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# Inequity Aversion and Team Incentives

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## Abstract

We study optimal contracts in a simple model where employees are averse to inequity, as modeled by Fehr and Schmidt (1999). A "selfish" employer can profitably exploit *envy* or *guilt* by offering contracts which create inequity off-equilibrium, i.e., when employees do not meet his demands. Such contracts resemble *team* and *relative performance* contracts. We derive conditions for inequity aversion to be in itself a reason to form work teams of distributionally concerned employees, even in situations in which effort is contractible.

*Keywords*: Inequity aversion; team incentives; behavioral contract theory

*JEL classification*: $C72$; $D23$; $D63$; $M12$

## I. Introduction

One of the most striking results from interview studies with firm managers and employees, as in Blinder and Choi (1990), Campbell and Kamlani (1997) and Agell and Lundborg (1999) is that employees report caring about the well-being of their co-workers and not only their own. In particular, employees compare co-workers' rewards and performance in the firm with their own. Bewley (1999) shows that 69% of firm managers interviewed offer formal pay structures because they can create internal equity, which they believe employees care about. Asked why internal equity among employees is relevant, 78% of managers answered that it was important for morale and internal harmony, and 49% responded that internal equity was a key factor in job performance. Our aim is to capture how managers should structure reward schemes when their employees care about the distribution of payoffs among their co-workers in a simple model.

We discuss how contracts can exploit distributional preferences to the manager's advantage. Our main result is that a "selfish" principal can

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devise schemes which exploit agents' preference for equity by offering them more equitable outcomes when a manager's demands are met than when they are not. The reason is that equity affects the employees' incentives to work hard and thus job performance. Following Holmström and Milgrom's (1991) seminal paper, optimal contracts must account for everything employees care about. When agents care about equity, the principal has two instruments at his disposal: monetary rewards and equity. By offering bonuses which generate more equity when employees perform at the effort level desired by the manager than when they do not, the manager does not need to pay as high monetary rewards to provide incentives for employees to meet his demands. Moreover, since providing incentives to distributionally concerned agents to work hard may be relatively cheaper, it may be optimal to form work teams of employees who care about each other, even if effort complementarities are not high.

Distributional preferences are one of the most frequent explanations for subjects' behavior in a wide variety of experiments.[1] In prominent experimental work, Fehr and Schmidt (2000a) have argued that fairness leads principals to write incomplete contracts which implement less severe incentives than conventional theory would predict. Here, we develop a simple model in which a principal has to design a reward scheme for two agents who dislike inequity in the way envisaged by Fehr and Schmidt. However, in our model, the principal is not distributionally concerned and agents do not care about the principal's welfare, but only about the welfare of other agents' and their own. It seems natural to assume that welfare comparisons are enhanced, the closer the interaction between agents is, and that employees at the same hierarchical level interact more closely among themselves than with their superiors. In addition, welfare comparisons among employees who perform similar tasks may be more accessible because rewards and costs of effort might be more easily observable. Sociologists have long argued that individuals rarely have altruistic feelings towards others who have direct authority over their actions.[2] Thus, welfare comparisons seem more meaningful among employees on the same hierarchical level than on different levels.[3]

We have chosen Fehr and Schmidt's (1999) inequity-aversion model as a reduced form of social preferences due to its prominence and simplicity, although we also briefly consider preferences for *status seeking* and *efficiency*

[1] See, for example, Fehr and Schmidt (1999) and Engelmann and Strobel (2004).
[2] See Homans (1950) and Festinger (1954) for a summary.
[3] Dufwenberg and Kirchsteiger (2000) express doubts regarding which variables would be used to compare employees' and employers' utilities. They wonder how meaningful it is to compare employees' salaries with a firm's profits or stock value.

*concerns*.[4] We do not deal with more complicated forms of social preferences related to reciprocal behavior and intentions.[5] These preferences could play a role if we studied repeated interactions in the context of the firm. However, it would then be crucial to study agents' reactions to threats of inequity by the principal, which in turn may imply that employees would care about the intentions signaled by the employer, from which we want to abstract.

We develop the simplest possible model in which the pure effect of inequity aversion on optimal contract design can be shown. First, we focus on incentive compatibility instead of on participation because there are realistic situations in which employers cannot force employees down to their participation constraint. In any case, we specifically discuss participation constraints in Section IV.

Second, we do not consider an uncertain production environment. There exist plausible and interesting situations in which an extra level of effort may produce a deterministic output, such as staying longer hours in the office or contributing to administrative tasks. In our model, effort is observable and verifiable, and, thus, output is contractible. Itoh (2004) uses a moral hazard framework where output is uncertain and shows that inequity aversion calls for optimal contracts to specify both agents' rewards under all possible circumstances, which also occurs in our model. However, Itoh's mechanism is different from ours. In his model, each agent undertakes a different project and the principal writes the contract such that both agents always exert high effort. More equal (or unequal) rewards are used in Itoh's paper to compensate for the risk that one of the agent's projects fails. Here, we isolate the effects of inequity aversion in order to separate them from the effects of risk aversion. Therefore, while Itoh uses equality in rewards to compensate for uncertainty, we show how equal rewards must be paid (and unequal rewards offered) to provide extra incentives to work hard, even if employers are restricted by limited liability. In practical terms, our model shows that if employees are distributionally concerned, employers may not need to pay bonuses covering the effort costs of staying longer hours or performing extra duties, as long as threats of inequity when they shirk are optimally designed. Thus, our results can be interpreted as showing that uncertainty is not essential for inequity aversion to have an important

[4] With simple parameter transformations we can obtain similar results for other types of distributional preferences which might be relevant in the workplace. In particular, our qualitative results would hold for the models proposed by Bazerman, Loewenstein and Thompson (1989), Andreoni and Miller (1998), Bolton and Ockenfels (2000) and Cox and Friedman (2002), and the model without intentions by Charness and Rabin (2002).

[5] For good surveys on social preferences, see Fehr and Schmidt (2000b) and Sobel (2000).

effect on contracts. Once the pure effect of inequity aversion on contracts is understood, complementary approaches emerge.[6]

The paper is organized as follows. The model is described in Section II and optimal contracts when agents are inequity averse are characterized in Section III. Section IV addresses possible extensions. Section V concludes. Proofs for the main results are in the Appendix.

## II. The Model

There are a principal and two agents $i, j \in \{1, 2\}$ with $i \neq j$. Agents who work for the principal receive the same minimum wage equal to $\overline{w} > 0$, production is normalized to $\overline{K}$ and agents' cost of working in this firm is normalized to 0. However, agents can be asked to exert an extra level of effort (work hard) or not (shirk). If both agents work hard, the extra level of production is normalized to 1 (joint extra production). If only agent $i$ works hard, the extra level of production is $q_i$, where $0 < q_i < 1$ (individual production by agent $i$). If both agents shirk, the extra level of production is 0. This extra level of output is observable and, thus, the extra level of effort is verifiable and contractible. Alternatively, agents who are not in the firm have an outside option whose value is normalized to 0.

