $P \geq 0.28$ with equal sharing. With partial concealment of the less productive agent, surplus decreases faster if P decreases, and in our example, this implies equal sharing is preferred to $\boldsymbol{\alpha}^{sym}$ for the range $P \in [0.240, 0.287]$.

Instead of comparing equal shares with $\boldsymbol{\alpha}^{sym}$, we can directly consider the optimality of equal shares. There always exists a $P^e \in [\underline{P}, \bar{P})$ for which $\alpha_L^*(P^e) = \frac{1}{2}$. Hence, $\alpha_L^* = \frac{1}{2}$ is indeed optimal in some situations.

Proposition 6 (Optimal equal sharing)**.** *If* $\gamma > \tilde{\gamma} \equiv (\sqrt{6}-2)^{1/2}$ *and* $q < \tilde{q} \equiv \frac{(4-\gamma^{12}-4\gamma^{10}+9\gamma^8+24\gamma^6+4\gamma^4)^{1/2}}{\gamma^2(2+2\gamma^2-\gamma^4)} - \frac{1}{\gamma^2} \in (0,1)$*, there exists a range* $P \in [\hat{P}, P^e)$ *in which giving a higher than equal share to the less productive agent* $\alpha_L^* > \frac{1}{2}$ *is optimal and equal shares* $\alpha_L^* = \frac{1}{2}$ *are optimal for* $P^e \in [\underline{P}, \bar{P})$*.*

You find the proof in the Appendix. In other words, Proposition 6 states that for some range of P it is optimal to give a higher share to the less productive agent if agents are rather homogeneous and the low quality of project Q is rather low. If agents are homogeneous, the loss of motivation is less severe than the loss due to worse adaptation when agents start to conceal. Furthermore, it is more likely to benefit from equal sharing if the low quality of project Q is low since the gain of better adaptation is high. In such a situation, inducing full disclosure and thereby adaptation is important and not the costs of sub-optimal motivation are not too high. Optimality then requires increasing the share of the less productive agent.

Consider the percentage loss of equal sharing relative to optimal sharing in this team situation with asymmetric information. In the symmetric information benchmark, we found that the percentage loss only depends on effort productivities and can go up to 25%. In the asymmetric information case with project selection, the percentage loss is a function of effort productivity γ, the low quality of project Q and the quality of project P. In our range of interest $P \in [\underline{P}, E[Q])$, we can calculate the loss whenever we can determine the optimal $\boldsymbol{\alpha}^*$:

$$\Delta E[S] = \frac{E[S(\boldsymbol{\alpha}^*)] - E[S(\boldsymbol{\alpha}^{equal})]}{E[S(\boldsymbol{\alpha}^*)]}. \tag{28}$$

For $q < \bar{q}$ and $\gamma > \underline{\gamma}$, we can determine $\boldsymbol{\alpha}^*$ for the full range $P \in [\underline{P}, E[Q])$. In such a situation, Figure 6 depicts the percentage loss from equal sharing in the symmetric information benchmark $\Delta E^{sym}[S]$ and in the asymmetric information case $\Delta E[S]$ as a function of quality P.

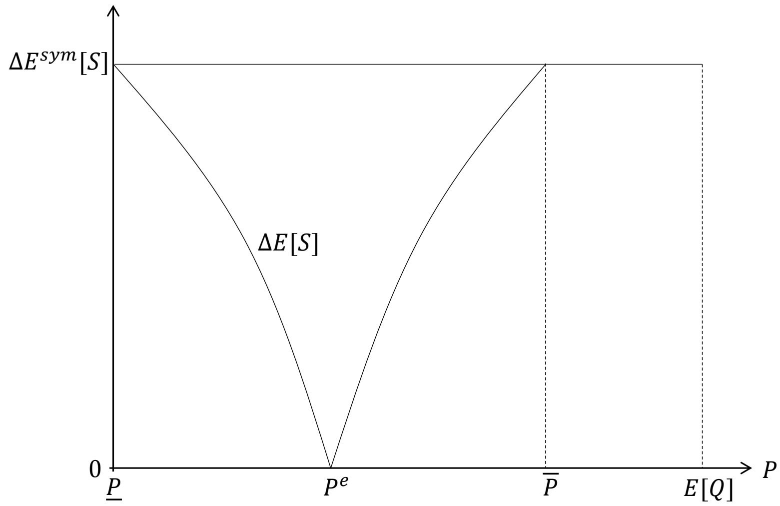


Figure 6: **Percentage loss in surplus from equal revenue sharing.** $\Delta E^{sym}[S]$ and $\Delta E[S]$ in dependence of the alternative project's quality P for given $\gamma > \underline{\gamma}$ and $q < \bar{q}$.

The percentage loss in surplus in the benchmark case is independent of P. The percentage loss in surplus given asymmetric information and project selection is lower for $P \in (\underline{P}, \bar{P})$, i.e. in the range of P in which full information sharing cannot be induced with $\boldsymbol{\alpha}^{sym}$ but would actually be surplus-maximizing. The loss is zero at P^e since equal sharing is then optimal.

Consider a team that only deviates from equal sharing if the gain is large enough. Such a decision rule would take into account that there are typically bureaucratic cost and rent-seeking when deviating from equal shares. Given asymmetric information and project selection, there is a larger set of parameters for which a team would stick to the default of equal sharing than in the symmetric information benchmark. In that sense, our model provides a rationale for more equal revenue sharing.

7 Robustness

In this section, we relax some assumptions of our model and show that Propositions 1 and 3 remain unchanged. Hence, our result that optimal incentives given symmetric information and optimal incentives for information sharing are diametrically opposed is robust regarding these assumptions. More specifically, we allow agents to differ in their ability to acquire information (7.1), we consider unverifiable evidence (7.2) and the possibility of “good news” (7.3). Finally, we let project success depend non-linearly on efforts which introduces inter-dependency of efforts (7.4).

7.1 Information acquisition

So far, we assumed that both agents are equally likely to receive information. In this section, we consider the case when agents differ in their ability to acquire information, i.e. in the likelihood of receiving information. Given the quality of project Q is low, agent L receives evidence with probability $\pi_L \in (0,1)$ while agent H gets evidence with $\pi_H \in (0,1)$. We assume that these probabilities are independent, i.e. it is possible that both, one or none of the agents is informed about the low quality of the status quo project. When an informed agent i decides whether to disclose, he knows that with some probability π_j, the other agent j is informed too and will then disclose his information with d_j. With some probability $(1-d_j)$, the other agent will not disclose given he is informed. Finally, with probability $(1-\pi_j)$, the other agent is not informed and updates his beliefs. We assume again that project P is selected if and only if evidence was disclosed.

If an agent j remains uninformed, his updated beliefs reflect the fact that being uninformed could mean that quality is high or that quality is low and the other agent was not informed either or that he was informed but conceals. These beliefs thus depend on the probabilities of being informed, π_i and π_j, of both agents:

$$\hat{E}_j[Q] = \frac{(1-d_i\pi_i)(1-\pi_j)q+1}{(1-d_i\pi_i)(1-\pi_j)+1}. \tag{29}$$

Since the incentives to disclose depend on the uninformed agent’s beliefs, the threshold for disclosure now also depends on the probabilities of receiving information. The informed agent i discloses if and only if $P \geq P_i^d$, with

$$P_i^d = \left[\frac{q\{q\alpha_i\gamma_i^2[2-\pi_i-\pi_j(1-\pi_i)]+2\alpha_j\gamma_j^2[1+(1-\pi_j)(1-\pi_i)q]\}}{(\alpha_i\gamma_i^2+2\alpha_j\gamma_j^2)[2-\pi_i-\pi_j(1-\pi_i)]}\right]^{1/2}. \tag{30}$$

As in the case of symmetric ability of information acquisition, this threshold decreases in the own share α_i and increases in the other’s share α_j. We show that in the Appendix. Therefore, we again maximize the range of P in which both agents disclose by minimizing the maximum of these two thresholds. The range is maximized when the thresholds are just equal which is true at $\alpha_L^{dis} = \frac{\gamma_H^2}{\gamma_L^2+\gamma_H^2}$. Hence, our result that the less productive agent needs a higher share to disclose information holds. The benchmark case does not change, i.e. $\boldsymbol{\alpha}^{sym}$ would be optimal with symmetric information. Information sharing and project selection provide a reason for more balanced sharing also in this setting. Since the overall optimal shares have to balance the incentives to provide effort and to disclose information, they are tilted towards more equality even if one agent is more productive *and* better at information acquisition.

