Accountability versus Social Comparisons: A Theory of Pay Secrecy (and Transparency) in Organizations

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Abstract

This paper develops a formal model to analyze how organizations should choose between pay secrecy and transparency. We argue that by preventing employees from monitoring each other's pay, secrecy reduces envious social comparisons relative to transparency. At the same time, secrecy weakens the employees' ability to jointly sanction the employer for reneging on promised pay, thereby reducing the organization's accountability. Thus, secrecy is optimal when social comparisons are pervasive, when employees' effort is verifiable and does not require implicit incentives, or when bilateral employment relationships are strong enough to enforce implicit incentives. Our model suggests that transparency policies often advocated by consultants and policy-makers may have ambiguous effects on employee motivation and organizational performance, and that one-sidedly favorable or unfavorable views of pay secrecy should be replaced by a case-by-case approach.

Keywords: Social Comparisons, Secrecy, Transparency, Relational Contracts, Formal Contracts.

JEL Classification: D03, D23, M52, M54.

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1. Introduction

Should organizations inform employees on their peers' pay? While governments have increasingly promoted transparency as a means to prevent discrimination in the workplace (Siniscalco et al., 2017; Obloj and Zenger, 2019), the effect of this policy on organizational performance remains controversial. On the one hand, consultants often advocate pay transparency as a managerial "best practice" that will foster employees' trust and motivation (e.g., Burkus, 2016). On the other hand, most employers are reportedly reluctant to abandon pay secrecy (Gely and Bierman, 2003; Edwards, 2005; Hill, 2016).

Scholarly research provides limited and at times conflicting guidance to organizations on this matter (Colella et al., 2007). Some studies suggest that secrecy discourages employees' effort by reducing their trust in the organization and their ability to estimate the link between pay and performance (Futrell, 1978; Lawler, 2000; Bamberger and Belongowski, 2010; Belogolowski and Bamberger, 2014). Other studies, however, argue that pay transparency fosters envious social comparisons between employees (Nickerson and Zenger, 2008; Zenger, 2016), and there is evidence that transparency reduces on-the-job satisfaction (Card et al., 2012), effort (Cohn et al., 2014), and the use of high-powered incentives (Ockenfels et al., 2015; Gartenberg and Wulf, 2017; Obloj and Zenger, 2019).

We propose that these divergent assessments originate, at least in part, from two analytical limitations of the existing literature. The first one is a lack of precision in defining multi-faceted outcomes like employee motivation and trust, and how transparency and secrecy may affect them. A second and related limitation of current research is the reliance on partial theories that alternatively emphasize the costs or the benefits of transparency and secrecy, disregarding the fact that often the same forces simultaneously affect both costs *and* benefits of a given organizational policy (Gibbons, 2005a). To overcome these limitations our paper develops a formal theory, grounded in economic models of relational contracting (e.g., Baker, Gibbons, & Murphy, 1994, 2002; Levin, 2003), which offers a unified account of the costs and benefits of pay secrecy (and transparency) for organizations. While our formal approach limits the detail and depth with which we can describe organizations, it complements and innovates on existing qualitative analyses in two important ways. First, it uncovers novel mechanisms through which pay transparency and secrecy may affect employees and firm performance. Second, it generates testable predictions on which of the two policies is optimal in different kinds of organizations.

Our theory builds on the view of the firm as a nexus of social relations (e.g., Granovetter, 1985; Baron, 1988). We argue that the employees' "embeddedness" in these relations is simultaneously a source of benefits and costs for the organization, and that both the benefits and costs of embeddedness are importantly affected by the choice between pay transparency and secrecy. On the benefit side, we posit that social ties between employees increase an organization's accountability. They do so by enabling multilateral – as opposed to bilateral – enforcement of the employees' "relational contracts" with the organization (Greif, 1994; Spagnolo, 1999; Levin, 2002). To the extent that colleagues develop norms of solidarity and shared views of the employment relationship, they will jointly blame (and sanction) the organization if the latter behaves opportunistically towards one of them (Granovetter, 1985; Burt and Knetz, 1995; Gulati, 1995). Anticipating that the organization's cost of opportunism is high, each employee will trust it to reward her own efforts as promised, and will therefore be motivated and productive even if output and effort are non-verifiable, and formal incentive mechanisms are dysfunctional (e.g., Kerr, 1975; Gibbons, 2005b). To model the costs of embeddedness, we draw on research in social psychology, strategy and economics, which suggests that the very same proximity and social ties that enable multilateral monitoring and enforcement also facilitate social comparisons among the employees (e.g., Festinger, 1954; Adams, 1965). In turn, these comparisons may generate emotions of unfairness and envy, and ultimately loss of morale and motivation, in those employees who perceive themselves as underpaid or otherwise underappreciated (e.g., Akerlof and Yellen, 1990; Fehr and Schmidt, 1999; Nickerson and Zenger, 2008; Gino and Pierce, 2009, 2010; Edelman and Larkin, 2014; Obloj and Zenger, 2017).

The key insight from our integrative model is that by limiting an employee's ability to monitor the compensation of peers, pay secrecy weakens both accountability and envious social comparisons – that is, it reduces both the benefits and the costs of intra-firm social ties. This observation generates novel predictions on the link between pay secrecy, employees' performance, and organizational efficiency. First, secrecy is less likely to be an optimal policy when reward of the employees' efforts is at the discretion of the employer. This may occur if the employees' tasks are idiosyncratic, firm-specific or creative, such that effort can be assessed by the employer (and by the employee's peers) but cannot be verified by a court. While this novel prediction awaits thorough empirical verification, it is consistent with the fact that transparency has been found to decrease on-the-job satisfaction for employees whose pay is fixed or predetermined, such as academic staff and faculty (Card et al., 2012), and to increase it for employees whose pay is at least partially determined ex post by the employer, such as sales managers (Futrell, 1978). Second, our model predicts that pay secrecy is unlikely to be optimal when bilateral employer-employee relationships are weak and therefore insufficient to motivate employees. This may be the case if the employer and/or some individual employees estimate their relationship to end soon due to exogenous events such as financial distress, ownership changes, reduced business opportunities, or outside offers (e.g., Gillan et al., 2009; Gil and Marion, 2013). Third, pay secrecy is more likely to be optimal when envious social comparisons are stronger – for instance, due to geographical and social proximity between employees (Obloj and Zenger, 2017; Gartenberg and Wulf, 2017) – such that reducing them outweighs the loss of multilateral enforcement and employer's accountability.

Besides contributing to the scholarly (and policy) debate on pay secrecy, our theory relates to an emerging literature that analyzes organizational responses to social comparisons. Most of these studies focus on the relationship between social comparisons and compensation design. For instance, Larkin et al. (2012) argue theoretically that social comparisons raise the organizational costs of pay-for-performance, and that firms may resort to alternative compensation schemes, such as seniority-based and flat wages, to mitigate these costs.[1] Consistent with these predictions, several empirical studies have found a positive association between social comparisons, wage compression, and a reduced use of pay-for-performance

[1] See also Englmaier and Wambach (2010), and Bartling and von Siemens (2010).

(Wade et al., 2006; Shue, 2013; Gartenberg and Wulf, 2017; Obloj and Zenger, 2017; Mas, 2017).[2] A few studies have looked at the complementary issue of how social comparisons affect firm boundaries. Nickerson and Zenger (2008) argue that social comparisons are more pronounced within firms than between and therefore represent a central cost of firm scope. Consistent with their theoretical insight, recent empirical studies have shown that intra-firm social comparisons lead to divestitures (Feldman et al., 2018) and to greater degrees of pay compression within firms than between (Gartenberg and Wulf, 2019). To the best of our knowledge, ours is the first theoretical paper on organizational responses to social comparisons that analyzes the choice between pay transparency and secrecy.

Our paper also relates to the literature on the interaction between formal governance and relational contracts. The key point in this literature is that an organization's formal governance structure (including contracts with employees and independent partners) affects its ability to sustain self-enforcing agreements (Klein, 2000; Poppo and Zenger, 2012). Theoretical contributions to this literature have analyzed how relational contracts interact, among others, with formal incentive pay (Baker et al., 1994), firm boundaries (Baker et al., 2002), the allocation of control (Baker et al., 2011; Zanarone, 2013), and the scope of partnerships (Argyres et al., 2020). The complementarity between formal governance and relational contracts has also been supported by empirical studies on inter-firm collaborations (e.g., Poppo and Zenger, 2002; Ryall and Sampson, 2009; Kosova and Sertsios, 2018; Barron et al., 2019; Gil et al., 2020).[3] While existing theories focus on how formal allocations of control and income rights (via asset ownership or contracts) affect relational agreements, our paper focuses on a novel aspect of formal governance – informational restrictions on pay – and shows that it importantly affects relational collaboration.

Finally, our paper is among the first to incorporate social preferences into formal models of relational contracts. Dur and Tichem (2015) demonstrate that altruistic preferences of supervisors (towards their

[2] Kragl and Schmid (2009) argue that social comparisons may also increase the incentive benefits of pay-for-performance by inducing low performers to raise their efforts in order to reduce their pay gap with respect to high performers.
[3] See Cao and Lumineau (2015), and Gil and Zanarone (2017, 2018), for complementary reviews of the empirical literature.

