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Abstract

In a two-period continuous effort investment game as in Mohnen, et al. (2008), we demonstrate that peer transparency can be strictly harmful. This contrasts with Mohnen et al.'s result that transparency, through the observability of interim efforts, induces more effort and is thus beneficial if team members are inequity-averse. If, instead, preferences are standard utilitarian, the marginal benefit is decreasing and marginal cost is increasing in a player's own effort, then players' collective and individual efforts are strictly less with transparency than under non-transparency.

***JEL* Classification:** D02.

Key Words: Transparency, team, perfect substitution, free-riding.

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1 Introduction

Mohnen et al. (2008) show that peer transparency in teams, by allowing inequity-averse workers to observe each others' efforts, induces more individual and collective efforts. This is because when workers are averse to inequality of contributions, the observability of efforts creates peer pressure: more first-round effort by a player creates pressure on her team members to reciprocate with increased efforts in later rounds, and similarly less early efforts induces lower efforts in response. When this information is not available, however, inequity-averse workers behave as though they are selfish: the feedback loop from early to later efforts gets broken, making non-transparency worse.

In contrast to the above model of Mohnen et al., we resort to standard utilitarian agents. Now despite the link between early round and later round efforts under effort observability, absence of peer pressure due to utilitarian preferences makes transparency sterile. This has two implications. In one, when marginal cost effort is constant but marginal benefit of individual efforts is decreasing (due to decreasing marginal probability of the team project's success from higher efforts), transparency and non-transparency yield identical aggregate efforts. Thus the outcome is neutral with respect to peer information. On the other hand, when marginal cost of effort is increasing and marginal benefit is decreasing, induced aggregate efforts under transparency falls below the efforts under non-transparency. This makes transparency harmful. The striking difference (of harmful transparency) from Mohnen et al. arises due to two factors: (i) utilitarian preferences vs. inequity aversion, (ii) technological differences. In Mohnen et al., while marginal cost of effort is increasing, marginal benefit of effort is constant: an agent's wage (i.e. benefit) is linear in aggregate team efforts.

In a related work, Winter (2010) has shown that in team projects with complementary efforts, greater transparency through better peer information in general architectures (where team members observe a subset of the predecessors' efforts) lowers full-efforts implementation costs, whereas effort substitution neutralizes the benefits of transparency.[1] The team production technology in ours and Mohnen et al. is one of perfect substitution.

In the next two sections, we develop the above result more formally.

[1] Winter (2006) employs, specifically, sequential architecture in teams, as opposed to the analysis of general architectures in Winter (2010). Some more recent works on peer monitoring and its role in incentives are Rahman (2012), Gershkov and Winter (2015).

2 The Model

Consider a project that consists of a single task that must be completed jointly by the players over two rounds. The probability of the project's success is $p(e)$, where $e = e_i + e_j = e_{i1} + e_{i2} + e_{j1} + e_{j2}$, $p(\cdot)$ is twice differentiable, $p(0) \geq 0$, $p'(e) > 0$, $p''(e) < 0$ for all $e \in [0, \bar{e}]$, $\bar{e} < \infty$, and $p'(\bar{e})$ is small enough (in a sense to become clear below). The project pays each player $v > 0$ if it succeeds and zero if it fails. Denote player i's cost of effort in round t $(= 1, 2)$, by $\psi(e_{it})$, where $\psi : [0, \bar{e}] \to \mathbb{R}_+$, $\psi(0) = 0$, $\psi'(0) = 0$, and $\psi'(\cdot) > 0$ and $\psi''(\cdot) \geq 0$ for all $e_{it} > 0$; further, $\psi'(\bar{e}) > p'(\bar{e})$. Given e_j, player i's utility following effort choices e_{i1} and e_{i2} is $u_i(e_i, e_j) = p(e_i + e_j)v - \sum_{t=1}^{2} \psi(e_{it})$.

3 The Analysis

Lemma 1. *Suppose that $\psi(\cdot)$ is strictly convex. Given e_j, for any e_i chosen by player i the payoff-maximizing breakdown of overall effort in the non-transparent environment is $e_{i1}^* = \frac{e_i}{2} = e_{i2}^*$.*

The proof is straightforward. Since, for any given aggregate effort e_j of player j, any (e_{i1}, e_{i2}) combination by player i over two rounds that add up to the same aggregate effort e_i yields the same probability of the project's success, player i would choose the effort combination that minimizes his overall effort costs. Since $\psi(\cdot)$ is strictly convex, splitting the aggregate effort, e_i, equally between the two rounds minimizes i's effort costs, so $e_{i1}^* = \frac{e_i}{2} = e_{i2}^*$.