7.2 Unverifiability

In this section, we consider the possibility that agents receive unverifiable and imperfect information about the status quo's quality. In comparison to our model with hard evidence, two novelties arise. First, agents are able to misrepresent their information and truth-telling becomes the issue. Second, agents are more motivated to exert effort on a given project when their "opinions" agree rather than disagree.

More specifically, we modify our model as follows. In Stage 1 each agent i receives a private, unverifiable, imperfect signal $s_i \in \{q, 1\}$ about the status quo's quality. Signals are independent and each signal has the same probability $\sigma \in (\frac{1}{2}, 1)$ of being correct. In Stage 2 agents communicate by sending a message $m_i \in \{q, 1\}$. As signals are unverifiable, agents may misrepresent their information by choosing $m_i \neq s_i$. In Stage 3 the status quo project is maintained unless both agents report low quality by issuing $m_L = m_H = q$.[7]

In the following, we derive the conditions that have to be satisfied for truth-telling $m_i = s_i$ to constitute an equilibrium. In a truth-telling equilibrium, the status quo's (updated) expected quality is given by

$$\hat{E}_i[Q] = \begin{cases} \frac{\sigma^2+(1-\sigma)^2 q}{\sigma^2+(1-\sigma)^2} \equiv \bar{Q} & \text{if} \quad s_L = s_H = 1 \\ \frac{1+q}{2} = E[Q] & \text{if} \quad s_L \neq s_H \\ \frac{\sigma^2 q+(1-\sigma)^2}{\sigma^2+(1-\sigma)^2} \equiv \underline{Q} & \text{if} \quad s_L = s_H = q \end{cases} \tag{31}$$

[7] We modify Assumption 1 by requiring $P > \underline{Q}$ rather than $P > q$ with $\underline{Q}$ as defined in (31). This ensures that, as in the model with evidence, the specified project selection rule can be rationalized as the outcome of an arbitrary voting procedure.

and agent i with revenue-share α_i and productivity γ_i who expects project X's quality to be $\hat{E}_i[X]$ exerts effort $e_i^*(\hat{E}_i[X]) = \alpha_i\gamma_i\hat{E}_i[X]$. Not surprisingly, agents have no incentive to lie when they observe "good news", $s_i = 1$, but might be tempted to misrepresent "bad news" by issuing $m_i = 1$ upon observation of $s_i = q$. Agent i's payoff from truth-telling $m_i = s_i = q$ is given by

$$\begin{aligned} U_i^t = & \; [\sigma^2 + (1-\sigma)^2]\left\{\alpha_i[\gamma_i e_i^*(P) + \gamma_j e_j^*(P)]P - \frac{1}{2}e_i^*(P)^2\right\} \\ & + 2\sigma(1-\sigma)\left\{\alpha_i[\gamma_i e_i^*(E[Q]) + \gamma_j e_j^*(E[Q])]E[Q] - \frac{1}{2}e_i^*(E[Q])^2\right\} \end{aligned} \tag{32}$$

whereas lying by issuing $m_i = 1$ when $s_i = q$ gives

$$\begin{aligned} U_i^l = & \; [\sigma^2 + (1-\sigma)^2]\left\{\alpha_i[\gamma_i e_i^*(\underline{Q}) + \gamma_j e_j^*(E[Q])]\underline{Q} - \frac{1}{2}e_i^*(\underline{Q})^2\right\} \\ & + 2\sigma(1-\sigma)\left\{\alpha_i[\gamma_i e_i^*(E[Q]) + \gamma_j e_j^*(\bar{Q})]E[Q] - \frac{1}{2}e_i^*(E[Q])^2\right\}. \end{aligned} \tag{33}$$

Truth-telling is optimal for agent i if and only if $U_i^t \geq U_i^l$ or equivalently $P > P_i^d$ with

$$P_i^d = \left[\frac{\frac{1}{2}\alpha_i^2\gamma_i^2\underline{Q}^2 + \alpha_i\alpha_j\gamma_j^2\underline{Q}E[Q] + \frac{2\sigma(1-\sigma)}{\sigma^2+(1-\sigma)^2}\alpha_i\alpha_j\gamma_j^2(\bar{Q} - E[Q])E[Q]}{\frac{1}{2}\alpha_i^2\gamma_i^2 + \alpha_i\alpha_j\gamma_j^2}\right]^{1/2}. \tag{34}$$

Truth-telling, $(m_L, m_H) = (s_L, s_H)$, forms an equilibrium if and only if $P \geq \max\{P_L^d, P_H^d\}$. Perhaps surprisingly, the range of parameters for which truth-telling constitutes an equilibrium is again maximized when $\alpha_L = \frac{\gamma_H^2}{\gamma_L^2+\gamma_H^2} = \alpha_L^{dis}$.

Our analysis in this section shows that Proposition 1 and the corresponding Corollary 1 remain valid in settings with non-verifiable information. In the model with signals, the economic mechanisms involved are similar to the ones in the model with evidence. However, there exists one additional mechanism. This mechanism is similar to a subordinate's propensity to conform with the views of his superior (Prendergast, 1993). Each agent has an incentive to issue a message that reinforces rather than contradicts his partner's signal. Since messages are issued simultaneously and signals are more likely to coincide than to contradict each other, agents therefore have an additional incentive to tell the truth. It is reassuring that our results remain unchanged even in the presence of such a *propensity to agree.*

7.3 Good news

Assume that agents also get information if there is "good news", i.e. if the quality of project Q is high. This means that there is *always* one agent informed and one agent uninformed. Given an agent receives "good news", he would want to work on project Q and the other agent to provide high effort. Both can be attained by disclosure and thus the only sub-game perfect strategy is to disclose whenever there is "good news". If an agent gets "bad news" and conceals, the uninformed agent knows that quality of project Q is low. He will thus provide low effort and the informed agent prefers to disclose and adopt project P. Hence, if there is *always* one agent who gets information, there is always full disclosure.

Alternatively, assume that if there is "good news", each agent gets information with independent probability $\pi \in (0,1)$. Again, if an agent gets "good news", he would always disclose since there is no trade-off between motivation and adaptation. If an agent remains uninformed, he knows for sure that there was no "good news". However, he is not sure whether there was "bad news" or "no news". With probability $\frac{1}{2}(1-\pi)^2$, the quality of project Q is high but there was no information. With probability $\frac{1}{4}(1-d_i)$, there was "bad news" but the other agent conceals. Hence, the uninformed agent expects the quality of project Q to be

$$\hat{E}_j[Q] = \frac{\frac{1}{4}(1-d_i)q + \frac{1}{2}(1-\pi)^2}{\frac{1}{4}(1-d_i) + \frac{1}{2}(1-\pi)^2}. \tag{35}$$

In a full disclosure equilibrium, i.e. when $d_L^* = d_H^* = 1$, uninformed agents are sure again that there was no "bad news". Hence, the disclosure thresholds of quality P are the same as in the case when only "bad news" is possible. $\alpha_L^{dis} > \frac{1}{2}$ maximizes the propensity of full disclosure, while $\alpha_L^{sym} < \frac{1}{2}$ would maximize surplus given symmetric information.

7.4 Technology

Our model assumes a linear relation between individual efforts and the projects' likelihood of success. In the following, we relax this assumption by requiring that, instead of (1),

$$R_X(e_L, e_H) = r(\Sigma)X \qquad \text{with} \qquad \Sigma = \gamma e_L + e_H. \tag{36}$$

The function r is assumed to be increasing and concave and to take values in $[0,1]$. Agents share the revenue according to the sharing rule $\alpha_L = \alpha$ and

$\alpha_H = 1-\alpha$. Note first that when the project's quality is (commonly) known to be X then equilibrium efforts, $e^*_L(X)$ and $e^*_H(X)$, are uniquely defined as the solution to the system of equations

$$e_L = \alpha\gamma r'(\Sigma)X \quad (37)$$

$$e_H = (1-\alpha) r'(\Sigma)X. \quad (38)$$

By the definition of Σ it must therefore hold that

$$\frac{\Sigma}{r'(\Sigma)} = (\alpha\gamma^2 + 1 - \alpha)X. \quad (39)$$

Define the solution to this equation as $\Sigma^*(\alpha)$ and note that $\Sigma^*(\alpha)$ is decreasing by the concavity of r.
Using $\Sigma^*(\alpha)$, we can write $e^*_L = \frac{\alpha\gamma}{\alpha\gamma^2+1-\alpha}\Sigma^*(\alpha)$ and $e^*_H = \frac{1-\alpha}{\alpha\gamma^2+1-\alpha}\Sigma^*(\alpha)$. In the symmetric information benchmark, the surplus-maximizing sharing rule is thus given by

$$\alpha^{sym} = \arg\max_{\alpha\in[0,1]} r(\Sigma^*(\alpha))X - \frac{1}{2}\frac{\alpha^2\gamma^2 + (1-\alpha)^2}{(\alpha\gamma^2+1-\alpha)^2}\Sigma^*(\alpha)^2. \quad (40)$$