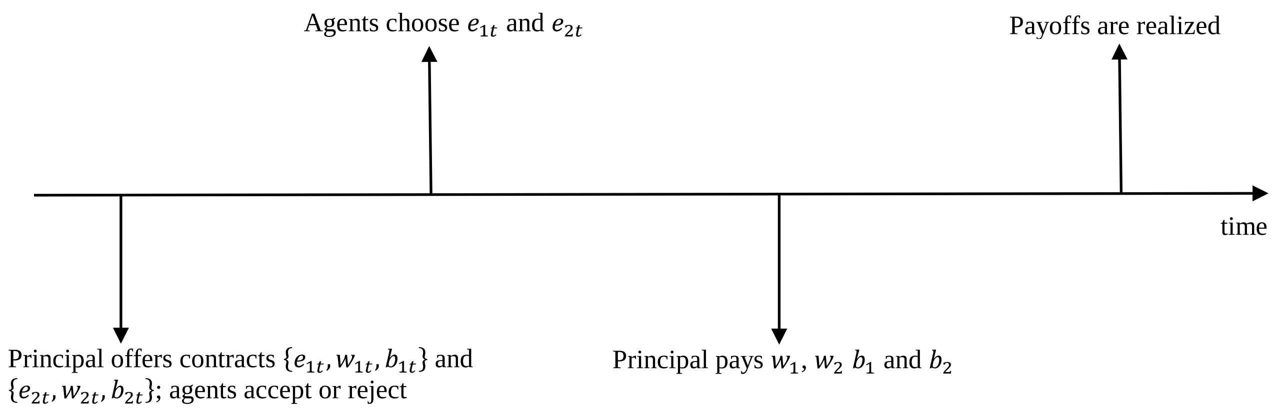
subordinates) may harm organizations by eroding the credibility of termination threats as a means to provide incentives. Fahn (2020) analyzes a relational contracting model with reciprocal employees, and shows that it is optimal for the firm to pay generous fixed wages to employees who are close to retirement, and performance-contingent bonuses to those in earlier stages of their career. Fahn *et al*. (2017) provide empirical evidence consistent with this prediction.

2. **Model**

2.1. The organization

Consider an organization that consists of three individuals: a principal (she), agent 1 (he), and agent 2 (he), all risk-neutral. Time is discrete, the time horizon is infinite, and the principal and both agents discount next-period payoffs by a common factor $\delta \in (0,1)$. Before the relationship with the two agents starts, the principal permanently commits to a policy $s \in \{0,1\}$, where $s = 1$ denotes "secrecy", and $s = 0$ denotes "transparency". Both policies will be precisely defined in a moment. Once the policy is chosen, the principal and the agents interact in each period $t = 1,2, \ldots$ as described by Figure 1 and below.

Figure 1. Timeline



At the beginning of period t the principal offers an employment contract $\{e_{it}, w_{it}, b_{it}\}$ to each agent $i \in \{1,2\}$, where $e_{it} \geq 0$ is the agent's required labor input (hereafter, "effort"), $w_{it} \in \mathbb{R}$ is a formal (i.e., court-enforceable) salary, and $b_{it} \geq 0$ is an informal (i.e., discretionary) bonus. If agent i accepts the proposed contract, he chooses whether to exert the agreed upon effort e_{it} at cost $c(e_{it})$. After observing the agent's effort, the principal pays the formal salary w_{it} and chooses whether to pay the agreed upon discretionary bonus, b_{it}. Finally, at the end of the period the principal receives the output generated by the two agents through their efforts, $y(e_1, e_2)$. We assume that for each agent $i \in \{1,2\}$, the effort cost is strictly increasing and convex ($c'(e_i) > 0$, $c''(e_i) > 0$, with $c(0) = c'(0) = 0$), and the output is strictly increasing ($y_i > 0$), weakly concave ($y_{ii} \leq 0$ and $y_{11} + y_{22} - y_{12}^2 \geq 0$), and satisfies $y(0,0) = 0$.

If agent i rejects the principal's offer, he receives an outside option $\underline{u}_i$, and the principal receives $\underline{\pi}$. Importantly for our subsequent analysis of social comparisons, we assume the agents have different outside options: $\underline{u}_1 > \underline{u}_2$. Without loss of generality, we normalize $\underline{\pi}$ and $\underline{u}_2$ to zero, such that $\underline{u}_1$ can be interpreted as the outside option differential between the two agents. For instance, agent 2 may face higher relocation costs because of his personal situation (married, with children, etc.), or may be less productive than agent 1 in alternative jobs (as an example close to home, think of the different non-academic options of an applied microeconomics professor as opposed to a corporate finance professor).

We conclude the model's setup by stating our informational assumptions and by providing a precise definition of transparency and secrecy and of how they affect the agents' information. First, we assume efforts are observed by the principal but may or may not be verifiable by third parties outside the organization, such as courts. We analyze below both the case of verifiable efforts, in which the principal can make formal salaries contingent on the observed effort levels, and the case of non-verifiable efforts in which the principal can make the informal bonuses, but not the formal salaries, contingent on effort.[4] We show below that effort verifiability importantly affects the choice between pay transparency and secrecy.

Second, we assume an agent's information on his peer's contract, effort and received compensation depends on the policy chosen by the principal, as follows. Under transparency ($s = 0$), each agent $i \in \{1,2\}$ in each period t observes: (1) the contract offered to the other agent j, $\{e_{jt}, w_{jt}, b_{jt}\}$, (2) whether agent j has exerted the agreed upon effort, and (3) whether the principal has paid the agreed upon compensation $w_{jt} + b_{jt}$ to agent j. Conversely, under secrecy ($s = 1$), agent i observes nothing about the contract, effort and received compensation of agent j.[5] We therefore interpret transparency as a policy in which the principal discloses (hides) information about contractual conditions and pay in the organization ("vertical" transparency) and simultaneously promotes social interactions communication among the agents, such that these end up observing both how much their peer is paid and how much he works ("horizontal" transparency). We interpret secrecy in a specular way. We further discuss our definitions of transparency and secrecy, as well as the other modeling assumptions, in section 2.3 below.

[4] We rule out for simplicity the case of "piece rate" contracts in which the principal does not observe efforts and therefore motivates the agents by making (formal or informal) pay contingent on output. Adding piece rates to the model would be straightforward but would not add much to its key insights.

[5] Contreras, Fahn and Zanarone (2019) analyze a model in which pay information may occasionally leak under a formal secrecy policy. They study how a firm can optimally design compensation to implement pay secrecy under these circumstances.

2.2. Payoffs and social comparisons

Given the definitions above, the principal's profit in period t when both agents accept to work for her is:

$$\pi_t \equiv y(e_{1t}, e_{2t}) - w_{1t} - w_{2t} - b_{1t} - b_{2t}.$$

Social comparisons make definition of the agents' utilities more complex. On the one hand, as in standard models of employment, each agent cares about his "material payoff", that is, total compensation minus the cost of effort:

$$m_{it} \equiv w_{it} + b_{it} - c(e_{it}), \text{ for } i \in \{1,2\}.$$

On the other hand, unlike in standard models, we assume that an agent suffers when his material payoff is lower than that of the other agent, in which case he feels less motivated to exert effort (e.g., Nickerson and Zenger, 2008; Larkin et al., 2012). To formally capture this idea we adapt models of social preferences (e.g., DellaVigna *et al.*, 2019) and assume that when payoff differences are observed (that is, under transparency), an individual agent's cost of effort increases by:

$$\eta e_{it} max\{0, m_{jt} - m_{it}\}, \text{ for } i \in \{1,2\}.$$ [6]

Thus, social comparisons imply that an agent's utility from working in the organization crucially depends on the principal's choice between transparency and secrecy:

$$u_{it} \equiv m_{it} - (1-s)\eta e_{it} max\{0, m_{jt} - m_{it}\}, \text{ for } i \in \{1,2\}.$$

The goal of our model is to characterize the principal's profit-maximizing policy given the effort and compensation levels the principal can implement under each policy. To facilitate our comparative analysis, it is useful to keep in mind as a benchmark the "first best" case in which the principal can efficiently produce output without the agents and therefore does not need to worry about incentives or social comparisons. In that case, the principal will choose in every period the effort levels e_1^{FB} and e_2^{FB}, which given our assumptions on the production technology are fully characterized by the first order conditions:

[6] Breza *et al.* (2018) and Cullen and Perez-Truglia (2019) model the effort disutility stemming from social comparisons in a similar way.

$$y_1(e_1^{FB}, e_2^{FB}) = c'(e_1^{FB}), \text{ and} \tag{1}$$

$$y_2(e_1^{FB}, e_2^{FB}) = c'(e_2^{FB}).$$

It is also useful for the purposes of our subsequent analyses to define an agent's (conditionally) efficient effort, $e_i^{FB}(e_j)$, as the effort that satisfies condition (1) above given that the other agent's effort is e_j. In the special case in which output is separable ($y_{12} = 0$), conditionally efficient and first best effort coincide.

2.3. Discussion of the model's assumptions and boundary conditions

Some features of our model deserve further discussion. First, we have assumed that social comparisons are triggered by *observed* payoff differences rather than by employees' inferences about equilibrium differences – that is, employees "believe what they see". This assumption seems necessary to analytically capture the intuitive idea that pay secrecy may reduce social comparisons. We are comfortable with this assumption because it is supported by psychological research on self-serving beliefs (e.g., Kunda, 1990), which suggests that individuals construct beliefs that make them better off so long as these are not inconsistent with the available evidence. In our model this notion implies that absent information on payoff differences between the agents (i.e., under secrecy), the agents will convince themselves to be equal, thus avoiding any disutility from social comparisons.

Second, our model assumes that agents do not respond to *favorable* social comparisons. This assumption is consistent with recent empirical studies (Card et al., 2012; Cohn et al., 2014; Ockenfels et al., 2015; Breza et al., 2018), which document negative employee reactions to unfavorable social comparisons but no reactions to favorable ones. Moreover, while there seems to be a theoretical consensus on the fact that people dislike unfavorable social comparisons, it is less clear whether people like favorable comparisons or dislike them due to compassion towards the "losers" (e.g., Ashraf, 2018).[7] Thus, our assumption that employees only respond to unfavorable social comparisons seems a natural starting point.