When efforts are not observable, Lemma 1 allows us to write player i's $(i = 1, 2)$ maximization problem as

$$\max_{e_i} \quad u_i = p(e_i + e_j)v - 2\psi\left(\frac{e_i}{2}\right), \quad i \neq j.$$

The first-order conditions,

$$p'(e_i + e_j)v = \psi'\left(\frac{e_i}{2}\right), \quad i \neq j,$$

uniquely solve for $\frac{e_i^*}{2} = \frac{e_j^*}{2} > 0$, or $e_i^* = e_j^* = \epsilon^*$ (second-order conditions are satisfied). That is, in the unique one-shot equilibrium, (ϵ^*, ϵ^*), each player chooses an overall effort so that

the marginal effort cost in each round equals the private marginal benefit:

$$p'(2\epsilon^*)v = \psi'\left(\frac{\epsilon^*}{2}\right). \tag{1}$$

With observable efforts, players i and j engage in a two-round repeated effort investment game. The game is solved backwards. Given the first-round efforts e_{i1} and e_{j1} and the aggregate effort $e_{i1} + e_{j1}$ denoted as ξ_1, player i's second-round choice of e_{i2}, taking player j's second-round choice e_{j2} as given, solves

$$\max_{e_{i2}} \quad p(\xi_1 + e_{i2} + e_{j2})v - \psi(e_{i2}).$$

The first-order conditions implicitly define the players' reaction functions in Round 2:

$$p'(\xi_1 + e_{i2} + e_{j2})v = \psi'(e_{i2}), \tag{2}$$

$$p'(\xi_1 + e_{i2} + e_{j2})v = \psi'(e_{j2}). \tag{3}$$

The Nash equilibrium strategies in round 2 obtained by solving (2) and (3) depend on the first-round aggregate effort ξ_1, and are denoted as $e_{i2}^{**}(\xi_1)$ and $e_{j2}^{**}(\xi_1)$. The solutions are symmetric: $e_{i2}^{**} = e_{j2}^{**}$.[2]

How do equilibrium second-round effort choices respond to changes in ξ_1? By differentiating (2) and (3) and solving, we obtain:

$$\frac{de_{j2}^{**}}{d\xi_1} = \frac{\partial e_{j2}^{**}}{\partial e_{i1}} = \frac{\partial e_{j2}^{**}}{\partial e_{j1}} = -\frac{\begin{vmatrix} p'' - \psi'' & p'' \\ p'' & p'' \end{vmatrix}}{\begin{vmatrix} p'' - \psi'' & p'' \\ p'' & p'' - \psi'' \end{vmatrix}} = -\frac{(p'')^2 - p''\psi'' - (p'')^2}{(p'')^2 - 2p''\psi'' + (\psi'')^2 - (p'')^2} = \frac{1}{-2 + \frac{\psi''}{p''}} < 0.$$

That is, the players' first- and second-round efforts (with respect to both own and the other player's first-round effort) are strategic substitutes. It is straightforward to check that $\frac{de_{j2}^{**}}{d\xi_1} = \frac{de_{i2}^{**}}{d\xi_1}$, and that

$$\left|\frac{de_{j2}^{**}}{d\xi_1}\right| = \left|\frac{de_{i2}^{**}}{d\xi_1}\right| < \frac{1}{2}, \qquad \text{if } \psi''(\cdot) > 0.$$

These last comparative statics show that if the first-round aggregate effort were to decrease by one unit, in the second round the increased efforts of the two players combined will be

[2]Note that the solutions to (2) and (3) certainly exist for $\xi_1 = 0$, and for $\xi_1 = 2\epsilon^*$ there will be no solutions. It will be shown below that in any equilibrium of the two-round game, $\xi_1 + e_{i2} + e_{j2}$ will be strictly less than $2\epsilon^*$. And we can make this last observation assuming that (2) and (3) have interior solutions for an appropriate range of ξ_1.

less than one; this is so because the marginal cost of effort function is increasing in effort.