Using (39), the first order condition of this maximization problem can be written as

$$\left[1 - \frac{\alpha^2\gamma^2 + (1-\alpha)^2}{\alpha\gamma^2 + 1 - \alpha}\right] r'(\Sigma^*(\alpha))X\frac{\partial\Sigma^*(\alpha)}{\partial\alpha} + \frac{(1-2\alpha)\gamma^2}{(\alpha\gamma^2+1-\alpha)^3}\Sigma^*(\alpha)^2 = 0. \quad (41)$$

As the first term is negative, for the first order condition to hold, the second term must be positive. This shows that in the symmetric information benchmark, $\alpha^{sym} < \frac{1}{2}$, i.e. surplus is maximized by granting the more productive agent a larger share of revenue.

Next, consider the agents' disclosure incentives. Full disclosure is an equilibrium if and only if the following two inequalities are satisfied:

$$U^d_L = \alpha r(\gamma e^*_L(P) + e^*_H(P))P - \frac{1}{2}e^*_L(P)^2 \geq \max_{e_L} \alpha r(\gamma e_L + e^*_H(1))q - \frac{1}{2}e_L^2 = U^c_L, \quad (42)$$

$$U^d_H = (1-\alpha) r(\gamma e^*_L(P) + e^*_H(P))P - \frac{1}{2}e^*_H(P)^2 \geq \max_{e_H}(1-\alpha) r(e_H + \gamma e^*_L(1))q - \frac{1}{2}e_H^2 = U^c_H. \quad (43)$$

From (37) and (38) it follows that $e_L^*(X) = \frac{\gamma\alpha}{1-\alpha} e_H^*(X)$ and setting $\alpha = \alpha^{dis} = \frac{1}{1+\gamma^2}$ therefore implies that $U_H^d = \gamma^2 U_L^d$ and $U_H^c = \gamma^2 U_L^c$.[8] Hence, $U_L^d \geq U_L^c$ if and only if $U_H^d \geq U_H^c$ or, in other words, disclosure incentives are equalized, $P_L^d(\alpha) = P_H^d(\alpha)$, when $\alpha = \alpha^{dis}$. As before, the parameter space for which full disclosure constitutes an equilibrium is maximized when the less productive agent receives a larger share of revenue $\alpha = \alpha^{dis} > \frac{1}{2}$.

While for technologies such as (36) a characterization of the partnership's surplus-maximizing sharing rule α^* proves elusive, our analysis in this section reveals that optimal incentives for motivation ($\alpha^{sym} < \frac{1}{2}$) and optimal incentives for adaptation ($\alpha^{dis} > \frac{1}{2}$) can be expected to be opposed quite generally.

8 Conclusion

This paper considers a standard situation of team production with effort substitutes, asymmetric information and project selection. When designing the optimal sharing rule, we find that there is a trade-off between motivation and information sharing. Optimal motivation given symmetric information requires giving a higher share to the more productive agent. Maximizing the propensity of information sharing requires the opposite distribution of revenue: to give a high share to the less productive agent. This result is robust to changes in the assumptions regarding the informational structure.

The trade-off gives a rationale for more equal sharing since there is a need to balance the incentives to provide effort and to share information.

Our main result characterizes the optimal shares when full disclosure is feasible. It turns out that if agents are rather heterogeneous and projects do not differ too much in quality in case of "bad news", some concealment is optimal. Furthermore, giving a higher or equal share to the less productive agent is optimal in a range of parameters, since the team benefits from improved information sharing.

A limitation of our results comes from the specific form of the revenue function. We do not consider complementary effort. However, complementarities would only bring more symmetry into the model and would therefore work in favor of equal sharing. Hence, we considered the most conservative

[8] To see that $U_H^c = \gamma^2 U_L^c$, transform the maximization variable e_H into $z = \frac{e_H}{\gamma}$ and use the fact that for $\alpha = \frac{\gamma^2}{1+\gamma^2}$, $\gamma e_L(1) = e_H(1)$.

case regarding equal sharing. Complementarities are left to future research.

In this paper, we took the organizational form (partnership) as given and determined the optimal shape (sharing rule). Our model could also be used to study the benefits of partnerships compared to other organizational forms.

9 Appendix

9.1 Proof of Proposition 1

Total expected surplus under symmetric information is

$$E^{sym}[S(\boldsymbol{\alpha})] = \frac{1}{2}S_1(e_L^*(1), e_H^*(1)) + \frac{1}{2}S_P(e_L^*(P), e_H^*(P)) \tag{44}$$

$$= \left[\gamma_L^2\alpha_L(1-\frac{\alpha_L}{2}) + \gamma_H^2\alpha_H(1-\frac{\alpha_H}{2})\right]\frac{1+P^2}{2}. \tag{45}$$

Take $\alpha_H = 1-\alpha_L$. We want to choose α_L in order to maximize the total expected surplus. The first order condition is

$$\frac{\partial E^{sym}[S(\boldsymbol{\alpha})]}{\partial \alpha_L} = \left[\gamma_L^2(1-\alpha_L) - \gamma_H^2\alpha_L\right]\frac{1+P^2}{2} \overset{!}{=} 0$$

$$\Leftrightarrow \alpha_L^{sym} = \frac{\gamma_L^2}{\gamma_L^2+\gamma_H^2} \tag{46}$$

The second order condition is

$$\frac{\partial^2 E^{sym}[S(\boldsymbol{\alpha})]}{\partial \alpha_L^2} = -(\gamma_L^2+\gamma_H^2)\frac{1+P^2}{2} < 0 \tag{47}$$

Strictly concave in α_L, hence we found the unique maximum.

9.2 Proof of Proposition 2

Total expected surplus given disclosure strategies is

$$\begin{aligned} E[S(\boldsymbol{\alpha}, d_L, d_H)] = & \\ & \frac{1}{4}(d_L+d_H)[(\alpha_L\gamma_L^2P + \alpha_H\gamma_H^2P)P - \frac{1}{2}\alpha_L^2\gamma_L^2P^2 - \frac{1}{2}\alpha_H^2\gamma_H^2P^2] \\ & +\frac{1}{4}(1-d_L)[(\alpha_L\gamma_L^2q + \alpha_H\gamma_H^2\hat{E}_H[Q])q - \frac{1}{2}\alpha_L^2\gamma_L^2q^2 - \frac{1}{2}\alpha_H^2\gamma_H^2\hat{E}_H[Q]^2] \\ & +\frac{1}{4}(1-d_H)[(\alpha_L\gamma_L^2\hat{E}_L[Q] + \alpha_H\gamma_H^2q)q - \frac{1}{2}\alpha_L^2\gamma_L^2\hat{E}_L[Q]^2 - \frac{1}{2}\alpha_H^2\gamma_H^2q^2] \\ & +\frac{1}{2}[(\alpha_L\gamma_L^2\hat{E}_L[Q] + \alpha_H\gamma_H^2\hat{E}_H[Q]) - \frac{1}{2}\alpha_L^2\gamma_L^2\hat{E}_L[Q]^2 - \frac{1}{2}\alpha_H^2\gamma_H^2\hat{E}_H[Q]^2] \end{aligned} \tag{48}$$

