Overconfidence and Team Production: When Ignorance About the Biases of Others is Bliss*

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Abstract. The present paper addresses the consequences of overconfidence within an intuitive model of team production taken from Gervais and Goldstein (2007). More specifically, it adds to the discussion by Gervais and Goldstein – who show that overconfidence of one team member may increase not only team productivity but also both agents' payoffs – in two ways. First, regarding the value of information about biases, we show that it is always optimal for an overconfident agent to be unaware of a potential bias of the colleague. Moreover, we show that individual payoffs may still be higher in a team of two overconfident agents than in a team of two rational ones irrespective of the agents' awareness of their colleagues' bias. Thus, our analysis suggests that overconfidence can indeed persist to a notable degree once it emerges in a society of rational agents.

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1 Introduction

It is well-known that many individuals tend to overestimate their own skills. This is confirmed by a broad field of research especially in psychology (e.g. Svenson, 1981; or Taylor and Brown, 1988). Moreover, several studies indicate that managers in particular are prone to such biases (see Larwood and Whittaker, 1977; or Weinstein, 1980). Analysing the economic effects of such managerial overconfidence, Malmendier and Tate (2005, 2006), for example, find that managers undertake more welfare-reducing mergers and investments as a result of the respective misconception of their ability. Another effect of overconfidence is that individuals who overestimate their own skill tend to work harder than individuals assessing their ability correctly (see Felson, 1984; Locke and Latham, 1990; and Heath et al., 1999).

The economic consequences of overconfidence, in particular of the effect that overconfident agents tend to exert a higher effort (because they perceive their marginal productivity as being higher), are addressed in a recent paper by Gervais and Goldstein (2007). Analysing a model of team production with effort complementarities, they show how overconfidence reduces free-riding and, thus, is beneficial for the principal. Moreover, they show that when a team consists of one overconfident and one rational agent, also the effort of the rational agent (who is aware of his colleague's bias) increases due to the effort complementarities. In particular, the higher effort of the biased agent increases the marginal productivity of the rational agent. Consequently, the rational agent increases his own effort, too. This increase in effort can give rise to a Pareto-improvement in the sense that not only the principal and the rational agent are better off but also the overconfident agent is better off compared to a team of two rational agents: If the bias is moderate and/or synergy effects are sufficiently large, the cost of the overconfident agent's overinvestment in effort is more than compensated by the induced increase in the rational agent's effort. Thus, although not the main focus of their study, the analysis by Gervais and Goldstein indicates that overconfidence may be beneficial not only for the principal but also for the (biased) agent.

In the present paper, we take up the idea that overconfidence may lead to an Pareto-improvement and elaborate on the potential individual benefits from being overconfident. To begin with, we consider the question in how far overconfident agents, who are obviously not aware of their own bias, would benefit from being aware of potential biases of others. As we will see, it is always optimal for an overconfident agent to be unaware of the colleague's bias. In a second step, we ask whether a team of two overconfident agents still outperforms a fully rational team in terms of individual payoffs. In doing so, we focus in particular on the individual optimal case where both agents are unaware of their colleague's bias in order to see whether overconfidence might improve not only the principal's but also the agents' situation (recall that team production with one or two overconfident agents is always higher than in a fully rational team because of the agents' increased effort). Thus, while the first question asks for the individual optimal information status taking overconfidence as given, the second addresses the comparison between the agents' payoffs with and without overconfidence.

Studying individual payoff effects in a team with two overconfident agents is interesting because, if individual payoffs were higher also in the case with two overconfident agents, this would give considerable support to a position advocating the advantage of such a bias: We already know from the analysis by Gervais and Goldstein that overconfidence is beneficial if the respective agent is paired with a rational colleague; and, due to increased efforts, overconfidence is obviously beneficial for the principal. In that sense, the ground is already prepared for overconfidence to emerge in a society of rational agents – at least to some degree. If on top of that individual payoffs in teams of two overconfident agents were again higher than in teams of two rational agents, this would render the prospects for the persistence of such a bias even better. In particular, it would imply that – from the perspective of both the agents and the principal – the worst that can happen is to have a team of two rational agents. Accordingly, it would substantially strengthen any argument in favour of a widespread occurrence of overconfidence.

In the remainder of this paper we first show that being aware only of the others' true abilities but not of their overconfidence is indeed beneficial for an agent who is overconfident himself - despite the fact that being aware of the biases of others is closer to the true state of the world. The intuition behind this result is rather straightforward. Due to the synergy effects, overconfidence of other team members increases the optimal effort level for any agent who is aware of these biases. However, if an agent is overconfident himself, his effort level is already above the individual optimum – because of his own bias which he is unaware of. Awareness of the other team member's bias, then, leads to a further (suboptimal) increase in his effort. By contrast, lack of such awareness keeps the expectation about the colleague's effort and, hence, the agent's extra effort, which he exerts in order to exploit effort complementarities, low. In combination with the increase in the agent's effort due to his own overconfidence this, however, brings the agent's resulting effort choice closer to the overall individual optimum. In a sense, all necessary upward-adjustments in the agent's effort (in order to exploit the synergies from the colleague's overconfidence) are already accounted for in the agent's actual effort choice – although for a different reason, namely the agent's own overconfidence (which he is unaware of).