Agent i's overall utility as evaluated in the first round, given first-round choices (e_{i1}, e_{j1}) and that both players follow their equilibrium strategies in the continuation game, is

$$u_i = p(e_{i1} + e_{j1} + e_{i2}^{**}(e_{i1} + e_{j1}) + e_{j2}^{**}(e_{i1} + e_{j1}))v - \psi(e_{i1}) - \psi(e_{i2}^{**}(e_{i1} + e_{j1})).$$

This is maximized by choosing e_{i1} such that

$$\frac{\partial u_i}{\partial e_{i1}} = 0 \Rightarrow p'(\cdot)\left[1 + \frac{\partial e_{i2}^{**}}{\partial e_{i1}} + \frac{\partial e_{j2}^{**}}{\partial e_{i1}}\right]v - \psi'(e_{i1}) - \psi'(e_{i2})\frac{\partial e_{i2}^{**}}{\partial e_{i1}} = 0.$$

Rewriting, and using the second-round first-order condition (2), yields

$$\begin{aligned} p'(\cdot)v + [p'(\cdot)v - \psi'(e_{i2})]\frac{\partial e_{i2}^{**}}{\partial e_{i1}} - \psi'(e_{i1}) + p'(\cdot)v\frac{\partial e_{j2}^{**}}{\partial e_{i1}} &= 0, \\ \text{i.e.,} \quad p'(\cdot)v - \psi'(e_{i1}) + p'(\cdot)v\frac{\partial e_{j2}^{**}}{\partial e_{i1}} &= 0, \\ \text{i.e.,} \quad p'(\cdot)\left[1 - \left|\frac{de_{j2}^{**}}{d\xi_1}\right|\right]v - \psi'(e_{i1}) &= 0. \end{aligned} \tag{4}$$

Agent j's utility-maximizing e_{j1} must similarly satisfy

$$p'(\cdot)\left[1 - \left|\frac{de_{i2}^{**}}{d\xi_1}\right|\right]v - \psi'(e_{j1}) = 0.$$

This, together with agent i's first-order condition (4) and $\frac{de_{j2}^{**}}{d\xi_1} = \frac{de_{i2}^{**}}{d\xi_1}$, implies that $e_{i1}^{**} = e_{j1}^{**}$.[3]

Finally, note that using (2),

$$p'(\cdot)\left[1 - \left|\frac{de_{i2}^{**}}{d\xi_1}\right|\right]v = \psi'(e_{i1}) < p'(\cdot)v = \psi'(e_{i2}),$$

implying

$$e_{i1}^{**} < e_{i2}^{**}. \tag{5}$$

Denote the subgame-perfect equilibrium aggregate effort in the extensive-form game by $2\tilde{e}$, where the sum of optimal first-round efforts is $\hat{e}$ and the sum of optimal second-round efforts is $\hat{\hat{e}}$. In equilibrium, each agent exerts $\tilde{e} = \frac{\hat{e}}{2} + \frac{\hat{\hat{e}}}{2}$, where $\frac{\hat{e}}{2} < \frac{\hat{\hat{e}}}{2}$.

Lemma 2. *Suppose* $\psi'(\cdot) > 0$. *Then the equilibrium aggregate effort in the two-round game*

[3]The solutions $(e_{i1}^{**}, e_{j1}^{**}; e_{i2}^{**}, e_{j2}^{**})$ will be unique if $\psi(.)$ is strictly convex; if $\psi(.)$ is linear, the equilibrium effort profile over the two rounds need not be unique but all such profiles will result in a unique overall effort for each agent.

will be different from the equilibrium aggregate effort in the one-shot game, that is, $2\tilde{\epsilon} \neq 2\epsilon^*$.

Proof. Suppose not so that $\tilde{\epsilon} = \epsilon^*$. First, consider the effort profile $(\frac{\epsilon^*}{2}, \frac{\epsilon^*}{2}; \frac{\epsilon^*}{2}, \frac{\epsilon^*}{2})$ as a candidate *SPE* in the two-round repeated effort game. Therefore, $p'(2\epsilon^*)v = \psi'\left(\frac{\epsilon^*}{2}\right) = \psi'(e_{i2})$; the first equality follows from (1), and the second equality is due to the hypothetical equilibrium split of efforts in the repeated effort game. Hence, $p'(2\epsilon^*)v = \psi'(e_{i2})$, implying that $(\frac{\epsilon^*}{2}, \frac{\epsilon^*}{2})$ is an optimal second-round response to $(e_{i1}, e_{j1}) = (\frac{\epsilon^*}{2}, \frac{\epsilon^*}{2})$ (see (2)). However, $(e_{i1}, e_{j1}) = (\frac{\epsilon^*}{2}, \frac{\epsilon^*}{2})$ fails the first-round first-order condition (4):

$$p'(2\epsilon^*)\left[1 - \left|\frac{de_{i2}^{**}}{d\xi_1}\right|\right]v - \psi'\left(\frac{\epsilon^*}{2}\right) < 0;$$

a contradiction.