Each agent's cost of working hard is $c_i > 0$. The cost of shirking is 0. A complete contract specifies the rewards (bonuses) offered to both agents for all possible extra levels of output. In order to standardize notation, assume that the principal offers bonuses $\{b_1, b_2\}$ to agents 1 and 2, respectively, when both agents work hard, $\{b_1^1, b_2^1\}$ when only agent 1 works hard and $\{b_1^2, b_2^2\}$ when only agent 2 works hard. If both agents shirk, bonuses are zero.[7]

The structure of the game is as follows. The principal offers bonuses for all possible production levels, agents decide whether to enter the firm and, once in, they simultaneously decide whether to work hard or shirk. Once production is realized, promised bonuses for the output level obtained are paid. Following Ma, Moore and Turnbull (1988), the contract is such that the implemented production level is the unique equilibrium of the game played by the agents.[8] As the game is $2 \times 2$, the contract that implements

[6] See Englmaier and Wambach (2002), Masclet (2002), Dur and Glazer (2003), Bartling and von Siemens (2004), Huck and Rey-Biel (2006) and Cabrales, Calvó-Armengol and Pavoni (2008).

[7] This is implied by assumptions (R1) and (R2) below.

[8] We do so in order to avoid the problem in Demski and Sappington (1984) that, given an optimal contract, there may exist another pair of equilibrium strategies whose outcome, from the agents' point of view, Pareto dominates the equilibrium outcome which the principal wants to implement and, thus, the contract may not implement the optimal output level.

a unique equilibrium makes the game played by the agents dominance-solvable.[9]

The principal seeks to maximize his profit, that is, production ($\overline{K}$), plus the extra production minus rewards paid (bonuses plus minimum wages).[10] Given the minimum bonuses needed to be paid in equilibrium to implement each extra production level and the productivity parameters ($q_i$ and $c_i$), the principal designs the contract that implements the level of extra production which maximizes his profit.

We assume two different specifications for the agents' utility functions. Standard agents maximize their utility, which equals the minimum wage ($\overline{w}$), plus their "direct utility" from the extra cost of effort ($U_i$). Direct utility equals the bonus each agent is offered minus the cost of the extra effort they may perform.

With respect to distributionally concerned agents, we follow Fehr and Schmidt's (1999) model of inequity aversion by adapting their utility function to our context with two agents. Inequity-averse agents' utility function is $U_i^{FS}$ where:

$$U_i^{FS} = \overline{w} + U_i - \alpha \max[U_j - U_i, 0] - \beta \max[U_i - U_j, 0], \quad \text{for } i, j = 1, 2,\ i \neq j, \tag{1}$$

where, as before, $U_i$ is each agent's "direct utility" for the extra cost of effort.[11, 12]

Assume the following:

(U1) *Agents dislike inequity:* $\alpha \geq 0$ and $\beta \geq 0$.

(U2) *Agents care more about their own direct utility than about inequity:* $\alpha \leq 1$ and $\beta \leq \frac{1}{2}$.

Assumption (U1) imposes inequity *aversion*. Agents derive disutility from direct utilities being unequal. In the following, $\alpha$ refers to *negative inequity aversion* or *envy* (dislike for being worse off than your peers),

[9] As shown below, in all but one case, equilibrium uniqueness does not require paying a higher sum of bonuses than required in equilibrium to obtain the optimal output level as one of the possible equilibria of the game played by the agents.

[10] We assume all production is sold at a price equal to 1.

[11] While Fehr and Schmidt's (1999) original formulation refers to agents who compare "payoffs", other authors use their preferences in our context and assume that only rewards enter into welfare comparisons but not the costs of effort; see Itoh (2004) and Grund and Sliwka (2005). Our qualitative results hold with this alternative specification, although more interesting issues arise when effort costs enter the comparison. Ultimately, this is an empirical question that may be context dependent. A first experimental study of this issue is Königstein (2000), who confirms that welfare comparisons are context dependent.

[12] Minimum wages ($\overline{w}$) are canceled in the comparison among agents as they are equal by construction.

while $\beta$ refers to *positive inequity aversion* or *guilt* (dislike for being better off than your peers). For simplicity, we assume that parameters $\alpha$ and $\beta$ are the same among agents.[13] Assumption (U2) implies that agents care more about their own direct utility than about the comparison with the other agent's direct utility. Fehr and Schmidt allow for $\alpha > 1$. We assume $\alpha \leq 1$ to show that even if inequity aversion is not dominant, its effects on the optimal contract design can still be substantial. Note that $\beta \leq (\frac{1}{2})$ is also necessary for inequity aversion not to be dominant. Otherwise, agents would be willing to transfer bonuses to the other agent *ex post*. In addition, Fehr and Schmidt impose $\beta \leq \alpha$, which we do not for generality.

The structure of the game is known by the principal and the agents and, in particular, they both know the bonuses offered, the extra production level each agent achieves if working hard individually and each agent's cost of exerting the extra effort. Agents cannot communicate among themselves.

Assume the following:

(C) *The sum of working agents' costs of extra effort is lower than the extra output produced.*

$$\begin{aligned} 0 \leq c_i &< q_i, \\ c_i + c_j &< 1, \quad \text{for } i, j \in \{1, 2\} \text{ with } i \neq j. \end{aligned} \tag{2}$$

(R1) *Agents' limited liability: negative bonuses are not possible.*

$$b_i, b_i^i, b_i^j \geq 0, \quad \text{for } i, j \in \{1, 2\} \text{ with } i \neq j. \tag{3}$$

(R2) *Bonuses are paid from the extra output produced.*

$$\begin{aligned} b_i + b_j &\leq 1, \\ b_i^i + b_j^i &\leq q_i, \quad \text{for } i, j \in \{1, 2\} \text{ with } i \neq j. \end{aligned} \tag{4}$$

(R3) *The principal wants both agents to work in the firm.*

$$\overline{K} \geq 2\overline{w}. \tag{5}$$

Assumption (C) implies that there always exists a surplus above the cost of effort exerted. Assumption (R1) implies that "bonuses are bonuses", that is, there exist limited liability constraints restricting how much the principal can monetarily punish agents for not exerting the extra effort required. Assumption (R2) is a budget constraint for the principal, established at those

[13] We focus on asymmetries in productivity parameters rather than on social preferences as they may be more easily observable and measurable.

levels for simplicity. Limited liability and budgetary constraints are important in order for the offers of the principal to be credible. Note that (R1) and (R2) should also be satisfied off the equilibrium of the game played by the agents.[14] Assumption (R3) ensures that the principal is interested in hiring the two agents.