Based on this result, we then proceed to show that individual welfare in a team with two overconfident agents is indeed higher than in a fully rational team, provided that either synergy effects are sufficiently large or biases are moderate. In fact, this result holds both for teams with two overconfident agents in general and for teams with two overconfident agents who are both unaware of each other's bias in particular. Again, the fact that individual payoffs are also enhanced for a team with two overconfident agents who are unaware of each other's bias is quite intuitive (all other cases follow a similar reasoning). In particular, an overconfident agent 2 who is unaware of a potential bias of his colleague, agent 1, exerts the same effort irrespective of whether agent 1 is actually rational or overconfident. This is because by assumption agent 2 is only aware of agent 1's ability and unaware of his own bias. Yet, if agent 1 is rational, we already know that he exerts an higher effort when he is paired with an overconfident agent 2 than when he is paired with a rational one (as he anticipates agent 2's higher effort due to agent 2's overconfidence and exploits the synergies). If this additional effort exerted by a rational agent 1, who is paired with an overconfident agent 2, suffices to overcompensate the biased agent 2 for his extra effort, then the additional effort exerted by a biased agent 1 (who exerts a higher effort only because of his own overconfidence but not because of his awareness of agent 2's bias) should have a similar effect on the payoff of an overconfident agent 1. Consequently, compared to the fully rational case, overconfidence in its "individual optimal form" (i.e. combined with unawareness of the colleague's bias) still provides a comparative advantage for both the team (due to the agents' increased efforts) and the individual. Moreover, as long as biases are small, even awareness of the other's bias will not obliterate these gains as the additional cost from any extra effort exerted in order to complement the colleague's bias is small.

The rest of the paper is organized as follows: In Section 2, we introduce the baseline model proposed by Gervais and Goldstein (2007) and briefly review the results in case one agent is overconfident and one is rational. We consider the different cases with two overconfident agents in Section 3. In Section 4 we conclude. All proofs and technical derivations are gathered in the Appendix.

2 Model and Review of First Results

This section is subdivided into two parts: First in Section 2.1, we introduce the baseline model proposed by Gervais and Goldstein (2007), then, in Section 2.2, we briefly summarise their results for teams of one overconfident and one rational agent.

2.1 The Baseline Model

Following Gervais and Goldstein (2007), we consider an all-equity firm which is owned by risk neutral shareholders and requires the effort of two risk neutral agents, $i = 1, 2$, for production. Output generates from a single one-period project, which can either succeed, with probability π, or fail, with probability $1 - \pi$. The value of the project is the value of its expected cash flow. The probability of success depends on the agents' unobservable efforts,

$e_i \in [0,1]$, their abilities, $a_i \in [0,1]$, and a synergy effect. In particular,

$$\pi = a_i e_i + a_{-i} e_{-i} + s e_i e_{-i}, \tag{1}$$

with $a_i + a_{-i} + s \leq 1$ so that success probabilities lie in $[0,1]$, and $s > 0$ so that agents' efforts create positive externalities.[1] The Agents' expected abilities are equal and this is common knowledge; realised abilities are known to the agent and his colleague but unknown to the principal. Effort is costly, with the cost being $c(e_i) = \frac{1}{2}e_i^2$. Since actual effort levels and abilities are not observable for the principal, wages condition only on the outcome of the project. Moreover, both agents are paid the same wage w: $0 < w \leq 1$, in case the project is successful, and 0 otherwise. Accordingly, agent i's maximisation problem is

$$\max_{e_i \in [0,1]} \; w \cdot (a_i e_i + a_{-i} e_{-i} + s e_i e_{-i}) - \frac{1}{2} e_i^2 \tag{2}$$

and equilibrium efforts are

$$e_i^* = \frac{(a_i + s w a_{-i}) w}{1 - s^2 w^2}, \; i = 1, 2. \tag{3}$$

Note that the derived efforts lie indeed in $[0,1]$ (cf. Appendix A.i). Moreover, equilibrium effort levels are below the social optimum, because of the positive externalities of effort which are not taken into account by the agents. Also, as the agents' efforts are unobservable to the principal, first best effort levels cannot be implemented.

Finally, substituting the agents' equilibrium efforts into their payoff functions, we obtain

$$U_i^* = \frac{w^2}{2(1 - s^2 w^2)^2} [2(a_{-i} + s w a_i)(1 - s^2 w^2) a_{-i} + (a_i + s w a_{-i})^2], \; i = 1, 2. \tag{4}$$

[1]The assumption of positive externalities, which follows Gervais and Goldstein, is e.g. consistent with Alchian and Demsetz (1972).