[7] See Ashraf and Bandiera (2018) for a literature review that discusses both favorable and unfavorable comparisons.

Third, our definition of the transparency and secrecy policies implies that either an agent observes *both the pay and the effort of his peer* or she observes nothing about the peer. This “reduced form” definition is consistent with the idea, emphasized in the literature (e.g., Gely and Bierman, 2003; Edwards, 2005; Cullen and Perez-Truglia, 2019), that pay disclosure by the principal (the lack thereof) is ineffective in the absence of a broader organizational culture that consistently promotes (discourages) communication and transparency among the employees. Most importantly, our assumption that transparency and secrecy simultaneously cover pay and effort is without loss of generality. It will soon become clear that since the benefit of transparency is to facilitate multilateral enforcement, while the benefit of secrecy is to reduce social comparisons, the principal would never find it optimal to disclose (hide) the peer’s pay to an agent without also disclosing (hiding) the peer’s effort, even if such a selective policy were feasible. In other words, transparency (secrecy) about pay and effort are inherently complementary.

3. Optimal pay policy: transparency vs. secrecy

In this section we use our model to characterize the organization’s profit-maximizing policy. As will soon become clear, the relative profitability of transparency and secrecy importantly depends on whether the agents’ effort is court-verifiable or not. We therefore separately analyze the tradeoff between transparency and secrecy under verifiable effort (section 3.1) and non-verifiable effort (section 3.2). The key difference between these two cases is that when effort is verifiable, the principal can implement the desired effort levels via court-enforceable formal contracts. In contrast, when effort is non-verifiable, the principal must use self-enforcing informal or “relational” incentive contracts to elicit effort from the agents.

3.1. Verifiable efforts

When efforts are verifiable, the principal can induce the agents to exert the desired effort levels in every period by conditioning the formal salaries to those efforts, such that each agent $i \in \{1,2\}$ receives w_{it} if he spends the agreed upon effort e_{it}, and zero otherwise. With verifiable efforts discretionary bonuses are not necessary to incentivize the agents and can thus be ignored. Note that since the production technology, and hence the principal's desired effort levels, do not change over time, we omit all time subscripts in this section.

3.1.1. Secrecy

Under secrecy the agents do not observe any information on their peer's material payoff and therefore do not suffer from social comparisons. Thus, the principal can induce the agents to exert the first best effort levels, e_1^{FB} and e_2^{FB}, and appropriate the resulting surplus, by offering effort-contingent formal salaries that compensate the agent's effort cost plus his outside option: $w_1 = c(e_1^{FB}) + \underline{u}_1$, $w_2 = c(e_2^{FB})$. Since the principal cannot achieve higher profits than the total surplus under first best efforts, it should already be clear that when the efforts are verifiable secrecy must be an optimal policy (i.e., one that generates at least as much profit as transparency). Nevertheless, we formally analyze transparency below. This will allow us to develop insights that will turn useful later on as we study the more complex case of transparency under non-verifiable efforts. The analysis below also provides testable predictions on the likely effects of increasingly popular "sunshine laws" that mandate pay transparency to organizations that had optimally chosen secrecy.

3.1.2. Transparency

Under transparency, the employment contracts the principal offers to the agents specify effort levels and formal salaries that maximize profit, $\pi \equiv y(e_1, e_2) - w_1 - w_2$, subject to the condition that the agents be willing to work for the principal (participation constraints):

$u_1 = m_1 - \eta e_1 max\{0, m_2 - m_1\} \geq \underline{u}_1$, and

$u_2 = m_2 - \eta e_2 max\{0, m_1 - m_2\} \geq 0$,

where $m_i = w_i - c(e_i)$ is the material payoff of agent i.

Naturally, agent 1 (the one with a more attractive outside option) will not suffer from social comparison costs, that is, it is optimal for the principal to offer effort and compensation levels such that $m_1 - m_2 \geq 0$. Intuitively, this is the case because agent 1 has the same preferences for effort and compensation as agent 2 but a more attractive outside option, so the principal must make him better off to induce him to work for the organization. Proposition 1 below formally proves this claim, and analyzes the distortions induced by social comparisons under transparency.

Proposition 1. *With verifiable efforts, optimal employment contracts under transparency have the following characteristics: (1) the agent with low outside option (agent 2) suffers from social comparisons:* $m_1 - m_2 > 0$*; (2) agent 1 exerts high effort (*$e_1 = e_1^{FB}(e_2)$*) whereas agent 2 exerts low effort (*$e_2 < e_2^{FB}$*); (3) the compensation of agent 2 is compressed upwards, relative to that of agent 1, as it includes a social comparison premium:* $w_2 > c(e_2)$.

Proof. In Appendix.

Proposition 1 is consistent with empirical findings that under transparency, organizations compress pay to compensate the employees who suffer from social comparisons (e.g., Gartenberg and Wulf, 2017; Ockenfels et al., 2017; Obloj and Zenger, 2019). Proposition 1 is also consistent with the finding that in organizations where employees earn a fixed salary, transparency reduces the effort of employees with lower pay (Cohn et al., 2014). Interestingly, the effort reduction of agent 2 is not due to shirking (we are currently assuming that effort is verifiable) but to the principal's (optimal) choice to reduce the agent's workload. The intuition is simple but compelling. Since the principal must compensate agent 2 for the disutility caused by social comparisons, and this disutility increases in the agent's effort, social comparisons make the envious agent's effort more costly for the principal and thus induce the principal to optimally "under-employ" the agent. Importantly, and unlike in standard principal-agent models, this workload distortion occurs even if effort is verifiable – that is, in the absence of incentive problems.

Proposition 1 also confirms our initial conjecture that with verifiable efforts, transparency cannot be more profitable for the organization than secrecy. In fact, the workload distortion for agent 2 implies that secrecy generates higher profits for the principal than transparency and is therefore strictly optimal.

Corollary 1. *With verifiable efforts, secrecy generates higher profits than transparency and is therefore optimal.*

3.2. Non-verifiable efforts

We now assume that while the agents' efforts are observed by the principal (and may be assessed by peers under transparency), they cannot be verified by parties outside the organization, such as courts. To incentivize the agents to exert non-verifiable effort, the principal must therefore rely on informal "relational contracts" in which she promises to pay each agent a bonus following the desired effort level, and the agent trusts the principal to honor this promise.

Following an extensive literature in economics (e.g., MacLeod and Malcomson, 1989; Levin 2002, 2003), we model relational contracts as subgame perfect equilibria of the infinitely repeated game between the principal and the agents, in which deviations (i.e., low effort by an agent or non-payment of a bonus by the principal) are "punished" by termination of the relationship in subsequent periods (Abreu, 1988). We focus on "stationary" relational contracts in which efforts and payments are the same in every period, and drop all time subscripts accordingly. This assumption is without any loss of generality in our model of secrecy (following arguments delivered by Levin, 2003), and it is without loss for all periods of the employment relationship but the first one in the model of transparency. Since we are mainly interested in the properties of ongoing employment relationships, we are comfortable with making the stationarity assumption throughout.

Our key insight here is that the principal's policy (transparency vs. secrecy) determines how harshly the agents can punish the principal for reneging on a relational contract, and therefore affects the effort levels that can be sustained in equilibrium. Under secrecy, whether the principal has failed to pay the promised bonus after the agent has exerted the promised effort can only be observed and punished (via termination) by the affected agent – that is, relational contracts are *bilateral* (as in Levin, 2003). In contrast, under transparency the principal's breach can be observed and punished by *both agents* – that is, relational contracts are *multilateral* (as in Levin, 2002). We show below that this unremarked benefit of transparency – facilitating collective action by turning relational employment contracts from bilateral into multilateral – counterbalances social comparison costs (as described by Proposition 1 and its Corollary), thereby creating a tradeoff between the two policies.

For the analysis in this section we assume the two agents' individual contributions to output can be separated: $y_{12} = 0$. Moreover, we assume for simplicity that the agents are equally productive, such that we can rewrite output as $y(e_1, e_2) \equiv y(e_1) + y(e_2)$, with $y(\cdot)$ increasing and concave. This implies that the two first best efforts are identical: $\mathrm{e}_1^{\mathrm{FB}} = \mathrm{e}_2^{\mathrm{FB}} = e^{FB}$. We discuss and motivate these assumptions on the production technology below, in section 3.3.

3.2.1. Secrecy

We begin by analyzing the case of secrecy, in which (1) there are no social comparisons between agents and (2) relational employment contracts are bilateral. Under secrecy the employment contracts the principal offers to the agents specify (formal) salaries and (informal) effort levels and bonuses that maximize profit, $\pi \equiv y(e_1, e_2) - w_1 - w_2 - b_1 - b_2$, subject to the agents' participation and incentive constraints, and to the principal's *self-enforceability constraints*. The participation constraints are as above, except that now there is no social comparison disutility to compensate, and the agents receive both a formal salary and an informal bonus:

$u_1 = m_1 \geq \underline{u}_1$, and

$u_2 = m_2 \geq 0$,

where $m_i = w_i + b_i - c(e_i)$ is the material payoff of agent i.

The incentive constraints require that each agent prefer to exert the prescribed effort and receive the bonus in the current period over saving the effort, not receiving the bonus, and terminating his relationship with the principal in the subsequent periods:

$\frac{\delta}{1-\delta}\left(m_i - \underline{u}_i\right) \geq c(e_i) - b_i$, for $i \in \{1,2\}$.