## III. Optimal Contract Design

Before solving for the optimal contract when agents are inequity averse, we show, as a reference, the optimal contract design when agents are standard. The principal designs the optimal contract in two phases. First, he chooses the minimum bonuses to implement each production level (joint or individual extra output). Given these bonuses, the principal chooses the output level which maximizes his profits, and thus chooses the bonuses accordingly. Assuming agents work hard when just indifferent between working hard or shirking, the solution to this problem is straightforward. Each agent needs to be compensated for his cost of effort when he performs at the effort level the principal wants to implement.

That is, to implement individual extra production by agent $i$ at the minimum cost, agent $i$ needs to be paid a bonus equal to his effort cost when he works hard, no matter what the other agent does. Moreover, agent $j$ is paid no bonus regardless of what he or the other agent does. Thus,

$$b_i = b_i^i = c_i, \tag{6}$$

$$b_j = b_j^i = b_j^j = 0, \tag{7}$$

$$b_i^j = 0. \tag{8}$$

In order to implement joint extra production, both agents need to be paid a bonus equal to their effort cost when each of them works hard and no bonus when they shirk. Thus,

$$b_i = b_i^i = c_i, \tag{9}$$

$$b_i^j = 0, \quad \text{for } i, j = 1, 2, i \neq j. \tag{10}$$

Assume agent 1 is more productive than agent 2, i.e., $q_1 - c_1 \geq q_2 - c_2$. Given these optimal bonuses, the principal compares his profits when implementing individual extra effort by the most productive agent

[14] As will become clear below, we impose budget constraints off-equilibrium to show the interesting interplay between creating inequity off-equilibrium via *envy* or *guilt.* Without budget constraints, the principal could offer infinite bonuses to one agent off-equilibrium, thereby maximizing the other agent's *envy* when not performing at the optimal extra production level.

$(\overline{K}+q_1-c_1-2\overline{w})$ with his profits when joint extra effort is implemented $(\overline{K}+1-c_1-c_2-2\overline{w})$. Hence, joint extra effort is implemented if $1-c_1-c_2>q_1-c_1$ or, equivalently, $1-q_1>c_2$, i.e., the incremental output of agent 2 is greater than the agent's cost.

We now turn to optimal contract design with inequity-averse agents, which is our focus. For simplicity, assume that the minimum wage $(\overline{w})$ is sufficiently high, such that agents prefer to work in this firm rather than take the outside option. (The effects of removing this assumption are discussed below.) Note that when an agent is inequity averse, bonuses offered to the other agent are an externality in his utility function. Hence, creating inequality with the rewards offered off-equilibrium may provide incentives for agents to exert extra effort.

We start by looking at the minimal bonuses needed to implement individual extra production by agent $i$. If the contract designed for individual extra production by standard agents is offered to inequity-averse agents, agent $i$ is indifferent between working and not working when agent $j$ does not work hard. We maintain our assumption that when indifferent agents work hard, this reward scheme implements individual production by agent $i$ as the unique equilibrium of the game.[15] The cost of implementing individual extra production by agent $i$ is thus his cost of effort, $b_i^i=c_i$. It is not possible to obtain individual production by agent $i$ by paying a lower bonus. The reason is that if agent $j$ shirks, and given limited liability (R1) and budget constraints (R2), both agents are paid no bonus when they both shirk. Hence, there is no inequity when agent $i$ also shirks. Therefore, the only way to provide incentives for agent $i$ to individually work hard is via bonuses, not by offering more equity when he works hard than when he shirks. The bonus paid in equilibrium must at least compensate agent $i$ for his cost of effort and thus $b_i^i=c_i$.

We now consider joint extra production. First, Propositions 1 and 2 state general results that describe the worst possible punishment for each agent when he shirks. By punishing agents when they shirk, agents' incentive-compatibility constraints are relaxed and bonuses paid in equilibrium may be low.

**Proposition 1.** *To generate the worst possible punishment to an inequity-averse agent who shirks, it is optimal to offer no bonus to the agent who shirks while the other agent individually works hard* $(b_i^j=0)$.

The intuition behind this result is that due to limited liability (R1), bonuses offered cannot be negative, and due to (U2) agents care more

[15] Agent $j$ prefers not to work hard both because he is not rewarded for it and because he suffers from *envy* when working hard, as agent $i$ is better off.

about their direct utility than about the comparison with the other agent. Thus, the disutility of an agent who shirks is maximized when he is offered no bonus.

**Proposition 2.** *To generate the worst possible punishment to an inequity-averse agent who shirks, it is optimal to offer extreme bonuses to the agent who individually works hard (agent i). If the potential effect of envy on the shirking agent (j) is relatively high ($\alpha(q_i - c_i) \geq \beta c_i$), agent i must be offered all the extra output when he individually works hard ($b_i^i = q_i$). If, in contrast, the potential effect of guilt is relatively high ($\alpha(q_i - c_i) < \beta c_i$), agent i must be offered no bonus when he individually works hard ($b_i^i = 0$).*

Agent $j$ derives disutility from both *envy* and *guilt,* but not from both at the same time. The punishment via *envy* is maximized when the other agent is offered all available extra output ($b_i^i = q_i$), and thus the maximum disutility generated by *envy* is equal to $\alpha(q_i - c_i)$. The punishment via *guilt* is maximized when the other agent is not offered any bonus when he performs the costly extra effort ($b_i^i = 0$). Thus, the maximum disutility generated by *guilt* equals $\beta c_i$. Therefore, the relevant comparison in order for the principal to generate maximum punishment when agent $j$ shirks is $\alpha(q_i - c_i) \gtreqless \beta c_i$. Using Propositions 1 and 2, the *envious* agent $j$ obtains minimum utility when he shirks and agent $i$ works hard, not only because he does not get any reward (by Proposition 1), but also because he experiences the maximum feasible *envy*, as agent $i$ is paid the maximum available reward. On the other hand, the *guilty* agent $j$ obtains minimum utility when he shirks, not only because he is not paid any bonus, but also because he experiences the maximum feasible *guilt* as agent $i$ exerts a costly effort and is paid the lowest feasible bonus, which given (R1) is zero.

We now consider the optimal contract for implementing joint production. The following proposition shows the optimal bonuses for all levels of extra production when joint extra production is implemented as the unique equilibrium of the game.

**Proposition 3.** *To implement joint extra production when agents are inequity averse, the optimal contract is as follows:*

1. *An agent who shirks is offered no bonus ($b_i^j = b_j^i = 0$).*
2. *Case (a). If the maximum feasible punishment for both shirking agents is generated via envy ($\alpha(q_i - c_i) \geq \beta c_i$ for $i = 1, 2$), both agents are offered all available extra output when they individually work hard ($b_i^i = q_i$ and $b_j^j = q_j$).*

*Case (b). If the maximum feasible punishment for one shirking agent (i) is generated via envy and for the other agent (agent j) is generated via* *guilt* ($\alpha(q_j - c_j) \geq \beta c_j$ *and* $\alpha(q_i - c_i) < \beta c_i$ *for* $i, j = 1, 2, i \neq j$), *then one agent is offered all available extra output when he individually works hard* ($b_j^j = q_j$) *while the other agent is offered no bonus when he individually works hard* ($b_i^i = 0$).