2.2 A Rational Agent 1

Next, we briefly recap the argument of Gervais and Goldstein (2007) for the case that agent 2 is overconfident while agent 1 is still rational and aware of agent 2's bias. Following Gervais and Goldstein, agent 2 is assumed to overrate his own skill by $b > 0$, i.e. his perceived ability is $a_2' := a_2 + b$, with $a_1 + a_2 + s + b \leq 1$;[2] and is not aware of his bias. Accordingly, substituting agent 2's perceived ability into his maximisation problem, we obtain

$$\max_{e_2 \in [0,1]} \; w \cdot (a_1 e_1 + (a_2 + b) e_2 + s e_1 e_2) - \frac{1}{2} e_2^2 \,. \tag{5}$$

By contrast, the maximisation problem of agent 1 is similar to the one from the baseline model with a fully rational team. Yet, agent 1 now takes the bias b of agent 2 into account; i.e. he knows that agent 2's effort reaction is different and accounts for this in his maximisation problem. The resulting equilibrium efforts are

$$\hat{e}_1 = \frac{(a_1 + (a_2 + b)sw)w}{1 - s^2 w^2} = e_1^* + \frac{bsw^2}{1 - s^2 w^2} \;; \tag{6}$$

$$\hat{e}_2 = \frac{(a_2 + b + a_1 sw)w}{1 - s^2 w^2} = e_2^* + \frac{bw}{1 - s^2 w^2} \;; \tag{7}$$

see Gervais and Goldstein (2007) for a derivation.[3] Moreover, the agents' individual equilibrium payoffs in this situation are

$$\hat{U}_1 = U_1^* + \frac{bw^2}{2(1 - s^2 w^2)^2} [2(a_2 + swa_1) + bs^2 w^2] \tag{8}$$

and

$$\hat{U}_2 = U_2^* + \frac{bw^2}{2(1 - s^2 w^2)^2} [2(a_1 + swa_2)sw - b(1 - 2s^2 w^2)] \,. \tag{9}$$

[4]

Obviously, compared to a situation without overconfidence, $b = 0$, both agents' efforts increase. This not only leads to a higher team productivity (i.e. a higher firm value) and a higher expected payoff of agent 1 (which is

[2] This assumption ensures that the success probabilities still lie in $[0, 1]$.
[3] Note again that these effort levels lie in $[0, 1]$ (cf. Appendix A.ii).
[4] See Appendix B.i for a derivation of the equilibrium payoffs.

increasing in b). It also increases the expected payoff of the overconfident agent 2, provided either synergies are large or both the bias b and synergies are sufficiently small, i.e. $\hat{U}_2 > U_2^*$ if $s \geq \frac{1}{\sqrt{2}w}$ or if

$$b \leq \frac{2(a_1 + a_2 sw)sw}{1 - 2s^2w^2} =: \hat{b}_2^c \text{ and } s < \frac{1}{\sqrt{2}w} \quad .^{5} \tag{10}$$

Intuitively, the latter effect is due to the fact that agent 2 profits from the positive externalities of the increased effort of agent 1. Even if these externalities are rather small, this outweighs the decrease in expected payoff resulting from agent 2's own increased effort as long as the extent of overconfidence is moderate.

3 Two Overconfident Agents

Extending the preceding analysis, we now turn to the discussion of teams consisting of two overconfident agents. In particular, we subsequently address (i) the individual optimal information status of an overconfident agent regarding the (potential) overconfidence of his colleague, and (ii) the comparison between individual payoffs in a team of two overconfident agents and a team of two rational agents.

In doing so, we distinguish two main settings, namely a situation where agent 1 is aware of agent 2's bias (Section 3.1) and one where he is not (Section 3.2). In both settings, the focus of the analysis is on the question whether agent 2 is better off by taking into account that agent 1 is overconfident or not – given the type (rational or overconfident) of agent 1 and his information about agent 2. As we will see, it is always better for agent 2 to be unaware of the colleague's overconfidence. The section concludes with the remaining payoff comparison between a fully rational and a fully overconfident team and a brief summary of the main results (Section 3.3). Regarding the payoff comparison, we show that individual payoffs are higher in a team

[5] See Appendix D.i for a derivation. Gervais and Goldstein (2007) consider only under which conditions expected payoffs are increasing in the bias, which holds for agent 2 if $b \leq \frac{1}{2}\hat{b}_2^c$.

of two overconfident agents than those in a team of two rational agents under fairly weak conditions.

For the sake of argument, we assume for all subsequent cases that the agents' biases are identical, i.e. $a_1'' := a_1+b, a_2'' := a_2+b$ with $a_1+a_2+s+b < 1$. This assumption is not crucial, though, as agents take at most one bias into account when determining their equilibrium effort. Yet, it ensures that all subsequently derived comparative effects are solely due to the assumed differences in the information structure.

3.1 Two Overconfident Agents - Agent 1 Unaware

To begin with, we consider the situation where agent 1 is unaware of the bias of agent 2. We distinguish two cases: First, agent 2 is also unaware of the bias of agent 1 (Case 1), then, he is aware of it (Case 2).