The left-hand side is the net present discounted value of the agent's future benefits from the employment relationship, and the right-hand side is the agent's net present benefit from shirking. Finally, the enforceability constraints require that the principal prefer to pay the promised bonus to each agent over saving the bonus and terminating the relationship. A key point here is that given bilateral relational contracts, termination of the relationship with one agent does not compromise the principal's relationship with the other agent. Accordingly, we define $\tilde{\pi}_j$ as the principal's per period profit from the relationship with agent j after the relationship with agent i terminates, such that $\tilde{\pi}_1 = y(e_1) - w_1 - b_1$, and $\tilde{\pi}_2 = y(e_2) - w_2 - b_2$. Given these definitions, the enforceability constraints require:

$\frac{\delta}{1-\delta}\left(\pi - \tilde{\pi}_j\right) \geq b_i$, for $i \in \{1,2\}$, $i \neq j$.

As shown formally in the proof of Proposition 2 below, absent social comparisons the intuitively optimal policy for the principal is to appropriate the entire surplus by paying the minimum salaries and bonuses such that the agents' participation and incentive constraints bind, that is: $w_i = \underline{u}_i$ and $b_i = c(e_i)$. This implies that there is no pay compression under secrecy. Then, we can rewrite the self-enforceability constraints as:

$$\frac{\delta}{1-\delta}\left(y(e_1) - c(e_1) - \underline{u}_1\right) \geq c(e_1), \text{ and} \tag{2}$$

$$\frac{\delta}{1-\delta}\left(y(e_2) - c(e_2)\right) \geq c(e_2). \tag{3}$$

These constraints imply that *for a given level of desired effort*, the principal is more tempted to renege on the bonus promised to agent 1. This occurs because agent 1 has a higher outside option, and hence commands a higher salary, than agent 2, which implies that the principal's profit from the relationship with agent 1 is smaller than that from the relationship with agent 2. This observation leads us to our next result.

Proposition 2. *With non-verifiable efforts, optimal employment contracts under secrecy have the following characteristics: (1) there is no pay compression. Moreover, there exist* $\delta_1 \in (0,1)$ *and* $\delta_2 \in (0,1)$*, with* $\delta_2 < \delta_1$*, such that (2) at high discount factors (*$\delta \geq \delta_1$*) both agents exert efficient effort (*$e_1 = e_2 = e^{FB}$*); (3) at intermediate discount factors (*$\delta_2 \leq \delta < \delta_1$*) agent 2 exerts efficient effort while agent 1 exerts low effort (*$e_1 < e^{FB} = e_2$*); (4) at low discount factors (*$\delta < \delta_2$*) both agents exert low effort, with agent 1 exerting even lower effort than agent 2 (*$e_1 < e_2 < e^{FB}$*).*

Proof. In Appendix.

Given the absence of social comparisons, the only source of inefficiency under secrecy is non-verifiability of the agents' efforts. This forces the principal to motivate the agents through a promise of informal incentives, whose credibility is constrained by the lack of court enforcement. Then, proposition 2 confirms the basic tenet that an organization can elicit greater effort from an employee via informal incentives the more it stands to lose from termination of the relationship – that is, the higher the value δ the organization and the employee attach to future payoffs, and the lower the employee's outside option (e.g., MacLeod and Malcomson, 1989; Levin, 2003). When the present value of the relationship is high enough, the employee "trusts" the organization to hold on to its bonus promise and is therefore motivated to perform.

3.2.2. Transparency

We know from our earlier analysis that transparency triggers social comparisons between the two agents. We show below that as in the verifiable effort case, only the agent with low outside option suffers from social comparisons, which implies that the participation and incentive constraints of agent 1 are the same as under secrecy. However, the participation and incentive constraints of agent 2 are more stringent than under secrecy. First, social comparison costs, measured by the extra effort cost $\eta e_2(m_1 - m_2)$, reduce the agent's motivation to work for the organization (participation constraint):

$u_2 = m_2 - \eta e_2(m_1 - m_2) \geq 0,$

where $m_i = w_i + b_i - c(e_i)$, as usual.

Second, social comparison costs reduce the agent's motivation to exert effort once he has joined the organization (incentive constraint) as they simultaneously reduce the agent's future gains from the employment relationship (on the left hand side) and increase his present cost of exerting the promised effort level (on the right hand side):

$$\frac{\delta}{1-\delta}\left(m_2 - \eta e_2(m_1 - m_2)\right) \geq c(e_2) + \eta e_2(m_1 - m_2) - b_2.$$

This double loss of motivation of agent 2 caused by social comparisons is potentially counterbalanced by the fact that transparency makes the relational employment contract multilateral, thereby making the principal more accountable to the agents and increasing the credibility of the incentives she offers them. Under transparency if the principal fails to pay one agent, both agents will observe it and punish the principal by terminating the relationship, which implies that the principal's "optimal breach" is to pay neither agent. Thus, the principal has only one self-enforceability constraint, which is the sum of the two bilateral enforceability constraints under secrecy:

$$\frac{\delta}{1-\delta}\pi \geq b_1 + b_2. \tag{4}$$

As in the case of secrecy, the principal can credibly promise high bonuses, and hence motivate the agents to exert high effort, provided her valuation of future profits (measured by δ) is high enough. However, the fact that under transparency the two enforceability constraints are pooled into (4) allows the principal to flexibly allocate her total "relational capital" among the two agents. This "cross-subsidization" of the enforceability constraints, in turn, enables the principal to promise bonus combinations that would not be sustainable under secrecy and hence implement a more efficient allocation of the agents' efforts.[8] To further illustrate this point, suppose momentarily that the agents do not suffer from social comparisons (η is close to zero), which implies that as in our analysis of secrecy, the participation and incentive constraints are binding and the agents' bonuses simply cover their effort costs. Then, we can rewrite the multilateral enforceability constraint (4) as:

[8] See also Bernheim and Whinston (1990), who first introduced the idea that multilateral relationships allow to cross-subsidize incentives in the context of multimarket collusion.

$$\frac{\delta}{1-\delta}\left(y(e_1, e_2) - c(e_1) - c(e_2) - \underline{u}_1\right) \geq c(e_1) + c(e_1). \quad (5)$$

Suppose further that under secrecy the principal can elicit first best effort from agent 2 but not from agent 1 ($\delta_2 < \delta < \delta_1$). This case may occur because agent 1 has a better outside option, and hence a weaker bilateral relationships with the principal, than agent 2. Then, the enforceability constraint for the bonus of agent 2 under secrecy, (3), is slack whereas the constraint for agent 1, (2), is binding, so the principal would like to use the "excess" value of the relationship with agent 2 to sustain the promise of a higher bonus for agent 1. This would induce agent 1 to raise effort without reducing the effort of agent 2, thereby increasing the principal's profit. Under transparency the principal can do exactly that: if she fails to pay agent 1, she loses the weaker relationship with agent 1 (as under pay secrecy) *and also* the stronger relationship with agent 2. Since the sum of the two relationships' values is larger than the sum of the two bonuses, the multilateral self-enforceability constraint (4) is slack, and the principal can raise the bonus of agent 1 and, through that channel, the agent's effort and the organization's profits.[9]

As the agents become envious (i.e., as η grows above zero), both the participation and the incentive constraint of agent 2 become more stringent, implying that the social comparison costs of transparency grow relative to its accountability benefits. As shown in our next proposition, this results in upwards pay compression of the envious agent and may also result in workload reduction.

Proposition 3. *With non-verifiable efforts, optimal employment contracts under transparency have the following characteristics: (1) the compensation of agent 2 is compressed upwards, relative to that of agent 1, as it includes a social comparison premium ($w_2 + b_2 > c(e_2)$); (2) agent 2 exerts low effort, $e_2 < e^{FB}$. Moreover, (3) there exists $\delta^T \in (0,1)$ such that agent 1 exerts efficient effort, $e_1 = e^{FB}$, at high enough discount factors ($\delta \geq \delta^T$), and low effort, $e_1 < e^{FB}$, otherwise ($\delta < \delta^T$).*

[9] Note that transparency allows the principal to efficiently reallocate efforts even if the two enforceability constraints under secrecy are binding ($\delta < \delta_2$). Then, we know from Proposition 2 that under secrecy neither agent exerts first best effort, and agent 1 works even less than agent 2 because his bilateral relationship with the principal is weaker: $e_1 < e_2$. Since the efforts have decreasing marginal productivities, the principal would then benefit from increasing e_1 while simultaneously decreasing e_2, and that is possible once the enforceability constraints are pooled under transparency (Levin, 2002).

Proof. In Appendix.

3.2.3. Transparency vs. secrecy

Our analysis allows us to assess informal claims on the beneficial effects of transparency on organizations that abound in the managerial literature on human resources. As a representative example consider Lawler (2000), who asserts: “There is a tremendous advantage to be gained from making pay rates and policies public. Because pay secrecy leads to misunderstandings and perceptions that are more negative than the reality of how pay is actually administered, companies that want to establish a high-performance culture can gain from making pay information public and open to discussion. *Openness can increase trust, perception of fairness, understanding of the business, and respect for the organization and its management*” (Lawler, 2000, p.287).

Our model suggests an important sense in which transparency increases the employees’ “trust” in the organization, as argued by Lawler (2000). By allowing multilateral enforcement, transparency enables the principal to use the stronger relationship with agent 2 to “subsidize” the weaker relationship with agent 1. As a result, agent 1 is willing to trust higher bonus promises from the principal than he would under secrecy. Thus, transparency increases the overall level of “calculative” trust (Williamson, 1993) available in the organization.[10]

At the same time, since transparency fosters envious social comparisons, our model suggests that one should reject Lawler’s (2000) one-sided claim that a switch from secrecy to transparency increases employees’ performance and firm profits. While transparency unambiguously reduces profits when the agents’ efforts are verifiable (see proposition 1 and its corollary), it has ambiguous effects when efforts are non-verifiable. The next results make this point precise and formally characterizes the tradeoff between transparency and secrecy that emerges from our model.