*Case (c). If the maximum feasible punishment for both shirking agents is generated via guilt* ($\alpha(q_i - c_i) < \beta c_i$ *for* $i = 1, 2$), *then one agent is offered all available extra output when he individually works hard* ($b_j^j = q_j$) *while the other agent is offered no bonus when he individually works hard* ($b_i^i = 0$). *Which agent is offered all available extra output is determined by the relative maximum effect of guilt and envy for each agent.*

3. *Indifference between working hard and shirking when the other agent works hard determines the bonuses agents are paid in equilibrium* ($b_i$ *and* $b_j$), *as long as bonuses are positive. Otherwise, agents are paid no bonus* ($b_i = 0$ *for* $i = 1, 2$).

This result uses Propositions 2 and 3 in order to punish agents who shirk, thus providing incentives for both agents to work hard. In cases (a) and (b) it is optimal to maximize the punishment to the shirking agent so that extreme bonuses are offered to the agent who individually works hard.

In order to explain the intuition behind this result we consider case (b) graphically. Figure 1 shows the optimal bonuses paid when $\alpha(q_j - c_j) \geq \beta c_i$ and thus it is optimal to exploit agent *i*'s *envy* and agent *j*'s *guilt.* In such a case, it is optimal to offer all available extra output to agent *j* when he individually works hard ($b_j^j = q_j$) and no bonus to agent *i* when he individually works hard ($b_i^i = 0$). Equilibrium bonuses are combinations of $b_i$ and $b_j$, obtained by indifference between each agent's utility when both agents work hard and their utility when they individually shirk. The principal seeks to maximize profits and thus chooses equilibrium bonuses such that both agents choose to work hard (which occurs in the shaded area) and such that the sum of equilibrium bonuses is the minimum possible. Given the slopes of the indifference curves defined by (U1) and (U2), this occurs at the unique point at which both agents' indifference curves intersect and thus agent *i* suffers more from *envy* when he individually shirks than agent *j* suffers from *guilt* when he individually shirks. Therefore, equilibrium wages are on the left-hand side of the 45° line, implying that in equilibrium agent *i* obtains less direct utility than agent *j*. A symmetric graph can be drawn for the case where $\alpha(q_j - c_j) < \beta c_i$.

In case (c) it is not optimal to maximize the punishment to the shirking agent as the equilibrium of the game played by the agents would not be unique. Given (R1) and (R2), the case where both agents shirk would also be an equilibrium in which the utility of both agents would Pareto dominate the utility when they both work. Thus, the principal could not be certain

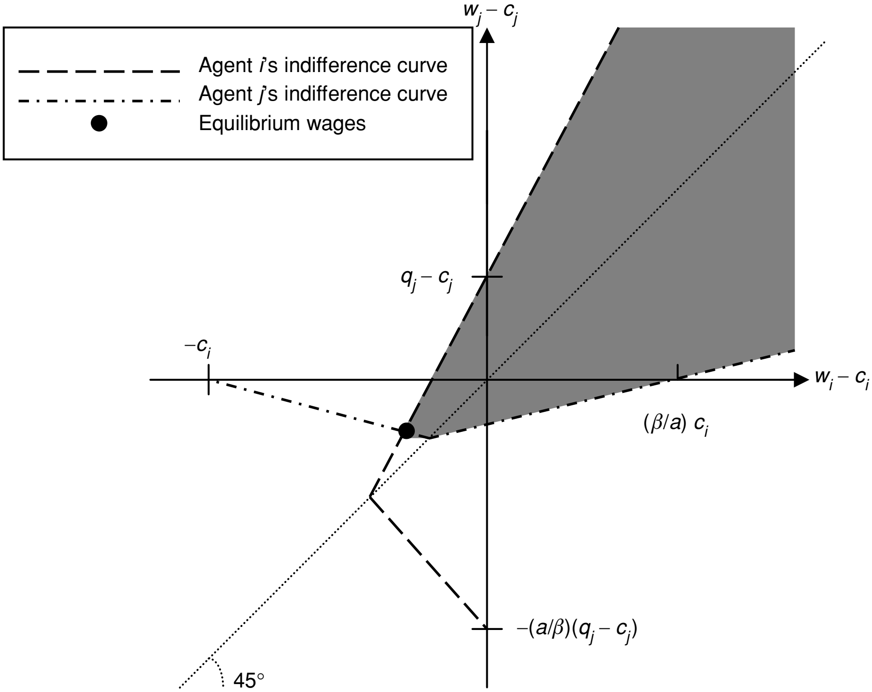


*Fig. 1.* Equilibrium bonuses when *envy* agent *i*, *guilt* dominates for agent *j* and $\alpha(q_j - c_j) > \beta c_i$

that such a contract would implement joint production when it is optimal to do so. The expression for the bonuses paid in equilibrium in each of the three cases is shown in the proof of Proposition 3 in the Appendix. Note that the sum of bonuses paid in equilibrium is always lower than the sum of both agents' cost of effort, and thus it is immediate to conclude the following:

**Corollary 1.** *The principal obtains higher profits when implementing joint production with inequity-averse agents than with standard agents.*

Intuitively, the contract that implements extra joint production with standard agents also implements joint production with inequity-averse agents. The reason is that in all possible circumstances, all direct utilities are equal and thus inequity does not play a role. The sum of bonuses needed to be paid in equilibrium is $c_i + c_j$. However, when $\overline{w}$ is sufficiently high, the principal can do better than exactly compensate agents' costs of extra effort. Following Propositions 1–3, the principal can generate inequity off the equilibrium of the game such that inequity-averse agents' utilities are lower than standard agents' direct utilities. Thus, by paying agents a bonus lower than their cost of extra effort but maintaining more equity in equilibrium than off-equilibrium, joint production is optimally implemented at a lower total cost for the principal than with standard preferences.

Each agent's equilibrium bonuses are not necessarily lower than in the standard case, but the sum of the two bonuses paid is. In addition, there may still exist inequity when joint extra production is implemented and bonuses paid in equilibrium need not be the same for both agents. Bonuses paid just need to be sufficiently close for both incentive-compatibility constraints to hold at the lowest total cost of bonuses in equilibrium for the principal.

Next, we consider the conditions for each level of extra production to be optimal and, in particular, we state the main result of this paper.