Case 1: Agent 2 is unaware of agent 1's overconfidence.
If both agents are overconfident but unaware of their colleague's bias, the derivation of the maximisation problems and equilibrium efforts for both agents is analogous to the derivation for agent 2 in the previous case, i.e. when an overconfident agent 2 is paired with a rational agent 1, cf. Equations (5) and (7). Accordingly, we obtain[6]

$$e_1^{11} = e_1^* + \frac{bw}{1 - s^2w^2} \ , \tag{11}$$

$$e_2^{11} = e_2^* + \frac{bw}{1 - s^2w^2} \ . \tag{12}$$

Agent 2's decision is the same as before. Agent 1, however, now acts in the same way as agent 2. This means, agent 1 increases his effort above the individual rational level, i.e. above e_1^*, because of his *own* overconfidence – and no longer, as he did before, due to the knowledge of his colleague's bias.

Substituting equilibrium efforts into the agents' payoff functions (compare Appendix B.ii), we obtain the following equilibrium payoffs for this case

[6] That these efforts lie in $[0, 1]$ is shown by the argument given in Appendix A.ii.

$$U_1^{11} = U_1^* + \frac{bw^2}{2(1-s^2w^2)^2}[2(a_2 + swa_1) - b(1-2sw)] \tag{13}$$

and

$$U_2^{11} = U_2^* + \frac{bw^2}{2(1-s^2w^2)^2}[2(a_1 + swa_2) - b(1-2sw)] \ . \tag{14}$$

Case 2: Agent 2 is aware of agent 1's overconfidence.
In order to examine the effect of the agents' awareness of the colleague's bias, we next consider the case in which agent 2 is aware of the bias of agent 1. Obviously, the maximisation problem and the corresponding equilibrium effort of agent 1 remain the same as in Case 1. Yet, agent 2 now accounts for the different reaction function of agent 1 (i.e. the increased effort due to agent 1's bias) when maximising his payoff. Thus, equilibrium efforts become (cf. Appendix C for the derivation)

$$e_1^{12} = \frac{w(a_1 + b + a_2sw)}{1-s^2w^2} = e_1^* + \frac{bw}{1-s^2w^2} \ , \tag{15}$$

$$e_2^{12} = \frac{w(a_2 + b + sw(a_1+b))}{1-s^2w^2} = e_2^* + \frac{bw(1+sw)}{1-s^2w^2} \ . \tag{16}$$

Note that in this case there are two reasons why agent 2 increases his effort: (i) the biased perception of his own ability (he is not aware of), and (ii) the awareness of the colleague's overconfidence. Therefore, agent 2's effort is not only higher than in the fully rational team (cf. Equation (3)), but also higher than it is in case he is unaware of agent 1's bias. This implies that the team's productivity rises compared to the fully rational team, the team with only one overconfident agent, and the team with two overconfident agents who are both unaware of their colleague's bias.

Substituting the agents' equilibrium efforts into the agents' payoff functions (the argument is analogous to the one given in Appendix B.i), we obtain the following equilibrium payoffs

$$U_1^{12} = U_1^* + \frac{bw^2}{2(1-s^2w^2)^2}[2(a_2 + swa_1)(1+sw) - b(1-2sw(1+sw))] \ , \tag{17}$$

$$U_2^{12} = U_2^* + \frac{bw^2}{2(1-s^2w^2)^2}[2(a_1 + swa_2) - b(1-s^2w^2)] \ . \tag{18}$$

Comparison of agent 2's payoffs in Case 1 and 2.
A simple payoff comparison yields that if agent 1 is unaware of agent 2's bias, agent 2 is better off being unaware of the bias of agent 1, i.e.

$$U_2^{11} > U_2^{12} \ , \tag{19}$$

as $0 < sw < 1$. Intuitively, accounting for agent 1's overconfidence induces agent 2 to further increase his effort in an attempt to exploit effort complementarities. Yet, doing so is unfavourable for agent 2. His effort is already above the individual optimum – because of his own overconfidence – and the further increase in effort is not complemented by agent 1. Thus, we conclude:

Lemma 1 *If both agents are overconfident and agent 1 is unaware of the bias of agent 2, then agent 2, ceteris paribus, is better off if he is also unaware of agent 1's bias than if he is aware of it.*

3.2 Two Overconfident Agents - Agent 1 Aware

Next, we turn to the analysis of the situation in which agent 1 is aware of (and accounts for) the overconfidence bias of agent 2. Again, we consider the case that agent 2 is unaware and the case that he is aware of agent 1's bias (Case 1 and 2, respectively).