We can simplify this expression by separating revenues and costs for each agent:

$$E[S(\boldsymbol{\alpha}, d_L, d_H)] = \tag{49}$$
$$\alpha_L\gamma_L^2[\frac{1}{4}(d_L + d_H)P^2 + \frac{1}{4}(1 - d_L)q^2 + \frac{1}{4}(1 - d_H)q\hat{E}_L[Q] + \frac{1}{2}\hat{E}_L[Q]]$$
$$+\alpha_H\gamma_H^2[\frac{1}{4}(d_L + d_H)P^2 + \frac{1}{4}(1 - d_H)q^2 + \frac{1}{4}(1 - d_L)q\hat{E}_H[Q] + \frac{1}{2}\hat{E}_H[Q]]$$
$$-\frac{1}{2}\alpha_L^2\gamma_L^2[\frac{1}{4}(d_L + d_H)P^2 + \frac{1}{4}(1 - d_L)q^2 + \frac{1}{4}(1 - d_H)\hat{E}_L[Q]^2 + \frac{1}{2}\hat{E}_L[Q]^2]$$
$$-\frac{1}{2}\alpha_H^2\gamma_H^2[\frac{1}{4}(d_L + d_H)P^2 + \frac{1}{4}(1 - d_H)q^2 + \frac{1}{4}(1 - d_L)\hat{E}_H[Q]^2 + \frac{1}{2}\hat{E}_H[Q]^2]$$

Note that $\frac{1}{4}(1 - d_i)q\hat{E}_j[Q] + \frac{1}{2}\hat{E}_j[Q] = \frac{1}{4}(1 - d_i)\hat{E}_j[Q]^2 + \frac{1}{2}\hat{E}_j[Q]^2$ for $i = L, H$. Hence, the expected surplus can be written as

$$E[S(\boldsymbol{\alpha}, d_L, d_H)] = \alpha_L\gamma_L^2\hat{q}_L + \alpha_H\gamma_H^2\hat{q}_H - \frac{1}{2}\alpha_L^2\gamma_L^2\hat{q}_L - \frac{1}{2}\alpha_H^2\gamma_H^2\hat{q}_H \tag{50}$$

with

$$\hat{q}_i = \frac{1}{4}\left[(d_i + d_{-i})P^2 + (1 - d_i)q^2 + (1 - d_{-i})q\hat{E}_i[Q] + 2\hat{E}_i[Q]\right] \tag{51}$$

and

$$\hat{E}_i[Q] = \frac{1 - d_{-i}}{3 - d_{-i}}q + \frac{2}{3 - d_{-i}}, \quad i = L, H. \tag{52}$$

Take $\alpha_H = 1 - \alpha_L$. We want to choose α_L in order to maximize the total expected surplus. The optimal shares given disclosure strategies follow from the first order condition

$$\frac{\partial E[S(\boldsymbol{\alpha}, d_L, d_H)]}{\partial \alpha_L} = \gamma_L^2\hat{q}_L - \gamma_H^2\hat{q}_H - \alpha_L\gamma_L^2\hat{q}_L + (1 - \alpha_L)\gamma_H^2\hat{q}_H \stackrel{!}{=} 0 \tag{53}$$

$$\Leftrightarrow \alpha_L^*(d_L, d_H) = \frac{\gamma_L^2\hat{q}_L}{\gamma_L^2\hat{q}_L + \gamma_H^2\hat{q}_H}. \tag{54}$$

The second order condition is

$$\frac{\partial^2 E[S(\boldsymbol{\alpha}, d_L, d_H)]}{\partial \alpha_L^2} = -\gamma_L^2\hat{q}_L - \gamma_H^2\hat{q}_H < 0. \tag{55}$$

Expected surplus given disclosure strategies is strictly concave in α_L, hence we found the unique maximum.

Note that $d_L = d_H$ implies that $\hat{q}_L = \hat{q}_H$. Hence, if both agents play the same disclosure strategy, we are back to the shares $\boldsymbol{\alpha}^{sym}$.

It is optimal to give a higher share to the less productive agent iff

$$\alpha_L^*(d_L, d_H) \geq \frac{1}{2} \Leftrightarrow \gamma_L^2 \geq \gamma_H^2\frac{\hat{q}_H}{\hat{q}_L}. \tag{56}$$

9.3 Proof of Lemma 1

P_i^d is strictly decreasing in i's share α_i:

$$\frac{\partial P_i^d}{\partial \alpha_i} = -\frac{q(1-q)\gamma_i^2\gamma_j^2}{\left[(\alpha_i\gamma_i^2 q + 2\alpha_j\gamma_j^2)q(\alpha_i\gamma_i^2 + 2\alpha_j\gamma_j^2)^3\right]^{1/2}} < 0. \tag{57}$$

P_i^d is strictly increasing in j's share α_j:

$$\frac{\partial P_i^d}{\partial \alpha_j} = \frac{q(1-q)\gamma_i^2\gamma_j^2}{\left[(\alpha_i\gamma_i^2 q + 2\alpha_j\gamma_j^2)q(\alpha_i\gamma_i^2 + 2\alpha_j\gamma_j^2)^3\right]^{1/2}} > 0. \tag{58}$$

P_i^c is strictly decreasing in i's share α_i:

$$\frac{\partial P_i^c}{\partial \alpha_i} = -\frac{\frac{2}{3}q(1-q)\gamma_i^2\gamma_j^2\alpha_j}{\left\{[\alpha_i\gamma_i^2 q + \frac{2}{3}\alpha_j\gamma_j^2(2+q)]q(\alpha_i\gamma_i^2 + 2\alpha_j\gamma_j^2)^3\right\}^{1/2}} < 0. \tag{59}$$

P_i^c is strictly increasing in j's share α_j:

$$\frac{\partial P_i^c}{\partial \alpha_j} = \frac{\frac{2}{3}q(1-q)\gamma_i^2\gamma_j^2\alpha_i}{\left\{[\alpha_i\gamma_i^2 q + \frac{2}{3}\alpha_j\gamma_j^2(2+q)]q(\alpha_i\gamma_i^2 + 2\alpha_j\gamma_j^2)^3\right\}^{1/2}} > 0. \tag{60}$$

δ_i is strictly increasing in i's share α_i:

$$\frac{\partial \delta_i}{\partial \alpha_i} = \frac{4q(1-q)\gamma_i^2\gamma_j^2\alpha_j}{(P^2-q^2)(\alpha_i\gamma_i^2 + 2\alpha_j\gamma_j^2)^2} > 0. \tag{61}$$

δ_i is strictly decreasing in j's share α_j:

$$\frac{\partial \delta_i}{\partial \alpha_j} = -\frac{4q(1-q)\gamma_i^2\gamma_j^2\alpha_j}{(P^2-q^2)(\alpha_i\gamma_i^2 + 2\alpha_j\gamma_j^2)^2} < 0. \tag{62}$$

9.4 Proof of Proposition 3

Agent L discloses if $P \geq P_L^d$ while agent H discloses if $P \geq P_H^d$. We want to find the shares α_L and $\alpha_H = 1 - \alpha_L$ that maximize the range of P in which both agents fully disclose. Hence, we need to find the α_L that minimizes the maximum of the two thresholds P_L^d and P_H^d. We know from (57) and (58) that the threshold P_L^d strictly decreases in α_L and P_H^d strictly increases in α_L. A change in α_L moves the thresholds in opposite directions. Thus, $\max[P_L^d, P_H^d]$ is minimized when the thresholds are just equal:

$$
\begin{aligned}
P_L^d &= P_H^d \\
\Leftrightarrow \left\{\frac{q[\alpha_L\gamma_L^2 q + 2(1-\alpha_L)\gamma_H^2]}{\alpha_L\gamma_L^2 + 2(1-\alpha_L)\gamma_H^2}\right\}^{1/2} &= \left\{\frac{q[(1-\alpha_L)\gamma_H^2 q + 2\alpha_L\gamma_L^2]}{(1-\alpha_L)\gamma_H^2 + 2\alpha_L\gamma_L^2}\right\}^{1/2} \\
\Leftrightarrow \alpha_L^{dis} &= \frac{\gamma_H^2}{\gamma_H^2 + \gamma_L^2}. \qquad (63)
\end{aligned}
$$

9.5 Proof of Proposition 4

We show that there exists a P^e for which $\alpha_L^*(P^e) = \frac{1}{2}$ and which lies in the range $[\underline{P}, \bar{P}]$:

1) Derivation of P^e:

$$
\alpha_L^*(P^e) = \frac{1}{2} \Leftrightarrow P^e = \left[\frac{q(q\gamma_L^2 + 2\gamma_H^2)}{\gamma_L^2 + 2\gamma_H^2}\right]^{1/2}. \qquad (64)
$$

2) The threshold P^e lies in the range $[\underline{P}, \bar{P}]$ for all $q \in (0, P)$ and $\gamma_L < \gamma_H \leq 1$:

$$
P^e \leq \bar{P} \Leftrightarrow \frac{2q\gamma_L^2\gamma_H^2(\gamma_H^2 - \gamma_L^2)(1-q)}{(\gamma_L^2 + 2\gamma_H^2)(\gamma_L^4 + 2\gamma_H^4)} \geq 0 \qquad (65)
$$

$$
P^e \geq \underline{P} \Leftrightarrow \frac{2q(\gamma_H^2 - \gamma_L^2)(1-q)}{3(\gamma_L^2 + 2\gamma_H^2)} \geq 0. \qquad (66)
$$