**Proposition 4.** *Inequity aversion may, in itself, be a reason to demand joint extra production by agents who compare themselves, even if the productivity of some agents is low.*

The proof is convoluted but straightforward and therefore omitted here.[16] Corollary 1 shows that the profits when implementing joint production may be higher if agents are inequity averse than if they are not. Consider the case in which adding the least productive agent to perform joint extra production is not profitable because he is not very productive ($1-q_1<c_2$ for $q_1-c_1\geq q_2-c_2$). If agents have standard preferences, the increased production by agent 2 does not compensate the added cost of having him exert extra effort ($b_2=c_2$). However, if agents are inequity averse, it is possible not only for agent 2 to perform the extra work when paid a lower bonus, but also for agent 1 to accept a lower bonus and work hard. Thus, the principal may be interested in implementing agent 2's high effort, not only because it adds extra production, but also because it makes agent 1 feel more envious or guilty off-equilibrium, thereby providing incentives for both agents to work hard even if bonuses paid do not cover their effort costs.

Our results imply that with inequity-averse agents, bonuses are interdependent and thus need to be carefully designed, a result also obtained by Itoh (2004) in a moral-hazard context.[17] When inequity-averse employees work in a firm, both bonuses and effort choices are interdependent, irrespective of whether employees are asked to exert extra effort. Here, we have extended this result by showing that inequity aversion may actually be a reason to demand extra effort from the least productive agents.

[16] Rey-Biel (2005) contains all proofs as well as expressions for the costs of implementing each level of effort in all cases.
[17] See Che and Yoo (2001).

## IV. Extensions

We now turn to some important issues regarding the relevance of our simple model.[18]

### *Effects of the Participation Constraint on Optimal Contracts*

Our analysis has focused on incentive-compatibility constraints instead of on participation constraints because there may exist realistic situations in which employers cannot force employees down to their participation constraint. Our model uses a minimum wage ($\overline{w}$) for the participation constraint to be satisfied. Here we discuss the effects of changes in such a minimum wage. Other alternatives such as reservation utilities, search costs of new jobs, disutility of unemployment or good matching with the employer would have equivalent effects and could be modeled identically. We have shown that the principal benefits from inequity aversion as long as agents have a higher reservation utility than in any possible outside option. Thus, the more attached employees are to their jobs, the more the employer can benefit from inequity aversion. We briefly consider the effects of changes in the value of this reservation utility using the perspective of a minimum wage, although ultimately, $\overline{w}$ may represent any reservation utility which is higher in the firm than in the outside option.

We have assumed that the minimum wage ($\overline{w}$) when working in the firm was sufficiently high in equilibrium for agents to prefer to work in the firm and perform at the effort levels required by the implemented equilibrium rather than taking the outside option, no matter how much disutility they obtain from inequity. If this is not the case, agents may prefer to quit the firm and take an outside option. Therefore, the exogenous value of the minimum wage limits the extent to which inequity aversion can be exploited by the principal.

We study the conditions on the participation constraints for the case where it is optimal to demand an extra level of effort from both agents. Note that the participation constraint only needs to be satisfied in the implemented equilibrium (both agents exert an extra level of effort). However, as incentive-compatibility constraints also need to be satisfied (both agents prefer to exert the extra effort than not), the participation constraint should also trivially hold off-equilibrium when only one agent exerts extra effort.

Assume that agent $i$ shirks off-equilibrium and that $\alpha(q_j - c_j) \geq \beta c_j$ for $i \neq j$. Thus, for incentive-compatibility reasons it would be optimal to make

[18] For more formal results in this section, see Rey-Biel (2005).

agent $i$ *envious* and offer all individual extra output to the agent who works hard off-equilibrium ($b_j^j = q_j$). However, given that it is still optimal to offer no reward to the shirking agent ($b_i^j = 0$), the participation constraint of the shirking agent will not hold when:

$$\overline{w} < \alpha(q_j - c_j). \tag{11}$$

In such cases, the maximum bonus that can be offered to agent $j$ when individually exerting the extra effort, such that the participation constraint of the shirking agent holds, is $b_j^j = (\overline{w}/\alpha) + c_j > 0$. This creates exact equality when agent $i$ shirks and thus the minimum bonus cost of providing incentives to agent $i$ to work hard, given that agent $j$ also works hard, would be the same as with standard agents. Alternatively, the principal could make agent $i$ feel *guilt* when shirking by setting $b_j^j = 0$. This creates inequity off-equilibrium and thus the possibility of a lower bonus to provide incentives to agent $i$. However, $b_j^j = 0$ will only satisfy agent $i$'s participation constraint for sufficiently high $\overline{w}$, in particular for $\overline{w} > \beta c_j$. Otherwise, the principal must set $b_j^j = c_j$ and, as there is no inequity when only agent $i$ shirks, $b_i = c_i$. Thus, for low enough $\overline{w}$, inequity aversion does not decrease the cost of implementing joint extra effort by agent $i$.

Assume now that agent $i$ shirks off-equilibrium but that $\alpha(q_j - c_j) < \beta c_j$ for $i \neq j$. It is still optimal to offer no reward to the shirking agent ($b_i^j = 0$). Thus, due to incentive compatibility, it would be optimal to make agent $i$ feel *guilty* and offer no bonus to the agent who works hard off-equilibrium ($b_j^j = 0$). Note that if $b_j^j = 0$, agent $j$'s participation constraint would not hold unless $\overline{w} \geq (1+\alpha)c_j$.[19] But when $b_j^j = 0$, the participation constraint of the agent who shirks off-equilibrium only holds for sufficiently high $\overline{w}$, in particular for $\overline{w} > \beta c_j$. Otherwise, the principal must set $b_j^j = c_j$ and, as there is no inequity when only agent $i$ shirks, $b_i = c_i$. Thus, equivalently, for low enough $\overline{w}$, inequity aversion does not decrease the cost of implementing joint extra effort by agent $i$.

Ultimately, it is clear that benefiting from the possibility of inducing extra effort while paying lower rewards than each agent's effort costs is only possible so long as the participation constraint is not binding.[20] Thus, for a low enough $\overline{w}$ and, in particular, for $\overline{w} \leq \beta c_j$, it may not be possible to create inequity off-equilibrium ($b_j^j = c_j$ and $b_i^j = 0$), and the joint extra level of effort will be implemented by paying exactly the same bonuses as when agents are not inequity averse.

[19] When $b_i^j = 0$ and $b_j^j = 0$, joint extra production may not be a unique equilibrium, as both agents will prefer to shirk given that the other agent is shirking. This is the same problem that arises in case (c) of Proposition 3.

[20] A similar issue is discussed in Demougin and Fluet (2006).

By normalizing the value of the outside option to zero, we are implicitly assuming that the extent to which agents suffer from utility comparisons when taking the outside option is more limited than inside the firm. However, it is still very plausible that agents would suffer from utility comparisons outside the firm. The analysis of the participation constraint is especially tricky when dealing with interdependent preferences because it is not clear what the reference point should be when agents take the outside option. In particular, a deeper analysis of the participation constraint would imply making strong assumptions on whether agents feel equally inequity averse when working in other firms or whether they may feel envious or guilty about other agents left behind in the original firm.[21] In such cases, the value of the outside option would be lower with respect to the firm, again opening the possibility of exploiting inequity aversion inside the firm.