Case 1: Agent 2 is unaware of agent 1's overconfidence.
The case where both agents are overconfident but only agent 1 is aware of the bias of agent 2, obviously, is analogous to Case 2 from Section 3.1, the only difference being that the information structure is reversed. Accordingly, the resulting equilibrium efforts are

$$e_1^{21} = \frac{w(a_1 + b + sw(a_2 + b))}{1-s^2w^2} = e_1^* + \frac{bw(1+sw)}{1-s^2w^2} \ , \tag{20}$$

$$e_2^{21} = \frac{w(a_2 + b + a_1 sw)}{1 - s^2w^2} = e_2^* + \frac{bw}{1 - s^2w^2} \ . \tag{21}$$

Similarly, individual payoffs are

$$U_1^{21} = U_1^* + \frac{bw^2}{2(1 - s^2w^2)^2}[2(a_2 + swa_1) - b(1 - s^2w^2)] \tag{22}$$

and

$$U_2^{21} = U_2^* + \frac{bw^2}{2(1 - s^2w^2)^2}[2(a_1 + swa_2)(1 + sw) - b(1 - 2sw(1 + sw))] \ ; \tag{23}$$

the derivation is analogous to the argument given in Appendix B.i.

Case 2: Agent 2 is aware of agent 1's overconfidence.
Finally, we turn to the case where both agents are overconfident and aware of their colleague's bias. This situation is analogous to the situation of agent 1 in Case 1 where agent 1 is aware of agent 2's bias. Hence, for both agents, equilibrium effort levels are determined accordingly and thus[7]

$$e_1^{22} = \frac{w[a_1 + b + sw(a_2 + b)]}{1 - s^2w^2} = e_1^* + \frac{bw(1 + sw)}{1 - s^2w^2} \ , \tag{24}$$

$$e_2^{22} = \frac{w[a_2 + b + sw(a_1 + b)]}{1 - s^2w^2} = e_2^* + \frac{bw(1 + sw)}{1 - s^2w^2} \ . \tag{25}$$

Note that both agents now increase their effort for two reasons, namely because of their own overconfidence as well as their attempt to complement the other agent's increased effort.

The agents' resulting equilibrium payoffs for this scenario are

$$U_1^{22} = U_1^* + \frac{bw^2}{2(1 - s^2w^2)^2}[2(a_2 + swa_1)(1 + sw) - b(1 - 2sw)(1 + sw)^2] \ , \tag{26}$$

$$U_2^{22} = U_2^* + \frac{bw^2}{2(1 - s^2w^2)^2}[2(a_1 + swa_2)(1 + sw) - b(1 - 2sw)(1 + sw)^2] \ ; \tag{27}$$

again the derivation is analogous to the argument given in Appendix B.i.

[7] Note that the derived efforts lie in $[0, 1]$ by the same argument as given in Appendix C for e_2^{12}.

Comparison of agent 2's payoffs in Case 1 and 2.
Straightforward calculations show that again agent 2 is better off being unaware of the bias of agent 1, i.e.

$$U_2^{21} > U_2^{22}; \tag{28}$$

see Appendix D.ii for a derivation. The intuition for this result is the same as before. Complementing agent 1's additional effort is unfavourable for agent 2 because his effort is already higher than optimal – due to his own bias – and because the further increase is not complemented by agent 1. Thus, similar to the previous situation, we conclude the following.

Lemma 2 *If both agents are overconfident and agent 1 is aware of the bias of agent 2, then agent 2, ceteris paribus, is better off if he is unaware of agent 1's bias than if he is aware of it.*

3.3 Comparison With Rational Team and Summary

The preceding analysis has shown that, if both agents of a team are overconfident, each of them is better off not being aware of the bias of the other one; cf. Lemma 1 and 2. Thus, given an agent is overconfident, it is always best for him to be unaware of a potential bias of his colleague. Yet, the question remains how individual payoffs for a team of two overconfident agents compare to those for a fully rational team. As the answer to this question is interesting in view of a general comparison between rational and overconfident agents, it shall be addressed in the sequel.

To begin with, we consider the case where both agents of the overconfident team are unaware of their colleague's bias. Thus, in a sense, we ask whether overconfidence is beneficial in its "individual optimal" form. Note that, different from the case with one overconfident and one rational agent which under certain conditions still was favourable even for the overconfident agent, overconfidence in this setting is not complemented by an increased effort of the respective colleague as all biases are unknown to the agents. Yet, a comparison of individual payoffs reveals that, ceteris paribus, these are indeed higher for an overconfident than for a fully rational team, i.e. $U_i^* < U_i^{11}$, provided that either synergy effects are large, i.e. $s \geq \frac{1}{2w}$ or synergy effects and the biases also are moderate, i.e. $s < \frac{1}{2w}$ and $b < \frac{2(a_{-i}+swa_i)}{1-2sw}$; see Appendix E.i for a formal derivation.

As already mentioned earlier, the above result in favour of overconfidence is rather intuitive given that under similar conditions both agents' payoffs are higher in a team with one overconfident and one rational agent (cf. Section 2.2). In particular, the maximisation problem of the overconfident agent is the same in both cases as he is only aware of the true ability of his colleague and unaware of his own bias. Thus, he will exert the same effort in both cases. Moreover, if the additional effort exerted by a rational agent 1 in order to complement the extra amount of effort agent 2 exerts (due to his overconfidence) is enough to overcompensate agent 2 for this extra effort, then it is natural to expect that also an overconfidence bias of agent 1 has a similar effect. Eventually, both the awareness of agent 2's bias and the own overconfidence of agent 1 have a similar effort-enhancing effect; and the increased effort of agent 1 (due to his overconfidence) is what compensates agent 2 for his additional cost.