[10] A complementary dimension of trust, emphasized by sociological research and not modeled in our paper, is given by norms of reciprocity. These have been also shown to play an important governance role, especially in collaborative interfirm relationships (e.g., Granovetter, 1985; Gulati, 1995; Larson, 1992; Ring & Van de Ven, 1992; Uzzi, 1997).

Proposition 4. *With non-verifiable efforts, secrecy generates higher profits than transparency, and is therefore the optimal policy, at high enough discount factor levels ($\delta \geq \delta_1$). At lower discount factor levels ($\delta < \delta_1$), either secrecy is optimal for all levels of social comparison between agents, or there exists $\tilde{\eta}$ such that transparency is optimal if social comparisons are not too strong ($\eta < \tilde{\eta}$), whereas secrecy is optimal if social comparisons are strong ($\eta \geq \tilde{\eta}$).*

Proof. In Appendix.

A "forward-looking" principal ($\delta \geq \delta_1$) has enough relational capital to persuade both agents to work efficiently under secrecy, as the two self-enforceability constraints are slack. In that case, secrecy is clearly optimal because it removes social comparisons and the ensuing distortion in the envious agent's workload. A less forward-looking principal ($\delta < \delta_1$), however, may need to submit herself to collective enforcement via transparency in order to persuade the agent to trust her promises. If social comparisons are weak (small η), the effort distortion of agent 2 will be more than compensated by the increased effort of agent 1, so transparency will be optimal. As η grows larger, the balance of costs and benefits may be reversed and secrecy may become optimal. This needs not be the case, however, as the principal can remove social comparisons and effort distortions under transparency by paying the envious agent a "rent" (that is, by paying her a salary above the outside option, such that the agent's participation constraint is slack). If the gains from eliminating effort distortions are large relative to this rent, transparency may be optimal even under strong social comparisons.

Aside from having an ambiguous effect on organizational profits, our model suggests that a switch from secrecy to transparency has also ambiguous and potentially opposite effects on the two agents' efforts. This observation is potentially important for organizations trying to assess how "sunshine laws" that impose pay transparency will affect employees' performance. To illustrate our point, consider the case in which the discount factor is low ($\delta < \delta_1$) but social comparisons are strong enough to make secrecy optimal (that is, the $\tilde{\eta}$ threshold exists and $\eta \gg \tilde{\eta}$). In that case, Proposition 4 predicts that the principal optimally choses secrecy. Moreover, Proposition 2 implies that agent 1 exerts lower effort than agent 2 as he has a weaker bilateral relationship with the principal: $e_1 < e_2$. Suppose, now, that the law forces the principal to switch to transparency. Then, our model predicts that the principal will decrease the effort of agent 2 while simultaneously *increasing* the effort of agent 1.

Corollary 2*: suppose efforts are non-verifiable and that the discount factor is low ($\delta < \delta_1$) but social comparisons are strong enough ($\eta \gg \tilde{\eta}$), such that secrecy is optimal. Then, an exogenous switch to transparency increases the effort of agent 1 while (weakly) decreasing the effort of agent 2.*

Proof. In Appendix.

As discussed above, for sufficiently large η the principal will find it optimal to pay agent 2 a rent and remove his envy. Absent social comparisons, the principal will choose efforts to maximize profits subject to the multilateral self-enforceability constraint (5), which is the sum of the two bilateral self-enforceability constraints under secrecy, and hence allows the principal to optimally allocate relational capital across the two agents. We already know that because efforts have decreasing marginal productivities, the principal will then choose to increase the effort of agent 1, and decrease (or leave unchanged) the effort of agent 2, relative to the initial secrecy equilibrium. This reallocation of effort increases output and gross surplus (the difference between output and the effort costs), and hence the organization's productive efficiency, although it reduces profits due to the high rent the principal pays the envious agent.

The fact that transparency may increase the non-envious agent's effort (even if it decreases overall profits) is inconsistent with the findings in Cohn *et al*. (2014), who observe no effect of pay transparency on the productivity of high-pay employees. The inconsistency is only apparent, however, as the organization in their field experiment paid fixed formal salaries, and no discretionary bonuses, to employees – that is, as in our verifiable efforts model, transparency had social comparison costs but no multilateral enforcement benefits in their context. Further empirical research should verify whether as predicted by our corollary, the effect of transparency on the productivity of non-envious employees switches from zero to positive when we move from organizations with fixed pay to organizations with discretionary pay.

3.3. Discussion

3.3.1. Managerial and testable implications

Our formal analysis of the organizational costs and benefits of pay secrecy reconciles and clarifies several claims in the current scholarly and policy debate on this topic. First, as mentioned above, our model provides a precise sense in which transparency increases employees' "trust" in the organization, relative to secrecy. Second, and in contrast with widespread one-sided "pro-transparency" or "pro-secrecy" arguments, our model indicates that a switch from secrecy to transparency has ambiguous effects on the employees' motivation to work and on the organization's profits. This observation is important for management as it suggests there is no "best practice" when it comes to choosing between secrecy and transparency. Instead, managers should make this choice piecemeal, weighing features of the organization and the social and institutional environment that may favor one or the other policy. Policymakers should also properly weigh these features as they assess the potential organizational costs of pay transparency against its social benefits.

Our analysis also provides guidance on the specific features that managers (as well as policy makers and empirical researchers) should pay attention to when assessing the relative costs and benefits of secrecy and transparency. First, all else equal, managers should favor pay secrecy when the organization relies on durable employment relationships (i.e., the discount factor δ is high). When that is the case each employee will trust the firm to reward performance as promised and therefore the firm will not need to promote "collective action" via transparency, which is costly due to social comparisons. All else equal, employment relationships are more likely to be durable if the organization is financially healthy and has a stable ownership structure (Gillan et al., 2009), and if it foresees high demand and future business opportunities (Gil and Marion, 2013).[11] Second, our model suggests that managers should favor pay secrecy when social comparisons between employees, measured by η, are strong. This is more likely to be the case when the

[11] See Gil and Zanarone (2017, 2018) for a discussion of how the empirical literature on relational contracting has measured the value of collaborative relationships in organizations.

organization operates within an egalitarian culture, and when it features high geographical and social proximity between employees (Obloj and Zenger, 2017; Gartenberg and Wulf, 2017). Third, our model suggests that managers should favor secrecy when employees in the organization perform verifiable tasks and, more broadly, when the organization does not rely on discretionary compensation to motivate them. Consistent with this prediction of our model, transparency has been found to decrease motivation for employees with fixed or predetermined pay such as academic faculty and staff (Card et al., 2012), and to increase motivation for employees whose pay is determined ex post by the organization via discretionary salary raises and promotions, such as sales managers (Futrell, 1978).

3.3.2. Assumptions on the production technology

For our analysis of transparency and secrecy under non-verifiable efforts we have assumed the two agents are equally productive and that their individual contributions to output can be separated. The equal productivity assumption seems natural in a model in which transparency generates social comparison costs. If besides having a higher outside option agent 1 were also more productive than his peer, then agent 2 might be more willing to accept a pay differential without suffering from envy (Breza et al., 2018). Having said that, it should be noticed that even if social comparisons did not depend on the agents' relative productivities, relaxing the equal productivity assumption would not alter the model's qualitative predictions. If agent 1 were more productive than agent 2, the secrecy self-enforceability constraint of agent 1, (2), may end up being less stringent than that of agent 2, (3). This would affect whose agent's effort is higher or lower under secrecy versus transparency, and the discount factor threshold above which transparency is optimal, but it would not modify the tradeoff between transparency and secrecy as described by Proposition 4 above.

The separability assumption is more consequential. If the two agents' efforts were complementary inputs ($y_{12} > 0$), termination of the relational contract with one agent would reduce the principal's future payoffs from the relationship with the other agent. This, in turn, would strengthen the punishment against principal's breach under secrecy, and would therefore reduce the need for transparency as a means to make the principal more accountable. We assume separability because we find it conceptually difficult to envision pay secrecy under strong team complementarities. To appreciate this point, recall that under secrecy the principal has an incentive to pay agent 2 if her profit loss from terminating the relationship with him, while continuing that with agent 1, is large enough. With separate output contributions this profit loss is simply equal to the individual output of agent 1 minus agent 1's total pay, so in order to assess the principal's "trustworthiness", agent 2 only needs to know his own terms of employment (salary, bonus and required effort) and productivity. In contrast, with production complementarities agent 2 also needs to think about how the terms of employment of agent 1, who becomes less productive once the relationship with agent 2 terminates, would change following the principal's breach. As he tries to anticipate that, agent 2 would likely suffer from social comparisons and the rationale for having secrecy in the first place would disappear. We therefore believe that when the principal uses the promise of relational incentives to motivate agents, and hence it is important for the agents to assess the principal's willingness to honor such promise, a conceptually coherent theory of pay secrecy requires that the agents separately contribute to the organization, such that their relationships with the principal under secrecy are truly bilateral.

4. Conclusion

This paper has developed a formal theory of the costs and benefits of pay secrecy (and transparency) in organizations. Building on Granovetter's insight that firms are networks of "embedded" social relationships, we have argued that these relationships increase the employees' ability to jointly hold their organization accountable through a threat of "multilateral enforcement". Accountability, in turn, enables the organization to motivate employees via relational incentive contracts. At the same time, we have argued that social relationships facilitate envious social comparisons among employees, which impose costs on the organization in the form of pay compression and the distortion of task assignments. We have shown that by limiting the employees' ability to monitor the organization's pay policy, secrecy reduces both multilateral enforcement and the social comparisons triggered by internal pay differences. Thus, secrecy tends to be an optimal policy when bilateral employment relationships are tight (and hence multilateral enforcement is not necessary to sustain relational contracts), when the employees' tasks are verifiable (and hence relational contracts are not necessary to provide incentives), and when social comparisons in the organization are strong.