9.6 Proof of generality of voting rule

Take any voting rule in which the probability that a project is chosen increases if an agent votes for that project. We denote the probability that project P is implemented given agent i votes for project X and given agent i's expectation about the other agent's vote as ρ_X. ρ_X is higher if an agent votes for project P: $\rho_P > \rho_Q$. An agent then chooses project P if and only if

$$
\begin{aligned}
\rho_P E_i[U_i^P] + (1-\rho_P)E_i[U_i^Q] &\geq \rho_Q E_i[U_i^P] + (1-\rho_Q)E_i[U_i^Q] \qquad (67) \\
\Leftrightarrow (\rho_P - \rho_Q)E_i[U_i^P] &\geq (\rho_P - \rho_Q)E_i[U_i^Q] \\
\Leftrightarrow E_i[U_i^P] &\geq E_i[U_i^Q].
\end{aligned}
$$

Hence, agent i votes for the project from which he expects a higher utility.

Since the quality of project P is common knowledge, the expected utility of project P is independent of any additional information agents might have:

$$E_i[U_i^P] = \alpha_i(\alpha_i\gamma_i^2 P + \alpha_j\gamma_j^2 P)P - \frac{1}{2}\alpha_i^2\gamma_i^2 P^2. \tag{68}$$

In contrast, the expected utility of project Q depends on whether an agent received evidence about the quality of project Q. If an agent remains uninformed, his expected utility of project Q takes into account that if the quality of project Q is low, the other agent was informed:

$$\begin{aligned} E_i[U_i^Q](\text{no info}) =& \frac{1-d_j}{3-d_j}[\alpha_i(\alpha_i\gamma_i^2\hat{E}_i[Q] + \alpha_j\gamma_j^2 q)q - \frac{1}{2}\alpha_i^2\gamma_i^2\hat{E}_i[Q]^2] \qquad (69)\\ &+ \frac{2}{3-d_j}[\alpha_i(\alpha_i\gamma_i^2\hat{E}_i[Q] + \alpha_j\gamma_j^2\hat{E}_j[Q]) - \frac{1}{2}\alpha_i^2\gamma_i^2\hat{E}_i[Q]^2] \end{aligned}$$

with

$$E_i[Q] = \frac{1-d_j}{3-d_j}q + \frac{2}{3-d_j}. \tag{70}$$

The difference $E_i[U_i^Q](\text{no info}) - E_i[U_i^P]$ is decreasing in P. There is thus a threshold $\tilde{P}$ such that the difference is positive for $P \leq \tilde{P}$. By Assumption 1 ($P \leq E[Q]$) we thus know that $E_i[U_i^Q](\text{no info}) > E_i[U_i^P]$ for all possible P since

$$\begin{aligned} \tilde{P} > E[Q] \Leftrightarrow\ & \alpha_i[7 - d_j + q(5-3d_j)](1+d_j)\gamma_i^2(3-d_i) \qquad (71)\\ &+ 2\alpha_j(3-d_j)\gamma_j^2[(3-d_i)(3q+1)d_j + (q+3)d_i + 7 - 3q] > 0. \end{aligned}$$

Hence, if an agent is uninformed, he would vote for project Q.

If an agent is informed and discloses, both agents know the qualities of both projects and will provide individually optimal efforts. The agent will then vote for the project with higher quality, i.e. for project P:

$$\begin{aligned} & E_i[U_i^P] > E_i[U_i^Q](\text{info, disclosed}) \qquad (72)\\ \Leftrightarrow\ & \alpha_i(\alpha_i\gamma_i^2 P + \alpha_j\gamma_j^2 P)P - \frac{1}{2}\alpha_i^2\gamma_i^2 P^2 > \alpha_i(\alpha_i\gamma_i^2 q + \alpha_j\gamma_j^2 q)q - \frac{1}{2}\alpha_i^2\gamma_i^2 q^2\\ \Leftrightarrow\ & P > q. \end{aligned}$$

If an agent is informed and does not disclose, his expected utility of project Q takes into account that the other agent forms expectations about the quality of project Q:

$$E_i[U_i^Q](\text{info, concealed}) = \alpha_i(\alpha_i\gamma_i^2 q + \alpha_j\gamma_H^2\hat{E}_j[Q]) - \frac{1}{2}\alpha_i^2\gamma_i^2 q^2. \tag{73}$$

If this was lower than the expected utility of project P, he would have disclosed in the first place, making sure that the other agent also votes for project P.

He knows, if he discloses, that project P will be chosen. If he conceals, the other agent will vote for project Q and hence he can make sure that project Q is chosen by also voting for project Q.

9.7 Proof of Lemma 2

Throughout this proof, we denote $\alpha_L = \alpha$ and $\alpha_H = 1 - \alpha$. We show with a series of lemmata that at least one agent fully discloses and none of them fully conceals if $P \in [\underline{P}, \sqrt{q})$ and both disclose if $P \geq \sqrt{q}$.

Lemma 3. *If $P \geq \underline{P}$, agent L is willing to disclose at least partially.*

Proof. $P_L^c(\alpha)$ is strictly decreasing in α (see 9.3) and $P_L^c(\alpha = 0) = \underline{P}$. Hence, $P_L^c(\alpha) \leq \underline{P}$ for all $\alpha \in [0, 1]$. □

Lemma 4. *If $P \geq \underline{P}$, agent H is willing to disclose at least partially.*

Proof. $P_H^c(\alpha)$ is strictly increasing in α (see 9.3) and $P_H^c(\alpha = 1) = \underline{P}$. Hence, $P_H^c(\alpha) \leq \underline{P}$ for all $\alpha \in [0, 1]$. □

Lemma 5. *If $P \geq \underline{P}$, at least one of the agents is willing to fully disclose.*

Proof. For $\alpha \leq \frac{\gamma_H^2}{\gamma_L^2 + \gamma_H^2}$, we have $P_H^d(\alpha) \leq \underline{P}$. For $\alpha \geq \frac{\gamma_H^2}{\gamma_L^2 + \gamma_H^2}$, we have $P_L^d(\alpha) \leq \underline{P}$. Thus, for all $\alpha \in [0, 1]$, $\min[P_L^d(\alpha), P_H^d(\alpha)] \leq \underline{P}$. □

Lemma 6. *If $P \geq \sqrt{q}$, both agents are willing to fully disclose, independent of α.*

Proof. $P_L^d(\alpha)$ is strictly decreasing in α (see 9.3) and $P_L^d(\alpha = 0) = \sqrt{q}$. Hence, $P_L^d(\alpha) \leq \sqrt{q}$ for all $\alpha \in [0, 1]$. $P_H^d(\alpha)$ is strictly increasing in α (see 9.3) and $P_H^d(\alpha = 1) = \sqrt{q}$. Hence, $P_H^d(\alpha) \leq \sqrt{q}$ for all $\alpha \in [0, 1]$. □

These Lemmata imply that in the range $P \in [\underline{P}, \sqrt{q})$, three types of equilibria can arise: both agents disclose, agent L discloses while agent H mixes and agent L mixes while agent H discloses. In the range $P \in [\sqrt{q}, E[Q])$, both agents always fully disclose information.

9.8 Proof of Proposition 5

Throughout this proof, we denote $\alpha_L = \alpha$ and $\alpha_H = 1 - \alpha$.

We showed in Section 5.1 that $\underline{\alpha}$ is optimal in the range $\alpha \in [\underline{\alpha}, \bar{\alpha}]$, i.e. if there is full disclosure.

If $\alpha \leq \underline{\alpha}$, agent L starts concealing partially. We prove in 1) that the surplus when agent H is disclosing and agent L partially conceals is concave in α. We also show that it is strictly increasing at $\underline{\alpha}$ for $P \in [\hat{P}, \bar{P}]$, with $\hat{P} \in [\underline{P}, \bar{P}]$. Hence, for such P, $\alpha < \underline{\alpha}$ would yield lower surplus than $\underline{\alpha}$. $\underline{\alpha}$ brings us back to full disclosure. For $P \in [\underline{P}, \hat{P}]$, $\alpha < \underline{\alpha}$ would yield higher surplus than $\underline{\alpha}$ and hence some concealment is optimal.