### *Continuous Effort*

Our results are not limited to the case in which effort is dichotomous. Assume the extra effort by agent $i$ is a continuous variable $e_i \in \mathbb{R}_+$ with an associated cost of effort $c_i(e_i) \in \mathbb{R}_+$. For each possible effort choice by the two agents $(e_i, e_j) \in \mathbb{R}^2_+$ for $i \neq j$, extra production is $f(e_i, e_j) \in \mathbb{R}^2_+$. Assume the principal finds it optimal to implement the extra level of effort $\overline{e_i}$ from agent $i$, and $\overline{e_j}$ from agent $j$, such that extra production is $f(\overline{e_i}, \overline{e_j})$. If agents have standard preferences, the principal implements this extra production level at minimum cost by paying bonuses $b_i(e_i, e_j) \in \mathbb{R}_+$, such that $b_i(\overline{e_i}, e_j) = c_i$ and such that $b_i(e_i, e_j) = 0$ for any $e_i \neq \overline{e_i}$, $i = 1, 2$, and thus the total bonus bill will be $c_i(\overline{e_i}) + c_j(\overline{e_j})$. However, if agents are inequity averse, the principal can obtain the extra production level $f(\overline{e_i}, \overline{e_j})$ at a lower cost. Given that extra effort by each agent is observable and verifiable, the results from Section III extend to this model. The optimal bonus contract is then to pay no bonus to an agent who does not meet the principal's demands, $b_i(e_i, e_j) = 0$ for any $e_i \neq \overline{e_i}$ and any $e_j \in \mathbb{R}_+$. If agent $i$ meets the principal's demands while agent $j$ does not, then either $b_i(\overline{e_i}, e_j) = f(\overline{e_i}, e_j)$ or $b_i(\overline{e_i}, e_j) = 0$, depending on whether it is optimal to exploit agent $i$'s *envy* or *guilt*, respectively.[22] Thus, both agents perform the extra level of effort required $(\overline{e_i}, \overline{e_j})$ and the total bonus bill is lower than when agents have standard preferences $b_i(\overline{e_i}, \overline{e_j}) + b_j(\overline{e_i}, \overline{e_j}) \leq c_i(\overline{e_i}) + c_j(\overline{e_j})$.

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[21] Demougin and Fluet (2003) and Grund and Sliwka (2005) have further studied the effect of the participation constraint in tournaments among inequity-averse agents.
[22] To obtain equilibrium uniqueness in the case where it is optimal to exploit both agents' guilt, the derivation is analogous to case (c) in Proposition 3.

Since effort is continuous, it is now possible that an agent ($i$) who does not meet the principal's demands still contributes to extra production. Thus, it would appear that given budget constraints (R2), it would be possible to use this extra production to pay a higher bonus to the agent who does not shirk ($j$), and thus exploit agent $i$'s *envy* even more, in order to pay him a lower bonus in equilibrium. However, this intuition is wrong, as agent $i$ still needs to prefer to exert $e_i = \overline{e_i}$ instead of $e_i = 0$ for $(\overline{e_i}, \overline{e_j})$ to be an equilibrium. Note that if $e_i = 0$, extra production is $f(0, \overline{e_j})$ and thus the output available to offer to agent $j$ when he works hard and agent $i$ does not work at all ($e_i = 0$) is the same as in the dichotomous case.

Our extended model yields a lower total bonus bill paid when agents are inequity averse than when they are standard for any possible effort level by each of the agents. Conditions for each level of effort by each agent to be optimal are analogous to the derivation in Section III.

### *Status and Efficiency-seeking Preferences*

We now focus on two other forms of social preferences that may be relevant in the context of the firm: *status seeking* and *efficiency concerns*.

In very competitive firms, an agent might not dislike inequity. Instead, he might enjoy it, at least as long as it is the other agent who is worse off than he is. Following Charness and Rabin (2002), we can model such preferences (status seeking) using the Fehr and Schmidt model but assuming $\alpha \in [0, 1)$, $\beta < 0$ and $|\beta| \leq 1$. Agents with such preferences enjoy advantageous inequality (*spite*) and dislike disadvantageous inequality (*envy*). Thus, they can only be punished when individually shirking by offering a high bonus to the agent who individually exerts the extra effort. The optimal contract to implement joint extra production looks exactly like case (a) in Proposition 3, although the value taken by the bonuses paid in equilibrium is now lower than with inequity-averse agents.

In contexts in which each agent contributes a lot to total production, agents might feel disutility when shirking because the total amount of extra output, and thus the total amount of bonuses available to be distributed among agents, gets smaller when they shirk. We call these agents "efficiency seeking", where efficiency in interpreted as the sum of agents' welfare net of the costs of the extra level of effort.[23] Assume now that $\alpha < 0, \beta \in [0, 1/2)$ and $|\alpha| \leq |\beta|$. This implies that agents care about the weighted sum of direct utilities, by putting more weight on one's own direct utility than on the other agent's direct utility. In such cases, the

[23] In a comparative test of distributional preferences, Engelmann and Strobel (2004) find that in the laboratory most data are better explained by efficiency concerns than by other distributional preferences such as inequity aversion.

optimal threat of inequality off-equilibrium would then be to offer no reward to any agent unless joint production is implemented. However, similarly to case (c) in Proposition 3, such a threat would make no extra production by both agents another (Pareto-dominating) equilibrium of the game. Thus, one of the agents, in particular the one whose effort cost is lowest, needs to be offered a reward equal to his effort cost when he individually works hard off-equilibrium. All remaining bonuses offered off-equilibrium are equal to zero. Finally, equilibrium bonuses paid are determined using the indifference condition. As in previous sections, the sum of bonuses paid can still be lower than the sum of the effort costs.

### *Budget Constraints*

Without limited liability (R1), the potential to maximize the punishment via *guilt* would be unlimited. Without budget constraints (R2), the potential to maximize the punishment via *envy* would also be unlimited. The principal could threaten an agent who shirks by offering the other agent an infinite positive bonus when he individually works (to maximize *envy*) or by offering a negative bonus, i.e., a penalty (to maximize *guilt*). Therefore, the deeper the pockets of firms or the lower the value of the outside option, the stronger our results and, thus, the more profitable exploiting inequity aversion can be. In cases in which firms are not budget constrained, it may then be possible to obtain individual extra joint production with inequity-averse agents while incurring a lower bonus cost than with standard agents. Optimal contract design would look different, although the main intuition remains.

In any case, threats of inequality off-equilibrium need to be credible to be effective in providing incentives to work hard. Thus, it is reasonable to establish some limitations on the offers made by the principal off-equilibrium in order to create inequality. Assumptions (R1) and (R2) are just natural benchmarks that allow us to describe the intuition of the reward mechanism in its simplest form.