Completing our analysis, it is interesting to note that the favourable comparison of individual payoffs for an overconfident team with those for a fully rational one does not depend on the overconfident agents' unawareness of their colleagues' biases. In fact, also if both agents are aware of their colleagues' biases, individual payoffs are higher than in a fully rational team if either synergy effects are large, i.e. $s \geq \frac{1}{2w}$, or if synergy effects and the biases also are moderate, i.e. $s < \frac{1}{2w}$ and $b < \frac{2(a_{-i}+swa_i)}{(1-2sw)(1+sw)}$ (cf. Appendix E.ii). The constraints on the agents' biases now are stronger (as $1 + sw > 1$), though, as both individual payoffs are lower than in the case where both agents are unaware of the colleague's bias. Similarly, in the case with two overconfident agents and one of whom being aware of the colleague's bias while the other is not, individual payoffs are again higher than for a fully rational team if either synergy effects are large or if synergy effects are small but also biases are moderate. In this asymmetric situation, the agent who is unaware of the other's bias has a comparative advantage within the team (at least if agents' abilities are sufficiently similar), though; see Appendix E.iii for a formal argument.

Both above results are again rather natural given that overconfidence is individually beneficial in case it is paired with unawareness of the other agent's bias. Eventually, awareness of the colleague's bias "only" induces a further increase in the agent's effort which is suboptimal in that the cost exceeds the corresponding benefit (because the agent's effort is already increased due to his own overconfidence). Yet, the cost effect of knowledge about the colleague's bias is not necessarily detrimental to the agent (relative to the fully rational case): On the one hand, the cost effect is small if the colleague's bias is small. On the other hand, the cost effect is at least smaller than the benefit from the colleague's excess effort (due to the colleague's overconfidence) if synergy effects are large. Thus, due to the continuity of the payoff functions, the respective increase in the agent's effort (resulting from the additional knowledge about the colleague's bias) will not affect the individual payoff-ranking compared to the fully rational team if either of the above mentioned conditions is satisfied.

Proposition 1 below summarises the main points of the preceding discussion.

Proposition 1 *For the above model of team production, in which agents' efforts exhibit synergy effects concerning productivity, it holds that:*

1. *The individual payoff of an overconfident agent whose colleague is also overconfident is always higher if he is not aware of his colleague's bias (irrespective of whether the colleague is aware of the agent's bias or not).*

2. *Individual payoffs in a team of two overconfident agents who are both unaware of the other's bias are higher than those in a team of two rational agents provided that either synergy effects are large, $s \geq \frac{1}{2w}$, or synergy effects and also biases are moderate, $s < \frac{1}{2w}$ and $b < \frac{2(a_{-i}+swa_i)}{1-2sw}$.*

3. *Individual payoffs in a team of two overconfident agents who are both aware of the other's bias are higher than those in a team of two rational*

agents provided that either synergy effects are large, $s \geq \frac{1}{2w}$*, or synergy effects and also biases are moderate,* $s < \frac{1}{2w}$ *and* $b < \frac{2(a_{-i}+swa_i)}{(1-2sw)(1+sw)}$.

4. *Individual payoffs in a team of two overconfident agents in which agent 1 is unaware of agent 2's bias while agent 2 is aware of agent 1's bias are higher than those in a team of two rational agents provided that either synergy effects are large,* $s \geq \frac{1}{w}$*, or synergy effects are intermediate and the bias of agent 1 is moderate, i.e.* $\frac{1}{2w}(\sqrt{3}-1) \leq s < \frac{1}{w}$ *and* $b < \frac{2(a_2+swa_1)(1+sw)}{1-2sw(1+sw)}$*, or synergy effects are small and also biases are moderate, i.e.* $s < \frac{1}{2w}(\sqrt{3}-1)$ *and* $b < min\{\frac{2(a_1+swa_2)}{1-s^2w^2}, \frac{2(a_2+swa_1)(1+sw)}{1-2sw(1+sw)}\}$.

4 Concluding Remarks

In the preceding sections, we have considered potential positive effects of being overconfident within a model of team production with effort complementarities. In particular, the focus of the analysis has been on the individual payoff effects of awareness of others' biases once an agent himself is overconfident.

As we have seen, a more rational perspective on others, i.e. awareness not only of the others' true abilities but also of their overconfidence, is suboptimal for an agent who is overconfident. More specifically, within the considered model of team production, the payoff of an overconfident agent 2, whose colleague (agent 1) is also overconfident, is always higher if agent 2 is unaware of agent 1's bias – irrespective of whether agent 1 is aware of agent 2's bias or not.

Moreover, we compared individual payoffs for fully rational teams with those for teams consisting of two overconfident agents (who are aware or unaware of the bias of the colleague). According to our analysis, individual payoffs in a team of two overconfident agents are higher than in a team of two rational agents when either synergy effects are sufficiently large or biases moderate.