If $\alpha \geq \bar{\alpha}$, agent H starts concealing partially. We prove in 2) that surplus is decreasing at $\alpha \geq \bar{\alpha}$ for all $P \in [\underline{P}, \bar{P})$. Hence, the maximal surplus we get for $\alpha \in [\bar{\alpha}, 1]$ is at $\bar{\alpha}$. Since we are then back to full disclosure, $\underline{\alpha}$ would yield a higher surplus.

1) Proof that $\underline{\alpha}$ is optimal in $[0, \underline{\alpha}]$ if $P \in [\hat{P}, \sqrt{q})$.

We denote the surplus if agent L mixes and agent H discloses fully as

$$\begin{aligned} S_{md} = \; & \frac{1}{4}(1 + d_L) S_P[e_L(P), e_H(P)] \\ & + \frac{1}{4}(1 - d_L) S_q[e_L(q), e_H(\hat{E}_H[Q])] \\ & + \frac{1}{2} S_1[e_L(\hat{E}_L[Q]), e_H(\hat{E}_H[Q])]. \end{aligned} \tag{74}$$

We first show that this surplus is concave in α for $P \geq \underline{P}$. Then we find conditions for the surplus to be increasing in α at $\underline{\alpha}$.

Surplus S_{md} is strictly concave in α for $P \geq \underline{P}$

Take the second derivative:

$$\begin{aligned}\frac{\partial^2 S_{md}}{\partial \alpha^2} =& \frac{1}{4}\frac{\partial^2 d_L}{\partial \alpha^2}\{S_P[e_L(P), e_H(P)] - S_q[e_L(q), e_H(\hat{E}_H[Q])]\} \\ &+ \frac{1}{2}\frac{\partial^2 S_1[e_L(\hat{E}_L[Q]), e_H(\hat{E}_H[Q])]}{\partial \alpha^2} \\ &+ \frac{1}{2}\frac{\partial d_L}{\partial \alpha}\left[\frac{\partial S_P[e_L(P), e_H(P)]}{\partial \alpha} - \frac{\partial S_q[e_L(q), e_H(\hat{E}_H[Q])]}{\partial \alpha}\right] \\ &+ \frac{1}{4}(1 + d_L)\frac{\partial^2 S_P[e_L(P), e_H(P)]}{\partial \alpha^2} \\ &+ \frac{1}{4}(1 - d_L)\frac{\partial^2 S_q[e_L(q), e_H(\hat{E}_H[Q])]}{\partial \alpha^2}.\end{aligned} \tag{75}$$

The second derivative depends on P only via P^2. We therefore replace P^2 by x and get a new function $C(x)$ where $C(P^2) = \frac{\partial^2 S_{md}}{\partial \alpha^2}(P)$. Note that, if $C(x^*) = 0$ then $\frac{\partial^2 S_{md}}{\partial \alpha^2}(P^*) = 0$ with $P^* = \sqrt{x^*}$. Furthermore $C(x) > 0 \Leftrightarrow \frac{\partial^2 S_{md}}{\partial \alpha^2}(P) > 0$ for $P = \sqrt{x}$. Therefore, by showing that $C(x)$ is negative for $x \in [\underline{P}^2, E[Q]^2)$, we also show that $\frac{\partial^2 S_{md}}{\partial \alpha^2}(P)$ is negative for $P \in [\underline{P}, E[Q])$.

We can indeed show that $C(x)$ is negative for $x \in [\underline{P}^2, E[Q]^2)$ by proving that 1) C strictly decreases in x and 2) C is strictly negative at $x = \underline{P}^2$. Hence it is strictly negative also for all $x > \underline{P}^2$. This implies that the second derivative is strictly negative for $P \in [\underline{P}, E[Q])$.

1) C strictly decreases in x:

$$\frac{\partial C}{\partial x} = -\frac{5}{4}\frac{[2 - (2 - \gamma^2)\alpha]^3[(\gamma^2 + \frac{2}{5})q + \frac{1}{5}(2 - \gamma^2)]}{q[\alpha\gamma^2 + 2(1 - \alpha)]^3} < 0. \tag{76}$$

2) At $x = \underline{P}^2$, $C(x)$ is strictly negative:

$$T \equiv \frac{4}{5}q[\alpha\gamma^2 + 2(1 - \alpha)]^3 C(\underline{P}^2). \tag{77}$$

Whenever T is strictly negative, $C(\underline{P}^2)$ is strictly negative too. We can show that T is strictly concave in α:

$$\begin{aligned}\frac{\partial^2 T}{\partial \alpha^2} =& -\frac{8}{5}[\alpha\gamma^2 + 2(1 - \alpha)]q(2 - \gamma^2)(\gamma^2 + 1) \\ &[(1 + \gamma^2)q^2 + 3q(1 - \gamma^2) + 2 - \gamma^2] < 0.\end{aligned} \tag{78}$$

At $\alpha = 1$, T is still increasing and negative:

$$\left.\frac{\partial T}{\partial \alpha}\right|_{\alpha=1} = \frac{4}{5} q\gamma^4(\gamma^2+1)[(\gamma^2+1)q^2 + 3(1-\gamma^2)q + 2 - \gamma^2] > 0, \quad (79)$$

$$T(\alpha = 1) = -\frac{4}{15} q\gamma^6[(3\gamma^2 - 4q + 6)q + \gamma^2(1-q^2) + 1] < 0. \quad (80)$$

Hence, $T < 0$ for all $\alpha \leq 1$. This implies that $C(\underline{P}^2) < 0$ for $\alpha \in [0, 1]$.

We showed that $C(x)$ is strictly decreasing in x and already strictly negative at $x = \underline{P}^2$. This implies that S_{md} is strictly concave in α for $P \geq \underline{P}$.

Surplus S_{md} is increasing in α at $\underline{\alpha}$ if $P \in [\hat{P}, \sqrt{q}]$ with $\hat{P} \in (\underline{P}, \bar{P})$.

We want to show that the derivative of S_{md} wrt α at $\underline{\alpha}$ ($=S'_{md}(\underline{\alpha})$) is positive if the quality of project P is high enough. Define

$$D(x) \equiv 8q(1-q)[2(q-x) + \gamma^2(x-q^2)]S'_{md}(\underline{\alpha}, P) \quad (81)$$

with $x = P^2$. Given $x \in [\underline{P}^2, q]$, in order to show that $S'_{md}(\underline{\alpha})$ is positive at a certain P, we need to show that $D(x)$ is positive at $x = P^2$.

We first observe (a) that $D(x)$ is strictly increasing in x for $x \in [\underline{P}^2, q]$. Then we show in (b) that $D(x)$ is strictly positive at $x = \bar{P}^2$ and in (c) that $D(x)$ is strictly negative at $x = \underline{P}^2$ if $q > \bar{q}$. These observations tell us that if $q > \bar{q}$ there exists a threshold $\hat{x} = \hat{P}^2 \in (\underline{P}^2, \bar{P}^2)$ such that $D(x) > 0$ if and only if $x \in [\hat{P}^2, q)$, which implies $S'_{md}(\underline{\alpha}) > 0$ if and only if $P \in [\hat{P}, \sqrt{q})$. When $q < \bar{q}$, $D(x) > 0$ for all $x \in [\underline{P}^2, q)$ and thus $S'_{md}(\underline{\alpha}) > 0$ for all $P \in [\underline{P}, \sqrt{q})$.

a) $D(x)$ is strictly increasing in x:

The first derivative of $D(x)$ wrt x is convex x:

$$\frac{\partial^3 D(x)}{\partial x^3} = 18\gamma^2(2-\gamma^2) > 0, \quad (82)$$

already increasing and positive at $x = \underline{P}^2$:

$$\left.\frac{\partial^2 D(x)}{\partial x^2}\right|_{\underline{P}^2} = 2(1-q)[(8+\gamma^4)(1+q) - 6\gamma^2] > 0. \quad (83)$$

$$\left.\frac{\partial D(x)}{\partial x}\right|_{\underline{P}^2} = \frac{4}{3}q(1-q^2)[(4-\gamma^4)q + 4\gamma^4 + 2 - \frac{3}{2}\gamma^2(1-q)] > 0. \quad (84)$$

Hence the first derivative with respect to x is strictly positive for all $x \geq \underline{P}^2$.