Our model provides novel testable predictions that reconcile conflicting theoretical arguments and empirical findings on the effects of pay secrecy and transparency on employee motivation and organizational success. The tradeoff between accountability and social comparisons that we have proposed here may also shed light on the choice between transparency and secrecy in contexts other than pay setting in which socially related individuals (e.g., students in a class, managers of similar firms) care about the decisions of a central entity. Examples would be grading in schools and universities, the ranking of candidates by a selection committee, the ranking of suppliers and distributors by a manufacturer, or quality certification by a regulator. We therefore hope that our model will inform both future empirical research on the impact of pay secrecy on organizations and further theoretical and empirical analyses of the tradeoff between accountability and social comparisons beyond compensation policy.

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Appendix

Proof of Proposition 1.

The principal maximizes $\pi = y(e_1, e_2) - w_1 - w_2$, subject to the following participation constraints (PC):

$$m_1 - \max\{0, \eta e_1 (m_2 - m_1)\} \geq \underline{u}_1 \tag{PC1}$$

$$m_2 - \max\{0, \eta e_2 (m_1 - m_2)\} \geq 0 \tag{PC2}$$

First, we show that $m_1 \geq m_2$, hence agent 1 does not suffer from social comparison costs. To the contrary, assume there is a profit-maximizing equilibrium with $m_1 < m_2$. Then, (PC2) must bind because otherwise, the principal could reduce w_2 without violating any constraint. Thus, $w_2 - c(e_2) = 0$. However, this contradicts $m_2 > m_1$ because (PC1) requires $m_1 \geq \underline{u}_1 > 0$. Therefore, $m_1 \geq m_2$ and, for the same reasons as just laid out, (PC1) must hold as an equality. This yields $w_1 = c(e_1) + \underline{u}_1$, which we can plug into (PC2) $(w_2 - c(e_2))(1 + \eta e_2) - \eta e_2 \underline{u}_1 \geq 0$. (PC2) must also bind because otherwise, the principal could reduce w_2 and thereby increase her profits. Thus, the principal chooses e_1 and e_2 to maximize

$$\pi = y(e_1, e_2) - \underline{u}_1 - c(e_1) - c(e_2) - \frac{\eta e_2 \underline{u}_1}{(1 + \eta e_2)},$$

and first-order conditions are

$$y_1 - c'(e_1) = 0$$
$$y_2 - c'(e_2) - \frac{\eta \underline{u}_1}{(1 + \eta e_2)^2} = 0.$$

Thus, $e_1 = e_1^{FB}$, whereas $e_2 < e_1^{FB}$ follows from $\frac{\eta}{(1+\eta e_2)^2}\underline{u}_1 > 0$ and the convexity of $c(\cdot)$. Finally, $w_2 = c(e_2) + \eta e_2 \underline{u}_1 / (1 + \eta e_2)$ delivers $w_2 > c(e_2)$.

$\blacksquare$

Proof of Proposition 2.

Note that, for production to potentially be optimal, we need to impose an assumption that the principal's profits are positive in case she appropriates the entire surplus and e^{FB} is implemented, hence

$$y(e^{FB}) - c(e^{FB}) - \underline{u}_1 > 0$$

must hold. For agent 2, this condition is always satisfied since $c'(0) = 0$ and $y' > 0$.

Now, due to stationarity, the principal's problem is to maximize

$$\pi = y(e_1, e_2) - w_1 - w_2 - b_1 - b_2$$

in every period, subject to the constraints

$$\frac{w_i + b_i - c(e_i)}{1-\delta} \geq \frac{\underline{u}_i}{1-\delta} \tag{PCi}$$

$$b_i - c(e_i) + \delta \frac{w_i + b_i - c(e_i)}{1-\delta} \geq \delta \frac{\underline{u}_i}{1-\delta} \tag{ICi}$$

$$-b_i + \delta \frac{\pi}{1-\delta} \geq \delta \frac{\tilde{\pi}_j}{1-\delta}, \tag{ECi}$$

for $i \in \{1,2\}$, $i \neq j$, and where (PC) stands for participation constraint, (IC) for incentive constraint, and (EC) for enforceability constraint. Moreover, $\tilde{\pi}_1 = y(e_1) - w_1 - b_1$ and $\tilde{\pi}_2 = y(e_2) - w_2 - b_2$. First, we show that there is a profit-maximizing equilibrium in which (PCi) and (ICi) hold as equalities: To the contrary, assume that (ICi) is slack. If $b_i > 0$, the principal can reduce b_i by a small $\varepsilon > 0$ and increase w_i by ε.This keeps (PCi) and π_i unaffected, but relaxes (ECi). If $b_i = 0$, the principal can reduce w_i by a small $\varepsilon > 0$ without violating any constraint (for $b_i = 0$, (ICi) is tighter than (PCi)). A binding (IC) yields $b_i = c(e_i) - \delta(w_i - \underline{u}_i)$, thus (PCi) becomes $w_i \geq \underline{u}_i$. If it is slack, the principal can reduce w_i by a small $\varepsilon > 0$ and increase b_i by $\delta\varepsilon$ to keep

(ICi) unaffected. This also keeps (DE) unaffected but increases π_i.

Binding (PCi) and (ICi) constraints yield $w_i + b_i - c(e_i) = \underline{u}_i$ and $b_i = c(e_i)$. Taking this into account, the optimization problem becomes to maximize

$$\pi = y(e_1, e_2) - c(e_1) - c(e_2) - \underline{u}_1,$$

subject to

$$-c(e_1) + \delta\left(y(e_1) - \underline{u}_1\right) \geq 0 \tag{EC1}$$

$$-c(e_2) + \delta y(e_2) \geq 0. \tag{EC2}$$

It follows that (EC1) holds for e^{FB} and (EC2) for e^{FB} if $\delta \to 1$. To establish the existence of the threshold $\bar{\delta}_1$, fix any effort level $\hat{e}_1 < e_1^{FB}$ such that $y(\hat{e}_1) - \underline{u}_1 > 0$. Then, the left hand side of (EC1) increases in δ, and (EC1) is satisfied for δ sufficiently large. If $y(\hat{e}_1) - \underline{u}_1 \leq 0$, only $e_1 = 0$ can be enforced. Thus, there exists a threshold $\bar{\delta}_1$ with the properties described in the Proposition. It follows that the same holds for (EC2) and $\bar{\delta}_2$. $\bar{\delta}_1 > \bar{\delta}_2$ (and $e_1 < e_2$ for $\delta < \bar{\delta}_1$) is implied by $\underline{u}_1 > 0$ and the concavity of $y(\cdot)$. ■

Proof of Proposition 3.

For general values of η, utilities become

$$u_1 = w_1 + b_1 - c(e_1) - \max\left\{0, \eta e_1\left(m_2 - m_1\right)\right\} \geq \underline{u}_1 \tag{IR1}$$

$$u_2 = w_2 + b_2 - c(e_2) - \max\left\{0, \eta e_2\left(m_1 - m_2\right)\right\} \geq 0, \tag{IR2}$$

where $m_i = w_i + b_i - c(e_i)$ is the material payoff player i expects to receive in any period.

Therefore, the principal maximizes

$$\pi = y(e_1, e_2) - w_1 - w_2 - b_1 - b_2$$

in every period, subject to the following constraints.

$$w_1 + b_1 - c(e_1) - \max\{0, \eta e_1 (m_2 - m_1)\} \geq \underline{u}_1 \tag{PC1}$$

$$w_2 + b_2 - c(e_2) - \max\{0, \eta e_2 (m_1 - m_2)\} \geq 0 \tag{PC2}$$

$$b_1 - c(e_1) - \max\{0, \eta e_1 (m_2 - m_1)\} + \delta \frac{u_1}{1-\delta} \geq \delta \frac{\underline{u}_1}{1-\delta} \tag{IC1}$$

$$b_2 - c(e_2) - \max\{0, \eta e_2 (m_1 - m_2)\} + \delta \frac{u_2}{1-\delta} \geq 0 \tag{IC2}$$

$$-b_1 - b_2 + \delta \frac{\pi}{1-\delta} \geq 0 \tag{EC}$$

First, we show that $m_1 - m_2 \geq 0$. To the contrary, assume $m_2 > m_1$. We now demonstrate that, with $m_2 > m_1$, (PC2) must bind in any profit-maximizing equilibrium. Then, we show that a binding (PC2) constraint is inconsistent with $m_2 > m_1$. Thus, assume that (PC2) is slack. In the following, we perform a number of operations which increase profits without violating any constraint. Throughout, we always maintain the assumption $m_2 > m_1$. We first assume $w_2 \geq 0$, hence (IC2) is tighter than (PC2). If (IC2) is slack, the principal can reduce w_2 until either (IC2) binds or $w_2 = 0$. In the latter case, (PC2) is equivalent to (IC2), and the principal can reduce b_2 until both constraints bind. Reducing w_2 and/or b_2 relaxes (PC1), (IC1) and (EC) and increases profits. If (IC2) binds and (PC2) is still slack (hence $w_2 > 0$), the principal can reduce w_2 by a small $\varepsilon > 0$ and increase b_2 by $\delta\varepsilon$. This operation does not affect (IC2) and (EC), but relaxes (PC1) and (IC1) and increases profits.

Second, assume $w_2 < 0$, hence (PC2) is tighter than (IC2), and $b_2 > c(e_2)$. If (PC2) is slack, the principal can reduce b_2 until it binds. This relaxes the (EC) constraint and increases profits.