As overconfidence also enhances the individual payoffs of an agent whose colleague is fully rational, the present analysis gives further support to the idea that being overconfident may indeed be advantageous not only for the principal (as overconfidence always enhances team productivity) but also for the individual. Thus, we hope, our results will contribute to the understanding of why overconfidence is as widespread a phenomenon as empirical studies indicate.

Appendix

A. Proof that efforts lie in $[0, 1]$.

(i) The derived efforts are positive as $a_i \in [0, 1]$, $a_{-i} \in [0, 1]$,$w \in [0, 1]$, $s > 0$, and $a_i + a_{-i} + s \leq 1$ such that also $1 > sw$. To see that efforts are also smaller than one, define $m = max\{a_i, a_{-i}\}$. Then, $e_i^* \leq \frac{m(1+sw)w}{1-s^2w^2} = \frac{mw}{1-sw}$. Using $1 > sw$, $\frac{mw}{1-sw}$ is smaller than one if $w(m + s) \leq 1$, which holds as $a_i + a_{-i} + s \leq 1$.

(ii) The efforts given in Equation (6) and (7) are positive as $a_i \in [0, 1]$, $a_{-i} \in [0, 1]$, $w \in [0, 1]$, $s > 0$, $b > 0$, and $a_i + a_{-i} + s + b \leq 1$ such that also $1 > sw$. To see that efforts are also smaller than one, we give an argument similar to the one in Appendix A.i: Define $\hat{m} = max\{a_1, a_2 + b\}$. Then, $\hat{e}_i \leq \frac{\hat{m}(1+sw)w}{1-s^2w^2} = \frac{\hat{m}w}{1-sw}$. Using $1 > sw$, $\frac{\hat{m}w}{1-sw}$ is smaller than one if $w(\hat{m} + s) \leq 1$, which holds as $a_i + a_{-i} + s + b \leq 1$.

■

B. Derivation of equilibrium payoffs.

(i) In order to derive the equilibrium payoffs, we substitute the respective equilibrium effort levels given in Equations (6) and (7) into the individual payoff function $U_i = w(a_ie_i + a_{-i}e_{-i} + se_ie_{-i}) - \frac{1}{2}e_i^2$. Note here that the bias only influences equilibrium efforts but not directly enters the payoff.

(ii) In order to derive the equilibrium payoffs, we proceed as above by using the equilibrium effort levels given in Equations (11) and (12).

■

C. Derivation of equilibrium efforts with two overconfident agents in Section 3.1 Case 2.

The effort of agent 1 is the same as the effort of agent 2 in the setting of Gervais and Goldstein (2007) discussed in Section 2.2. Both agents are overconfident and think their colleague is rational. However, in the current setting, agent 2 exerts a different effort than agent 1 in the setting of Section 2.2. This is due to the fact that, although he takes into account the bias of his colleague, he now is overconfident himself. Thus, his effort differs from the effort of the rational agent 1 in Section 2.2. In particular, agent 2 chooses his effort according to $e_2 = w(a_2 + b + se_1)$ where he takes into account that agent 1 is overconfident (but thinks agent 2 is rational); i.e. agent 2 expects agent 1 to react according to $e_1 = w(a_1 + b + se_2)$ where agent 1 expects agent 2 to choose his effort according to $e_2 = w(a_2 + se_1)$. Substituting $e_1 = w(a_1 + b + se_2)$ into the first equation for agent 2's effort leads to the following equilibrium effort levels of agent 1 and 2

$$e_1^{12} = \frac{w(a_1 + b + a_2 sw)}{1 - s^2w^2}, e_2^{12} = \frac{w(a_2 + b + sw(a_1 + b))}{1 - s^2w^2}$$

as specified in Equations (15) and (16). Note that these effort lie indeed in $[0, 1]$: For e_1^{12} the argument is identical to the one given in Appendix A.ii. For e_2^{12} the same argument applies, if instead of $\hat{m}$, we define $m^{12} = max\{a_1 + b, a_2 + b\}$ and substitute m^{12} for $\hat{m}$ in Appendix A.ii.

■

D. Proof of the comparative individual payoff effect for agent 2.

(i) Using the payoff expressions given by Equations (4) and (9), we have $\hat{U}_2 > U_2^* \Leftrightarrow \frac{bw^2}{2(1-s^2w^2)^2}[2(a_1 + swa_2)sw - b(1 - 2s^2w^2)] > 0$. As $b > 0$ and $w > 0$, $\hat{U}_2 > U_2^*$ holds if and only if $2(a_1 + swa_2)sw > b(1 - 2s^2w^2)$. If $1 - 2s^2w^2 > 0 \Leftrightarrow s < \frac{1}{\sqrt{2}w}$ the former condition is equivalent to

$b < \frac{2(a_1+swa_2)sw}{1-2s^2w^2}$. If $1-2s^2w^2 \leq 0 \Leftrightarrow s \geq \frac{1}{\sqrt{2}w}$, then $2(a_1+swa_2)sw > b(1-2s^2w^2)$ holds as $a_i > 0$ and $sw > 0$.