b) $D(x)$ is strictly positive at $x = \bar{P}^2$:

$$D(\bar{P}^2) = \frac{8q^2(1-q)^3(1+\gamma^2)\gamma^4[1 + 2\gamma^2 + \gamma^6 + \frac{1}{2}\gamma^4(1+3q)]}{(\gamma^4+2)^3} > 0. \quad (85)$$

c) $D(x)$ is strictly negative at $x = \underline{P}^2$ if $q > \bar{q}$:

$$\begin{aligned} D(\underline{P}^2) &= \frac{4}{9}(1+\gamma^2)q^2(1-q)^2[7\gamma^2 - 4 - (2-\gamma^2)q^2 - (6-4\gamma^2)q] < 0 \\ &\Leftrightarrow 0 > 7\gamma^2 - 4 - (2-\gamma^2)q^2 - (6-4\gamma^2)q \\ &\Leftrightarrow \gamma < \sqrt{\frac{2(2+3q+q^2)}{7+4q+q^2}} \equiv \underline{\gamma}(q). \end{aligned} \quad (86)$$

Homogeneity γ must be low enough to make it negative. If γ is low enough $\gamma < \underline{\gamma}(q)$, there exists a unique $\hat{P} \in (\underline{P}, \bar{P})$ for which $S'_{md}(\underline{\alpha}, \hat{P}) = 0$. The threshold $\underline{\gamma}(q)$ is strictly increasing in q:

$$\frac{\partial \underline{\gamma}(q)}{\partial q} = \frac{13 + 10q + q^2}{2^{1/2}(7+4q+q^2)^{3/2}(2+3q+q^2)^{1/2}} > 0, \quad (87)$$

2) <u>Proof that $\bar{\alpha}$ is optimal in $[\bar{\alpha}, 1]$</u>

The ex-ante expected total surplus of the team if agent L always discloses and agent H discloses with probability d_H is

$$\begin{aligned} S_{dm} =& \frac{1}{4}(1+d_H)S_P[e_L(P), e_H(P)] + \frac{1}{4}(1-d_H)S_q[e_L(\hat{E}_L[Q]), e_H(q)] \\ &+ \frac{1}{2}S_1[e_L(\hat{E}_L[Q]), e_H(\hat{E}_H[Q])]. \end{aligned} \quad (88)$$

We want to show that S_{dm} is decreasing for $\alpha \in [\bar{\alpha}, 1]$ in the range $P \in [\underline{P}, \sqrt{q})$. α^{dis} is the lowest share for which the equilibrium in which L fully discloses and H mixes exists given $P \geq \underline{P}$. If α was smaller ($\alpha < \alpha^{dis}$), agent H would want to disclose for all $P \geq \underline{P}$, i.e. $P_H^d(\alpha) < \underline{P}$. Hence,

$\bar{\alpha} \geq \alpha^{dis}$ and therefore it is sufficient to show that S_{dm} is decreasing for $\alpha \in [\alpha^{dis}, 1]$.

Surplus S_{dm} is strictly decreasing for $\alpha \in [\alpha^{dis}, 1]$

Consider the first derivative of S_{dm} with respect to α:

$$
\begin{aligned}
S'_{dm} = \frac{\partial S_{dm}}{\partial \alpha} =& \frac{1}{4}\frac{\partial d_H}{\partial \alpha}\{S_P[e_L(P), e_H(P)] - S_q[e_L(\hat{E}_L[Q]), e_H(q)]\} \\
&+ \frac{1}{4}(1 + d_H)\frac{\partial S_P[e_L(P), e_H(P)]}{\partial \alpha} \\
&+ \frac{1}{4}(1 - d_H)\frac{\partial S_q[e_L(\hat{E}_L[Q]), e_H(q)]}{\partial \alpha} \\
&+ \frac{1}{2}\frac{\partial S_1[e_L(\hat{E}_L[Q]), e_H(\hat{E}_H[Q])]}{\partial \alpha}.
\end{aligned} \tag{89}
$$

While the first term is negative, the other terms can be positive or negative. It is thus difficult to show directly that S'_{dm} is negative. However, we can show that it is convex in α:

$$
\frac{\partial^2 S'_{dm}}{\partial \alpha^2} = \frac{9\gamma^4 q(1-q)}{[2\alpha\gamma^2 + (1-\alpha)]^4} > 0. \tag{90}
$$

We thus only have to show that S'_{dm} is negative at $\alpha = \alpha^{dis}$ and $\alpha = 1$.

1) S'_{dm} is negative at $\alpha = \alpha^{dis}$:

$$
\begin{aligned}
S'_{dm}(\alpha^{dis}) =& -\frac{1}{24(1+\gamma^2)q^2}\{(2\gamma^4 - 5)q^4 - (\gamma^2 + 7)q^3 \\
&+ [12 + (4\gamma^6 - 8\gamma^4 - 15\gamma^2 + 21)P^2]q^2 \\
&+ P^2(3 - 12\gamma^4 + 9\gamma^2)q - 3P^4(2\gamma^2 - 1)\gamma^2\}.
\end{aligned} \tag{91}
$$

We replace $x = P^2$ and hence have to show that $S'_{dm}(\alpha^{dis})$ is strictly negative for all $x \in [\underline{P}^2, q]$. Take the second derivative wrt to x:

$$
\frac{\partial^2 S'_{dm}(\alpha^{dis})}{\partial x^2} = \frac{1}{2}\frac{(\gamma^2 - \frac{1}{2})\gamma^2}{(1+\gamma^2)q^2}. \tag{92}
$$

The second derivative is positive if $\gamma^2 > \frac{1}{2}$ and negative if $\gamma^2 < \frac{1}{2}$. If it is negative ii), $S'_{dm}(\alpha^{dis})$ is concave in x and we have to show that it is decreasing and negative at $x = \underline{P}^2$. If it is positive iii), $S'_{dm}(\alpha^{dis})$ is convex in x and we have to show that it is negative at $x = \underline{P}^2$ and at $x = q$.

i) $S'_{dm}(\alpha^{dis})$ is strictly negative for all x if $\gamma^2 = \frac{1}{2}$:

$$S'_{dm}(\alpha^{dis}, \gamma^2 = \frac{1}{2}) = \\ -\frac{3q(1-q^2) + 5q(1-q) + (8q+3)x}{24q} < 0. \tag{93}$$

ii) $S'_{dm}(\alpha^{dis})$ is strictly negative for all $x \in [\underline{P}^2, \bar{P}^2]$ if $\gamma^2 < \frac{1}{2}$:

If $\gamma^2 < \frac{1}{2}$, $S'_{dm}(\alpha^{dis})$ is strictly concave in x. In this case we have to show that $S'_{dm}(\alpha^{dis})$ is a) decreasing in x at $x = \underline{P}^2$ and b) negative at $x = \underline{P}^2$.

a) $S'_{dm}(\alpha^{dis})$ is strictly decreasing in x at $x = \underline{P}^2$ for $q > 0$:

$$\left.\frac{\partial S'_{dm}(\alpha^{dis})}{\partial x}\right|_{\underline{P}^2} < 0$$
$$\Leftrightarrow -\frac{3 + 13\gamma^2 - 20\gamma^4 + q(4\gamma^6 - 12\gamma^4 - 13\gamma^2 + 21)}{24(1+\gamma^2)q} < 0$$
$$\Leftrightarrow q > \frac{20\gamma^4 - 13\gamma^2 - 3}{4\gamma^6 - 12\gamma^4 - 13\gamma^2 + 21}. \tag{94}$$

This threshold for q is strictly negative for $\gamma^2 < \frac{1}{2}$: Define $T(z) \equiv \frac{20z^2-13z-3}{4z^3-12z^2-13z+21}$. Then we have to show that $T(z) < 0$ for $z < \frac{1}{2}$. The denominator DN is always strictly positive since it is concave in z ($DN'' = -24(1-z)$) and it is strictly positive at $z = 0$ (DN(z=0)=21) and at $z = \frac{1}{2}$ (DN(z=1/2)=12). The nominator N is strictly negative since it is convex in z ($N'' = 40$) and strictly negative at $z = 0$ ($N(z=0) = -3$) and $z = \frac{1}{2}$ ($N(z=1/2) = -\frac{9}{2}$) and hence also for all $z = \gamma^2 \in (0, \frac{1}{2})$.

b) $S'_{dm}(\alpha^{dis})$ is strictly negative at $x = \underline{P}^2$:

$$S'_{dm}(\alpha^{dis}, \underline{P}^2) = -\frac{1}{36(1+\gamma^2)}[(2q^2+4q)\gamma^6 \\ - (2q^2+18q+16)\gamma^4 \\ + (11 - 7q^2 - 10q)\gamma^2 + 3q^2 + 12q + 21]. \tag{95}$$

We replace $z = \gamma^2$ and then have to show that R is strictly positive for $z < \frac{1}{2}$:

$$R \equiv (2q^2 + 4q)z^3 - (2q^2 + 18q + 16)z^2 \\ + (11 - 7q^2 - 10q)z + 3q^2 + 12q + 21 > 0. \tag{96}$$

R is strictly concave in z ($R'' = -[4(8-3q^2z)+12q(3-2z)+4q^2]$) and strictly positive at $z = 0$ ($R(z = 0) = 3q^2+12q+21$) and at $z = 1$ ($R(z = 1) = 16 - 4q^2 - 12q$). Hence, $R > 0$ for all $z \in [0, 1]$.