Now, a binding (PC2) constraint would yield $m_2 = 0$. This is inconsistent with $m_2 > m_1$, though, because (PC1) and $\underline{u}_1 > 0$ require $m_1 > 0$. Therefore, a profit-maximizing equilibrium has

$$m_1 \geq m_2.$$

In the next step, we state that there is a profit-maximizing equilibrium in which (PC1) and (IC1) constraints bind. To the contrary, assume that either of them is slack. First, assume $w_1 \geq \underline{u}_1$, hence (IC1) is tighter than (PC1). If (IC1) is slack and $w_1 > \underline{u}_1$, the principal can reduce w_1 until either (IC1) binds or $w_1 = \underline{u}_1$. In the latter case, (PC1) is equivalent to (IC1), and the principal can reduce b_1 until both constraints bind. Reducing w_1 and/or b_1 relaxes (PC2), (IC2) and (EC) and increases profits. If (IC1) binds and (PC1) is still slack (hence $w_1 - \underline{u}_1 > 0$), the principal can reduce w_1 by a small $\varepsilon > 0$ and increase b_1 by $\delta\varepsilon$. This operation does not affect (IC1) and (EC), but relaxes (PC2) and (IC2) and increases profits.

Second, assume $w_1 < \underline{u}_1$, hence (PC1) is tighter than (IC1), and $b_1 > c(e_1)$. If (PC1) is slack, the principal can reduce b_1 until it binds. Thus, $w_1 + b_1 - c(e_1) = \underline{u}_1$, and (IC1) becomes $b_1 - c(e_1) \geq 0$. If (IC1) is still slack, the principal can reduce b_1 by a small $\varepsilon > 0$ (note that $b_1 > 0$ if (PC1) binds) and increase w_1 by ε to keep (PC1) satisfied. This keeps profits and all constraints besides (EC) unaffected, which is relaxed.

Thus, $w_1 = \underline{u}_1$ and $b_1 = c(e_1)$, and the remaining constraints are

$$(w_2 + b_2 - c(e_2))(1 + \eta e_2) - \eta e_2 \underline{u}_1 \geq 0 \tag{PC2}$$

$$(w_2 + b_2 - c(e_2))(1 + \eta e_2) - \eta e_2 \underline{u}_1 \geq w_2(1 - \delta) \tag{IC2}$$

$$-c(e_1) - b_2 + \delta \frac{y(e_1, e_2) - c(e_1) - \underline{u}_1 - b_2 - w_2}{1 - \delta} \geq 0 \tag{EC}$$

Now, we show that there exists a profit-maximizing equilibrium in which (IC2) binds as well. First, assume $w_2 \geq 0$, hence (IC2) is tighter than (PC2). Assume (IC2) is slack. Reduce w_2 until either (IC2) binds or $w_2 = 0$. In the latter case, (PC2) and (IC2) are identical and the principal can reduce b_2 until both bind. Second, assume $w_2 < 0$, hence (PC2) is tighter than (IC2). Then, reducing b_2 by a small $\varepsilon > 0$ and increasing w_2 by ε relaxes (EC) without violating any constraint.

A binding (IC2) yields

$$b_2 = c(e_2) + \frac{\eta e_2 \underline{u}_1 - w_2(\delta + \eta e_2)}{(1+\eta e_2)},$$

and (PC2) boils down to $w_2 \geq 0$. Moreover, $m_1 \geq m_2$ becomes $w_2 \leq \underline{u}_1/(1-\delta)$. In the following Lagrange function, we also include the latter as a constraint to be able to distinguish between the two cases $m_1 > m_2$ and $m_1 = m_2$.

Before continuing, note that these results already confirm that agent 2 receives a social comparison premium:

$$\begin{aligned}
& w_2 + b_2 - c(e_2) \\
=& \frac{\eta e_2 \underline{u}_1 + (1-\delta) w_2}{(1+\eta e_2)} \\
>& 0
\end{aligned}$$

The Lagrange function equals

$$\begin{aligned}
L =& y(e_1, e_2) - \underline{u}_1 - c(e_1) - c(e_2) - \frac{w_2(1-\delta) + \eta e_2 \underline{u}_1}{(1+\eta e_2)} \\
& + \lambda_{EC}\left[-c(e_1) - c(e_2) + \delta y(e_1, e_2) - \delta \underline{u}_1 + \eta e_2 \frac{w_2(1-\delta) - \underline{u}_1}{(1+\eta e_2)}\right] \\
& + \lambda_{PC2} w_2 + \lambda_{SC}\left[\frac{\underline{u}_1}{(1-\delta)} - w_2\right].
\end{aligned}$$

First-order conditions with respect to e_1 and e_2 are

$$
\begin{aligned}
\frac{\partial L}{\partial e_1} =& y_1 - c'(e_1) + \lambda_{EC}\left[-c'(e_1) + \delta y_1\right] = 0 \\
\frac{\partial L}{\partial e_2} =& y_2 - c'(e_2) - \eta \frac{\underline{u}_1 - w_2(1-\delta)}{(1+\eta e_2)^2} \\
& + \lambda_{EC}\left[\delta y_2 - c'(e_2) - \eta \frac{\underline{u}_1 - w_2(1-\delta)}{(1+\eta e_2)^2}\right] = 0
\end{aligned}
$$

To prove the remaining results of the proposition, it is sufficient to differentiate between the cases $\lambda_{EC} > 0$ ((EC) binds) and $\lambda_{EC} = 0$ ((EC) is slack)

A) EC is slack ($\lambda_{EC} = 0$). Thus, $\lambda_{PC2} > 0$ and $w_2 = 0$, hence

$$
\begin{aligned}
y_1 - c'(e_1) = 0 \\
y_2 - c'(e_2) - \eta \frac{\underline{u}_1}{(1+\eta e_2)^2} = 0,
\end{aligned}
$$

which yields $e_1 = e^{FB}$ and $e_2 < e^{FB}$.

These values satisfy the (EC) constraint if

$$
-c(e_1) - c(e_2) + \delta\left(y(e_1, e_2) - \underline{u}_1\right) - \frac{\underline{u}_1 \eta e_2}{(1+\eta e_2)} \geq 0
$$

holds. Holding e_i constant and presuming $y(e_1, e_2) - \underline{u}_1 > 0$, the left-hand side of (EC) increases in δ. Thus, if $\pi = y(e_1, e_2) - \underline{u}_1 - c(e_1) - c(e_2) - \frac{\underline{u}_1 \eta e_2}{(1+\eta e_2)} > 0$, there is a δ^T, with $0 < \delta^T < 1$, such that (EC) holds for e_1 and e_2 if and only if $\delta \geq \delta^T$.

B) EC binds ($\lambda_{EC} > 0$). (EC) binds for $\delta < \delta^T$. Then, e_1 is characterized by

$$
y_1 - c'(e_1) + \lambda_{EC}\left[-c'(e_1) + \delta y_1\right] = 0.
$$

$-c'(e_1) + \delta y_1 < 0$ because otherwise, a higher e_1 would relax (EC), contradicting that it binds.

Because $y(\cdot)$ is (weakly) concave and $c(\cdot)$ is convex, this implies $e_1 < e^{FB}$ for $\delta < \delta^T$.

e_2 is characterized by

$$
\begin{aligned}
& y_2 - c'(e_2) - \eta \frac{\underline{u}_1 - w_2(1-\delta)}{(1+\eta e_2)^2} \\
& + \lambda_{EC} \left[\delta y_2 - c'(e_2) - \eta \frac{\underline{u}_1 - w_2(1-\delta)}{(1+\eta e_2)^2} \right] = 0.
\end{aligned}
$$

Again, the term in squared brackets must be negative because otherwise, a higher e_2 would relax (EC). Furthermore, $\underline{u}_1 - w_2(1-\delta) \geq 0$, thus $e_2 < e^{FB}$ for $\delta < \delta^T$. ■

■

Before proving Proposition 4, we derive a number of preliminary results which deliver additional insights on outcomes under transparency.

Lemma A1: *With non-verifiable effort under transparency and $\delta < \delta^T$, there exist values $\underline{\eta}$ and $\bar{\eta}$, with $0 < \underline{\eta} < \bar{\eta}$, such that*

- $w_2 = 0$ *for* $\eta \leq \underline{\eta}$
- $w_2 \in (0, \underline{u}_1/(1-\delta))$ *and strictly increasing in* η *for* $\eta \in (\underline{\eta}, \bar{\eta})$
- $w_2 = \underline{u}_1/(1-\delta)$ for $\eta \geq \bar{\eta}$.

For $\delta \geq \delta^T$, $w_2 = 0$ for all η.

Moreover, profits are strictly decreasing in η for $\delta \geq \delta^T$. For $\delta < \delta^T$, profits are strictly decreasing in η for $\eta < \bar{\eta}$, and constant in η for $\eta \geq \bar{\eta}$.

Proof.

Recall that the Lagrange function for non-verifiable effort under transparency equals.

$$
\begin{aligned}
L =& y(e_1,e_2) - \underline{u}_1 - c(e_1) - c(e_2) - \frac{w_2(1-\delta) + \eta e_2 \underline{u}_1}{(1+\eta e_2)} \\
&+ \lambda_{EC}\left[-c(e_1) - c(e_2) + \delta y(e_1,e_2) - \delta \underline{u}_1 + \eta e_2 \frac{w_2(1-\delta) - \underline{u}_1}{(1+\eta e_2)}\right] \\
&+ \lambda_{PC2} w_2 + \lambda_{SC}\left[\frac{\underline{u}_1}{(1-\delta)} - w_2\right].
\end{aligned}
$$

Thus, the envelope condition yields

$$
\frac{d\pi}{d\eta} = \frac{\partial L}{\partial \eta} = e_2 \frac{w_2(1-\delta) - \underline{u}_1}{(1+\eta e_2)^2}(1+\lambda_{EC}) \leq 0, \tag{1}
$$

with a strict inequality for $w_2(1-\delta) - \underline{u}_1 < 0$.