(ii) Using the payoff expressions given by Equations (23) and (27), we have $U_2^{21} > U_2^{22} \Leftrightarrow -b(1-2sw(1+sw)) > -b(1-2sw)(1+sw)^2$ $\Leftrightarrow 2 - sw - s^2w^2 > 0$. This always holds true as $sw < 1$.

■

E. Proof of the comparative individual payoff effect between the fully rational team and the team with two overconfident agents who are both unaware of the other's bias.

(i) Using the payoff expressions given by Equations (4), (13) and (14) respectively, we have $U_i^{11} > U_i^* \Leftrightarrow 2(a_{-i}+swa_i) > b(1-2sw)$.
This holds true if either $s \geq \frac{1}{2w}$ or if $s < \frac{1}{2w}$ and $b < \frac{2(a_{-i}+swa_i)}{1-2sw}$.

(ii) Using the payoff expressions given by Equations (4), (26) and (27) respectively, we have $U_i^{22} > U_i^* \Leftrightarrow 2(a_{-i}+swa_i) > b(1-2sw)(1+sw)$.
This holds true if either $s \geq \frac{1}{2w}$ or if $s < \frac{1}{2w}$ and $b < \frac{2(a_{-i}+swa_i)}{(1-2sw)(1+sw)}$.

(iii) Using the payoff expressions given by Equations (4), (17) and (18) respectively, we have for agent 1 who is unaware of agent 2's bias $U_1^{12} > U_1^* \Leftrightarrow 2(a_{-i}+swa_i)(1+sw) > b(1-2sw(1+sw))$.
This holds true if either $1-2sw(1+sw) \leq 0 \Leftrightarrow s^2 + s\frac{1}{w} - \frac{1}{2w^2} \geq 0$ or if $1-2sw(1+sw) < 0$ and $b < \frac{2(a_2+swa_1)(1+sw)}{(1-2sw(1+sw))}$. Solving for s such that $s^2 + s\frac{1}{w} - \frac{1}{2w^2} = 0$ yields $s_{1,2} = -\frac{1}{2w}(1 \mp \sqrt{3})$. Since s has to be positive, the only solution is $s = -\frac{1}{2w}(1-\sqrt{3})$. Since $s^2 + s\frac{1}{w} - \frac{1}{2w^2}$ is increasing in s for $s > -\frac{1}{2w}$ and thus for all positive s, we have that $1-2sw(1+sw) \leq 0 \Leftrightarrow s \geq -\frac{1}{2w}(1-\sqrt{3})$. Thus, $U_1^{12} > U_1^*$ holds true if either $s \geq \frac{1}{2w}(\sqrt{3}-1)$ or if $s < \frac{1}{2w}(\sqrt{3}-1)$ and $b < \frac{2(a_2+swa_1)(1+sw)}{(1-2sw(1+sw))}$. Note that the threshold for b is weaker than in the case that both agents are unaware of the colleagues' biases (and thus also if both agents are aware of the biases) as $\frac{2(a_2+swa_1)(1+sw)}{(1-2sw(1+sw))} > \frac{2(a_2+swa_1)}{1-2sw} \Leftrightarrow 2sw(a_2+swa_1) > 0$.

Similarly, we have for agent 2 who is aware of agent 1's bias that $U_2^{12} > U_2^* \Leftrightarrow 2(a_1 + swa_2) > b(1 - s^2w^2))$. This holds true if either $s \geq \frac{1}{w}$ or if $s < \frac{1}{w}$ and $b < \frac{2(a_1+swa_2)}{1-s^2w^2}$. Note that now the threshold for the bias is more strict than in case both agents are aware (and thus also if both are unaware) of the colleague's bias as $\frac{2(a_1+swa_2)}{1-s^2w^2} < \frac{2(a_1+swa_2)}{(1-2sw)(1+sw)} \Leftrightarrow -sw(1+sw) < 0$. Hence, the payoffs of both agents are higher than in the fully rational case if either synergy effects are large, $s \geq \frac{1}{w}$, or synergy effects are intermediate and the bias of agent 1 is moderate, i.e. $\frac{1}{2w}(\sqrt{3}-1) \leq s < \frac{1}{w}$ and $b < \frac{2(a_2+swa_1)(1+sw)}{1-2sw(1+sw)}$, or synergy effects are small and also biases are moderate, i.e. $s < \frac{1}{2w}(\sqrt{3}-1)$ and $b < min\{\frac{2(a_1+swa_2)}{1-s^2w^2}, \frac{2(a_2+swa_1)(1+sw)}{1-2sw(1+sw)}\}$. Note that for $a_1 = a_2$ this minimum is given by the threshold for b derived for agent 2.

To see that agent 1 has a comparative advantage within the team, we compare Equations (17) and (18) for $a_1 = a_2 =: a$. Then, $U_1^{12} > U_2^{12} \Leftrightarrow 2asw(1+sw) > -bsw(2+sw)$ which always holds. Thus, as long as abilities are sufficiently similar, agent 1 is better off within the team.

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