## V. Discussion

We have shown the simplest possible model in which two novel and interesting results can be obtained. First, if welfare comparisons among employees exist within the firm, they should not be ignored and contracts should specify rewards for all agents under all possible circumstances. Second, optimally taking into account the design of bonuses offered to distributionally concerned employees may, in itself, provide a new reason to demand joint effort, even when efforts are not complementary or there are no informational problems.

Despite its simplicity, our model provides a new rationale for team and relative performance contracts in contexts with no informational asymmetries. In both types of contracts, agents are threatened with welfare inequities when some employees work harder than others. In team contracts (with joint performance evaluation), when a member of the team shirks, the team's performance is less successful. Thus, other members of the team who work hard do not see their efforts rewarded, which might make the shrinking agent feel guilty. Therefore, agents might decide not to shirk even if rewards offered to them are low in order to avoid feeling guilty about the members of the team who work hard. In relative performance contracts (with relative performance evaluation), when an agent shirks he will be ranked low. Thus, he will be worse off than higher ranked agents, which may actually make him feel envious. In competitive contexts, it may therefore not be necessary to offer such high bonuses when agents are envious of each other and compete so as not to be ranked lower than their peers. Thus, welfare comparisons among peers can be used by the employer to provide incentives to work hard. Our results show that team and relative performance contracts may be optimal even in many work situations in which output is deterministic and/or effort is easily observable by managers.

Our model highlights how behavioral contract theory can be useful to study issues of organization in the firm. Both the human resources literature and the personnel economics literature have considered these issues before.[24] The contribution of our study is that it indicates how comparisons among agents can be affected by the design of the contract. Our model suggests that optimal contracts may depend on the strength of welfare comparisons. If that is the case, it may be possible to affect the strength of those comparisons in the workplace. We have assumed here that everything was given and observable. However, in real firms, the employer might be able to influence which information is easily available to its employees, once it has been clarified which variables enter employees' welfare comparisons in different contexts. In particular, decisions such as whether to make salaries publicly available to co-workers or the allocation of office space (which might affect the observability of effort by co-workers) could be illuminated by the issues discussed here. Although in many firms rewards are kept secret[25] and employees work in separate and closed offices, we have provided a factor that in some cases may push towards the opposite direction.

[24] See Lazear (1995).

[25] However, Bewley (1999) reports that 87% of managers interviewed think that their employees know each others' wages.

## Appendix

### *Proof of Proposition 1*

Agent *i*'s utility when he shirks, given that agent *j* works is:

$$\overline{w} + b_i^j - \alpha \max\left[b_j^j - c_j - b_i^j, 0\right] - \beta \max\left[b_i^j - b_j^j + c_j, 0\right]. \tag{A1}$$

Note that inequity aversion imposes that an agent obtains disutility from being either better off or worse off than the other agent, but not from both at the same time.

(a) If agent $i$ is worse off than agent $j$, the effect of *envy* dominates and $b_j^j - c_j - b_i^j \geq 0$. Thus, to minimize the utility of agent $i$ when he shirks, $b_i^j = 0$, as the derivative of agent $i$'s utility with respect to the bonus offered to agent $j$ equals $1 + \alpha > 0$, by assumption (U1).
(b) If agent $i$ is better off than agent $j$, the effect of *guilt* dominates and $b_i^j - b_j^j + c_j \geq 0$. Thus, to minimize the utility of agent $i$ when he shirks, $b_i^j = 0$, as the derivative of agent $i$'s utility with respect to the bonus offered to agent $j$ equals $1 - \beta > 0$, by assumption (U2). ■

### *Proof of Proposition 2*

By Proposition 1, the bonus that maximizes agent $j$'s punishment when agent $i$ individually works hard is $b_j^i = 0$. The utility of agent $j$ when agent $i$ individually works hard is thus equal to $\overline{w} - \alpha \max[b_i^i - c_i, 0] - \beta \max[-b_i^i + c_i, 0] - \overline{w}$, where by (R1) and (R2) $b_i^i \in [0, q_i]$, and by (C) $0 \leq c_i \leq q_i$. Thus, to minimize agent $j$'s utility:

$$b_i^i = q_i \quad \text{if } \alpha(q_i - c_i) \geq \beta c_i, \tag{A2}$$

$$b_i^i = 0 \quad \text{if } \alpha(q_i - c_i) < \beta c_i. \tag{A3}$$

■

### *Proof of Proposition 3*

First, from Proposition 1 it is optimal not to offer any bonus to agents when they shirk, in order to create incentives for both agents to work: $b_i^j = b_j^i = 0$.

We now show the remaining bonuses in each of the three cases in Proposition 3.

Case (a): If $\alpha(q_i - c_i) \geq \beta c_i$ for $i = 1, 2$, it is optimal to choose $b_i^i = q_i$. Using Proposition 2, the only candidate for equilibrium is joint extra effort. The principal maximizes $1 - b_1 - b_2$ subject to both agents preferring to exert extra effort. Using the slopes of the indifference curves given by (U1) and (U2), the conditions optimally hold with equality and profits are maximized at the unique point at which the indifference curves intersect. Let $j$ be the agent for whom $q_j - c_j \geq q_i - c_i$, then:

$$b_i = c_i - \frac{\alpha^2(q_i - c_i) - \alpha(\beta - 1)(q_j - c_j)}{\alpha + (1 - \beta)} < c_i, \tag{A4}$$

$$b_i^i = q_i, \tag{A5}$$

$$b_j = c_j + \frac{\alpha\beta(q_j - c_j) - \alpha(1 + \alpha)(q_i - c_i)}{\alpha + (1 - \beta)} \gtreqless c_j, \tag{A6}$$

$$b_j^j = q_j. \tag{A7}$$

Given (R1), if

$$c_i < \frac{\alpha^2(q_i - c_i) - \alpha(\beta - 1)(q_j - c_j)}{\alpha + (1 - \beta)}$$

then $b_i = 0$ and $b_j$ is determined by indifference. If

$$c_j < -\left(\frac{\alpha\beta(q_j - c_j) - \alpha(1 + \alpha)(q_i - c_i)}{\alpha + (1 - \beta)}\right)$$

then $b_j = 0$ and $b_i$ is determined by indifference.

Case (b): If $\alpha(q_i - c_i) < \beta c_i$ and $\alpha(q_j - c_j) \geq \beta c_j$ for $i, j = 1, 2$, $i \neq j$, it is optimal to choose $b_i^i = 0$ and $b_j^j = q_j$. The two cases are created by whether the intersection of both indifference curves occurs at a point where $b_i - c_i \lesseqgtr b_j - c_j$.