Next consider an unequal split of ϵ^*, (e_{i1}, e_{i2}). This has to satisfy $e_{i1} < \frac{\epsilon^*}{2}$ and $e_{i2} > \frac{\epsilon^*}{2}$, since (5). However, $e_{i2} > \frac{\epsilon^*}{2}$ violates the second-round first-order condition (2):

$$p'(2\epsilon^*)v = \psi'\left(\frac{\epsilon^*}{2}\right) < \psi'(e_{i2});$$

a contradiction. ■

Lemma 3. *Suppose* $\psi'(\cdot) > 0$. *Then* $2\tilde{\epsilon} \not> 2\epsilon^*$.

Proof. Suppose not. Then by strict concavity of $p(\cdot)$,

$$\begin{aligned}
p'(2\tilde{\epsilon})v < p'(2\epsilon^*)v \quad &\Rightarrow \quad \psi'\left(\frac{\hat{\hat{\epsilon}}}{2}\right) < \psi'\left(\frac{\epsilon^*}{2}\right) \qquad \text{(by (2) and (1))} \\
&\Rightarrow \quad \hat{\hat{\epsilon}} < \epsilon^* \\
&\Rightarrow \quad \epsilon^* < \hat{\epsilon} \qquad [\text{since} \quad 2\tilde{\epsilon} > 2\epsilon^*] \\
&\Rightarrow \quad \frac{\hat{\hat{\epsilon}}}{2} < \frac{\epsilon^*}{2} < \frac{\hat{\epsilon}}{2} \\
&\Rightarrow \quad e_{i2}^{**} < e_{i1}^{**},
\end{aligned}$$

a violation of (5); a contradiction. ■

Finally, suppose that when $\psi(\cdot)$ is linear, it takes the form $\psi(e_{it}) = ce_{it}$. Moreover, suppose that $p'(0) \geq c$. Then combining these assumptions with conditions (2) and (3) when $\psi(\cdot)$ is linear, and using Lemmas 2 and 3 when $\psi(\cdot)$ is strictly convex, gives us the following result.

Proposition 1 (Harmful transparency). *Suppose the project's success probability depends only on the combined efforts of the two players, i.e., the production technology is one of perfect substitution.*

(i) *If the marginal cost of effort is constant, the equilibrium efforts under observability are the same as when efforts are not observable.*

(ii) *If the marginal cost of effort is increasing, observability results in lower collective as well as individual efforts in equilibrium relative to the case where efforts are not observable.*

The intuition is straightforward. With repeated contributions, an early mover can attempt to free-ride on the other player by decreasing his first-round contribution. This action has a commitment value only with convex effort cost, because then increasing his second-round contribution to make up for his earlier lower effort will push up his effort cost at an increasing rate; with constant marginal cost of effort, this increase in effort cost does not arise, thus his earlier action is not credible.

Besides the discussion of Mohnen et al. (2008) and Winter (2010) in the Introduction, our result also relates to papers on contributions and accumulation games. Varian (1994) shows that less of a public good will be supplied if players contribute sequentially instead of simultaneously. This is because the first player can credibly commit to contributing less than what he would have under simultaneous moves, thus he free-rides successfully on the second player and overall outcome is reduced. In two-round general accumulation games, Romano and Yildirim (2005) demonstrate that this first-mover advantage disappears when players make repeated contributions (i.e., players contribute simultaneously over multiple rounds) such that total contributions under the dynamic game would be the same as in the one-shot (non-transparent) setting. Our paper yields a similar result and thus provides another case where dynamic contributions need not result in sub-optimal outcomes, but *only when* marginal effort cost is *constant*; when marginal cost of effort is *increasing*, then once again the outcome worsens relative to total contributions under non-transparency, as in Varian (1994). So our paper reveals one way in which the incentive to free ride retains its bite under repeated contributions.

In a related paper on team incentives (Bag and Pepito [2012]), we derive a positive result showing the (weak) dominance of transparency over non-transparency in a two-period, discrete effort contribution game with linear cost of effort and selfish agents. This benefit from transparency arises largely because of the complementarity between workers' efforts. However, in the same setting, when efforts are substitutes transparency becomes neutral relative to non-transparency.

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