It follows that $S'_{dm}(\alpha^{dis}, \underline{P}^2) < 0$ for $q \in [0, p]$ and $z \in [0, 1]$.

iii) $S'_{dm}(\alpha^{dis})$ is strictly negative for all $x \in [\underline{P}^2, q]$ if $\gamma^2 > \frac{1}{2}$:

If $\gamma^2 > \frac{1}{2}$, $S'_{dm}(\alpha^{dis})$ is strictly convex in x. We just showed that $S'_{dm}(\alpha^{dis})$ is strictly negative at $x = \underline{P}^2$ for $\gamma^2 \in [0, 1]$. Hence, we are left to show that $S'_{dm}(\alpha^{dis})$ is also strictly negative at $x = q$. Convexity then implies that $S'_{dm}(\alpha^{dis})$ is strictly negative for all $x \in [\underline{P}^2, q]$.

$$S'_{dm}(\alpha^{dis}, q) = \\ \frac{(18 + 8q - 2q^2)\gamma^4 - 4q\gamma^6 + (16q - 12)\gamma^2 + 5q^2 - 14q - 15}{24(1 + \gamma^2)}. \tag{97}$$

We can show that this is a) strictly convex in q, b) strictly negative at $q = 0$ and c) strictly negative at $q = 1$:

a) $S'_{dm}(\alpha^{dis}, q)$ is strictly convex in q:

$$\frac{\partial^2 S'_{dm}(\alpha^{dis}, q)}{\partial q^2} = \frac{5 - 2\gamma^4}{12(1 + \gamma^2)} > 0. \tag{98}$$

b) $S'_{dm}(\alpha^{dis}, q)$ is strictly negative at $q = 0$:

$$S'_{dm}(\alpha^{dis}, q, q = 0) = -\frac{15 + 12\gamma^2 - 18\gamma^4}{24(1 + \gamma^2)} < 0. \tag{99}$$

c) $S'_{dm}(\alpha^{dis}, q)$ is non-positive at $q = 1$:

$$S'_{dm}(\alpha^{dis}, q, q = 1) = -\frac{(24 - 4\gamma^2)(1 - \gamma^4)}{24(1 + \gamma^2)} < 0. \tag{100}$$

2) S'_{dm} is strictly negative at $\alpha = 1$:

$$S'_{dm}(\alpha = 1) = -\frac{1}{8q}[7P^2 q + P^2 + 4q(1-q)]. \tag{101}$$

We showed that the surplus is decreasing in α. Hence, it is optimal to choose $\bar{\alpha}$.

9.9 Proof of Proposition 6

Throughout this proof, we denote $\alpha_L = \alpha$ and $\alpha_H = 1 - \alpha$. P^e (defined by $\alpha^*(P^e) = \frac{1}{2}$) lies in the range $[\hat{P}, \bar{P}]$, if and only if $S'_{md}(\bar{\alpha})$ is increasing at P^e. We show that this is true whenever $\gamma^2 > \sqrt{6} - 2$ and $q < \tilde{q}$. If these conditions are fulfilled, equal sharing is optimal at P^e.

$S'_{md}(\underline{\alpha})$ is positive at P^e if $\gamma^2 > \sqrt{6} - 2$ and $q < \tilde{q} \in (0, 1]$:

$$S'_{md}(\underline{\alpha}, P^e) = \frac{(q^2+1)\gamma^6 + (6 - 2q^2 + 2q)\gamma^4 + (6 - 2q^2 - 4q)\gamma^2 - 4q - 4}{4(\gamma^2+2)^2}. \tag{102}$$

This is strictly decreasing in q:

$$\frac{\partial S'_{md}(\underline{\alpha}, P^e)}{\partial q} = -\frac{(4 - 2\gamma^2)q\gamma^4 + (4 - 2\gamma^2)\gamma^2 + 4q\gamma^2 + 4}{4(\gamma^2+2)^2} < 0. \tag{103}$$

$S'_{md}(\underline{\alpha}, P^e)$ is strictly positive at $q = 0$ if $\gamma^2 > \sqrt{6} - 2 \approx 0.4495$. It is strictly negative at $q = 1$ if $\gamma^2 < 1$. Hence, if $\gamma^2 > \sqrt{6} - 2$, there exists a threshold $\tilde{q} \in (0, 1)$ such that $S'_{md}(\underline{\alpha}, P^e) > 0$ if $q < \tilde{q}$:

$$\tilde{q} = \frac{(4 - \gamma^{12} - 4\gamma^{10} + 9\gamma^8 + 24\gamma^6 + 4\gamma^4)^{1/2}}{\gamma^2(2 + 2\gamma^2 - \gamma^4)} - \frac{1}{\gamma^2}. \tag{104}$$

If $\gamma^2 < \sqrt{6} - 2$, $S'_{md}(\underline{\alpha}, P^e)$ is negative for all q, so equal shares are not optimal.

9.10 Proofs when different ability to receive information

We assume that given project Q is of low quality, agents receive information with independent probabilities $\pi_L \in (0, 1)$ and $\pi_H \in (0, 1)$. Agent i discloses information iff

$$U_i^d(\boldsymbol{\alpha}, P, e_i(P), e_j(P)) \geq \pi_j d_j U_i^d(\boldsymbol{\alpha}, P, e_i(P), e_j(P)) + \pi_j(1-d_j)U_i^c(\boldsymbol{\alpha}, q, e_i(q), e_j(q)) + (1-\pi_j)U_i^c(\boldsymbol{\alpha}, q, e_i(q), e_j(\hat{E}_j[Q])). \tag{105}$$

While agent i knows that quality is q, agent j might remain uninformed and has to form expectations over the quality of project Q. Agent i knows that if agent j remained uninformed, by Basian updating, he will believe quality of project Q is

$$\hat{E}_j[Q] = \frac{(1-d_i\pi_i)(1-\pi_j)q+1}{(1-d_i\pi_i)(1-\pi_j)+1}. \tag{106}$$

Agent i discloses iff $P \geq P_i^d$, with

$$P_i^d = \left[\frac{q\{q\alpha_i\gamma_i^2[2-\pi_i-\pi_j(1-\pi_i)] + 2\alpha_j\gamma_j^2[1+(1-\pi_j)(1-\pi_i)q]\}}{(\alpha_i\gamma_i^2+2\alpha_j\gamma_j^2)[2-\pi_i-\pi_j(1-\pi_i)]}\right]^{1/2}. \tag{107}$$

This threshold decreases in an agent's own share α_i and increases in the other agent's share α_j:

$$\frac{\partial P_i^d}{\partial \alpha_i} = -\frac{2\gamma_i^2\gamma_j^2\alpha_j q(1-q)}{(\alpha_i\gamma_i^2+2\alpha_j\gamma_j^2)^2[2-\pi_i-\pi_j(1-\pi_i)]} < 0, \tag{108}$$

$$\frac{\partial P_i^d}{\partial \alpha_j} = \frac{2\gamma_i^2\gamma_j^2\alpha_i q(1-q)}{(\alpha_i\gamma_i^2+2\alpha_j\gamma_j^2)^2[2-\pi_i-\pi_j(1-\pi_i)]} > 0. \tag{109}$$

Consider the benchmark of symmetrically informed agents (equivalent to full disclosure). The probability that they remain uninformed even though the quality of project Q is low is $(1-\pi_L)(1-\pi_H)$. If agents remain uninformed, they update beliefs about the quality of project Q to (106) with $d_L = d_H = 1$. In this situation, $\boldsymbol{\alpha}^{sym}$ maximizes the team's surplus.

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