Let $\alpha(q_i - c_i) < \beta c_i$ and $\alpha(q_j - c_j) \geq \beta c_j$. Then

$$b_i^i = 0 \quad b_j^j = q_j, \tag{A8}$$

and:

For $\alpha(q_j - c_j) \geq \beta c_i$, then

$$b_i = c_i - \frac{\alpha\beta c_i + \alpha(1 - \beta)(q_j - c_j)}{\alpha + (1 - \beta)} < c_i, \tag{A9}$$

$$b_j = c_j + \frac{\alpha\beta(q_j - c_j) - \beta(1 + \alpha)c_i}{\alpha + (1 - \beta)} \gtreqless c_j. \tag{A10}$$

Given (R1), if

$$c_i < \frac{\alpha\beta c_i + \alpha(1 - \beta)(q_j - c_j)}{\alpha + (1 - \beta)}$$

then $b_i = 0$ and $b_j$ is determined by indifference. If

$$c_j < -\left(\frac{\alpha\beta(q_j - c_j) - \beta(1 + \alpha)c_i}{\alpha + (1 - \beta)}\right)$$

then $b_j = 0$ and $b_i$ is determined by indifference.

For $\alpha(q_j - c_j) < \beta c_i$ then:

$$b_i = c_i + \frac{\beta^2 c_i - \alpha(1+\alpha)(q_j - c_j)}{\alpha + (1-\beta)} > c_i, \tag{A11}$$

$$b_j = c_j - \frac{\alpha^2(q_j - c_j) + \beta(1-\beta)c_i}{\alpha + (1-\beta)} < c_j. \tag{A12}$$

Given (R1), if

$$c_j < \frac{\alpha^2(q_j - c_j) + \beta(1-\beta)c_i}{\alpha + (1-\beta)}$$

then $b_j = 0$ and $b_i$ is determined by indifference.

Case (c): If $\alpha(q_i - c_i) < \beta c_i$ for $i = 1, 2$, inequity off-equilibrium would be maximized by setting $b_i^i = 0$ and $b_j^j = q_j$. However, the equilibrium would not be unique. Thus, one of the agents is offered a bonus equal to all available output when he individually works hard instead of no bonus. Therefore, off-equilibrium, one agent suffers the maximum effect of *guilt* when he shirks while the other suffers the maximum effect of *envy* ($b_i^i = 0$ and $b_j^j = q_j$ for $i, j = 1, 2$, $i \neq j$). Thus, one of the indifference curves is satisfied at the "optimal" level (for the agent who suffers *guilt* when he shirks) while the other is satisfied at the "suboptimal" level (for the agent who suffers *envy* when he shirks). The optimal bonuses paid are obtained at the intersection of one of the "optimal" and one of the "suboptimal" indifference curves. The conditions indicate for which of the four possible cases, profits are maximized.

Let $\alpha(q_i - c_i) < \beta c_i$, $\alpha(q_j - c_j) < \beta c_j$. Then for $c_j \geq c_i$:

For $\alpha(q_j - c_j) \geq \beta c_i$:

if $(1 - 2\beta)[\alpha(q_j - c_j) - \beta c_j] \geq (1 + 2\alpha)[\alpha(q_i - c_i) - \beta c_i]$, then:

$$b_i = c_i - \frac{\alpha\beta c_i + \alpha(1-\beta)(q_j - c_j)}{\alpha + (1-\beta)} < c_i, \tag{A13}$$

$$b_i^i = 0, \tag{A14}$$

$$b_j = c_j + \frac{\alpha\beta(q_j - c_j) - \beta(1+\alpha)c_i}{\alpha + (1-\beta)} \lesseqgtr c_j, \tag{A15}$$

$$b_j^j = q_j. \tag{A16}$$

Given (R1), if

$$c_i < \frac{\alpha\beta c_i + \alpha(1-\beta)(q_j - c_j)}{\alpha + (1-\beta)}$$

then $b_i = 0$ and $b_j$ is determined by indifference. If

$$c_j < -\left(\frac{\alpha\beta(q_j - c_j) - \beta(1+\alpha)c_i}{\alpha + (1-\beta)}\right)$$

then $b_j = 0$ and $b_i$ is determined by indifference.

If $(1-2\beta)[\alpha(q_j - c_j) - \beta c_j] < (1+2\alpha)[\alpha(q_i - c_i) - \beta c_i]$, then:

$$b_i = c_i - \frac{\alpha^2(q_i - c_i) + \beta(1-\beta)c_j}{\alpha + (1-\beta)} < c_i, \tag{A17}$$

$$b_i^i = q_i, \tag{A18}$$

$$b_j = c_j + \frac{\beta^2 c_j - \alpha(1+\alpha)(q_i - c_i)}{\alpha + (1-\beta)} \lesseqgtr c_j, \tag{A19}$$

$$b_j^j = 0. \tag{A20}$$

Given (R1), if

$$c_i < \frac{\alpha^2(q_i - c_i) + \beta(1-\beta)c_j}{\alpha + (1-\beta)}$$

then $b_i = 0$ and $b_j$ is determined by indifference. If

$$c_j < -\left(\frac{\beta^2 c_j - \alpha(1+\alpha)(q_i - c_i)}{\alpha + (1-\beta)}\right)$$

then $b_j = 0$ and $b_i$ is determined by indifference.

For $\alpha(q_j - c_j) < \beta c_i$:

if $\alpha(1+2\alpha)(q_j - c_j - q_i + c_i) \geq \beta(1-2\beta)(c_j - c_i)$, then:

$$b_i = c_i + \frac{\beta^2 c_i - \alpha(1+\alpha)(q_j - c_j)}{\alpha + (1-\beta)} > c_i, \tag{A21}$$

$$b_i^i = 0, \tag{A22}$$

$$b_j = c_j - \frac{\alpha^2(q_j - c_j) + \beta(1-\beta)c_i}{\alpha + (1-\beta)} < c_j, \tag{A23}$$

$$b_j^j = q_j, \tag{A24}$$

Given (R1), if

$$c_j < \frac{\alpha^2(q_j - c_j) + \beta(1-\beta)c_i}{\alpha + (1-\beta)}$$

then $b_i = 0$ and $b_j$ is determined by indifference.

If $\alpha(1+2\alpha)(q_j - c_j - q_i + c_i) < \beta(1-2\beta)(c_j - c_i)$, then:

$$b_i = c_i - \frac{\alpha^2(q_i - c_i) + \beta(1-\beta)c_j}{\alpha + (1-\beta)} < c_i, \tag{A25}$$

$$b_i^i = q_i, \tag{A26}$$

$$b_j = c_j + \frac{\beta^2 c_j - \alpha(1+\alpha)(q_i - c_i)}{\alpha + (1-\beta)} \lesseqqgtr c_j, \tag{A27}$$

$$b_j^j = 0. \tag{A28}$$

Given assumption (R1), if

$$c_i < \frac{\alpha^2(q_i - c_i) + \beta(1-\beta)c_j}{\alpha + (1-\beta)}$$

then $b_i = 0$ and $b_j$ is determined by indifference. If

$$c_j < -\left(\frac{\beta^2 c_j - \alpha(1+\alpha)(q_i - c_i)}{\alpha + (1-\beta)}\right)$$

then $b_j = 0$ and $b_i$ is determined by indifference. ■

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