Now, first-order conditions are

$$
\begin{aligned}
\frac{\partial L}{\partial e_1} =& y_1 - c'(e_1) + \lambda_{EC}\left[-c'(e_1) + \delta y_1\right] = 0 \\
\frac{\partial L}{\partial w_2} =& -\frac{(1-\delta)}{(1+\eta e_2)} + \lambda_{EC} \frac{\eta e_2 (1-\delta)}{(1+\eta e_2)} + \lambda_{PC2} - \lambda_{SC} = 0 \\
\Rightarrow& \lambda_{PC2} = \frac{(1-\delta)}{(1+\eta e_2)}(1 - \lambda_{EC}\eta e_2) + \lambda_{SC} \\
\frac{\partial L}{\partial e_2} =& y_2 - c'(e_2) - \eta \frac{\underline{u}_1 - w_2(1-\delta)}{(1+\eta e_2)^2} \\
&+ \lambda_{EC}\left[\delta y_2 - c'(e_2) - \eta \frac{\underline{u}_1 - w_2(1-\delta)}{(1+\eta e_2)^2}\right] = 0
\end{aligned}
$$

In the following, we derive additional results for all potential cases and show under which conditions $w_2 = 0$ or $w_2 > 0$.

A) EC is slack ($\lambda_{EC} = 0$). Thus, $\lambda_{PC2} > 0$ and $w_2 = 0$, which confirms that profits are strictly decreasing in η for $\delta \geq \delta^T$. It also follows that $m_1 > m_2$.

B) (EC) binds, (PC2) is slack ($\lambda_{EC} > 0$, $\lambda_{PC2} = 0$). First, we assume $\lambda_{SC} = 0$, thus $\lambda_{EC} = \frac{1}{\eta e_2}$. w_2, e_1 and e_2 are given by the binding (EC) constraint,

$$w_2 = \frac{\underline{u}_1}{(1-\delta)} - \frac{(1+\eta e_2)\left[-c(e_1) - c(e_2) + \delta\left(g(e_1, e_2) - \underline{u}_1\right)\right]}{\eta e_2 (1-\delta)},$$

and first-order conditions become

$$\begin{aligned} \left(y_1 - c'(e_1)\right)\eta e_2 + \left(\delta y_1 - c'(e_1)\right) &= 0 \\ \left(y_2 - c'(e_2)\right)\eta e_2^2 + e_2\left(\delta y_2 - c'(e_2)\right) - \left[-c(e_1) - c(e_2) + \delta\left(y(e_1, e_2) - \underline{u}_1\right)\right] &= 0. \end{aligned}$$

If the resulting values indeed satisfy $w_2 \geq 0$ and $w_2 \leq \underline{u}_1/(1-\delta)$, they constitute optimal outcomes.

To derive the thresholds $\underline{\eta}$ and $\bar{\eta}$ as characterized in the lemma, we compute comparative statics of effort levels and wages with respect to η:

$$\frac{de_2}{d\eta} = \frac{\begin{vmatrix} \left({}_{11} - c''(e_1)\right)\eta e_2 + \left(\delta y_{11} - c''(e_1)\right) & -\left(y_1 - c'(e_1)\right) e_2 \\ -\left[-c'(e_1) + \delta y_1\right] & -\left(y_2 - c'(e_2)\right) e_2^2 \end{vmatrix}}{\text{detH}},$$

where “detH” in the denominator refers to the determinant of the Hessian matrix of partial derivatives of the first-order conditions. Because of the second order condition for a maximum, detH > 0, and the sign of $de_2/d\eta$ is equivalent to the sign of

$$\begin{aligned} &-\left[\left(y_{11} - c''(e_1)\right)\eta e_2 + \left(\delta y_{11} - c''(e_1)\right)\right]\left(y_2 - c'(e_2)\right) e_2^2 \\ &+ \left(c'(e_1) - \delta y_1\right)\left(y_1 - c'(e_1)\right) e_2. \end{aligned}$$

This term is positive because $y_{11} \leq 0$, $c''(\cdot) > 0$, $y_1 - c'(e_1) > 0$ (due to a binding EC constraint) and $c'(e_1) - \delta y_1 > 0$ (if this term was negative, a higher e_1 would relax EC, contradicting that it binds). Thus,

$$\frac{de_2}{d\eta} > 0.$$

For the same reasons, the sign of $de_1/d\eta$ is equivalent to the sign of

$$\begin{aligned}
&-\left(y_1 - c'(e_1)\right) e_2 \left[\left(y_{22} - c''(e_2)\right) \eta e_2^2 + e_2 \left(\delta y_{22} - c''(e_2)\right) + 2\left(y_2 - c'(e_2)\right) \eta e_2\right] \\
&+ \left(y_2 - c'(e_2)\right) e_2^2 \left(y_1 - c'(e_1)\right) \eta \\
=& - \left(y_1 - c'(e_1)\right) e_2^2 \left[\left(y_{22} - c''(e_2)\right) \eta e_2 + \left(\delta y_{22} - c''(e_2)\right) + \left(y_2 - c'(e_2)\right) \eta\right]
\end{aligned}$$

There, note that

$(y_{22} - c''(e_2))\, \eta e_2^2 + 2\,(y_2 - c'(e_2))\, \eta e_2 + e_2\,(\delta y_{22} - c''(e_2)) < 0$ because of the second-order condition for a maximum, thus

$$\frac{de_1}{d\eta} > 0.$$

Re-writing w_2 to

$$w_2 = \frac{\underline{u}_1}{(1-\delta)} - \frac{\left(\frac{1}{\eta} + e_2\right)\left[-c(e_1) - c(e_2) + \delta\left(y(e_1, e_2) - \underline{u}_1\right)\right]}{e_2\,(1-\delta)},$$

we obtain

$$
\begin{aligned}
\frac{dw_2}{d\eta} =& \frac{\frac{1}{\eta^2}\left[-c(e_1)-c(e_2)+\delta\left(y(e_1,e_2)-\underline{u}_1\right)\right]}{e_2\left(1-\delta\right)} \\
&+\frac{\frac{1}{\eta}\left[\delta\left(y(e_1,e_2)-\underline{u}_1\right)-c(e_1)-c(e_2)\right]+\left(\frac{1}{\eta}+e_2\right)\left[c'(e_2)-\delta y_2\right]e_2}{e_2^2\left(1-\delta\right)}\frac{de_2}{d\eta} \\
&+\frac{\left(\frac{1}{\eta}+e_2\right)\left[c'(e_1)-\delta y_1\right]}{e_2\left(1-\delta\right)}\frac{de_1}{d\eta} \\
>& 0.
\end{aligned}
$$

There, note that $-c(e_1)-c(e_2)+\delta\left(y(e_1,e_2)-\underline{u}_1\right)>0$ because $w_2 \leq \underline{u}_1/\left(1-\delta\right)$.

Moreover, because e_1 and e_2 are bounded,

$$
\begin{aligned}
&\lim_{\eta\to 0} w_2 = -\infty < 0 \\
&\lim_{\eta\to\infty} w_2 = \frac{\underline{u}_1}{\left(1-\delta\right)} - \frac{-c(e_1)-c(e_2)+\delta\left(y(e_1,e_2)-\underline{u}_1\right)}{\left(1-\delta\right)} > \frac{\underline{u}_1}{\left(1-\delta\right)}.
\end{aligned}
$$

This establishes the existence of the two thresholds $\underline{\eta}$ and $\bar{\eta}$, with the additional properties that (PC2) binds (i.e., $w_2 = 0$) for $\eta \leq \underline{\eta}$, and that $w_2 = \underline{u}_1/\left(1-\delta\right)$ for $\eta \geq \bar{\eta}$.

C) (EC) and (PC2) bind ($\lambda_{EC} > 0$, $\lambda_{PC2} > 0$). This case is relevant for $\eta < \underline{\eta}$, as derived in the previous case. Here, we first assume $\lambda_{SC} = 0$ and later verify that this indeed holds. Now, first-order conditions yield $\lambda_{EC} = \frac{y_1 - c'(e_1)}{c'(e_1)-\delta y_1}$, hence

$$
\frac{y_1}{y_2} = \frac{c'(e_1)}{\left(c'(e_2)+\frac{\eta}{(1+\eta e_2)^2}\underline{u}_1\right)}
$$

which, together with a binding (EC) constraint, delivers optimal values e_1 and e_2, with $e_2 < e_1$.

Finally, $m_1 \geq m_2$ becomes $\underline{u}_1 \geq w_2 + b_2 - c(e_2) \Leftrightarrow \underline{u}_1 \geq \frac{\eta e_2}{1+\eta e_2}\underline{u}_1$, which holds for any $e_2 \geq 0$.

Therefore, $\lambda_{SC} = 0$ and $m_1 > m_2$. ■

Proof of Proposition 4.

For this proof, we use the superscript "T" to denote effort and profits under transparency, and "S" for the respective outcomes under secrecy. First $\delta \geq \delta_1$ implies that first-best effort levels can be implemented with secrecy. Because e_2^T is smaller than e^{FB} (see the proof to Proposition 3), profits are higher under secrecy even if $\delta \geq \delta^T$.

Now, assume that $\delta < \delta_1$. In the proof to Proposition 3, we have shown that, under transparency, profits are decreasing in η. Thus, we first show that transparency dominates secrecy for $\eta \to 0$ and then consider larger values: In the proof to Proposition 2, we have shown that, for $\delta < \delta_1$, $e_1^S < e^{FB}$, $e_2^S \leq e^{FB}$, and $\pi = y(e_1^S, e_2^S) - c(e_1^S) - c(e_2^S) - \underline{u}_1$.

Moreover, (EC) constraints under secrecy equal

$$-c(e_1^S) + \delta \left[y(e_1^S) - \underline{u}_1 \right] \geq 0 \tag{ECS1}$$

$$-c(e_2^S) + \delta y(e_2^S) \geq 0. \tag{ECS2}$$

With transparency, $\pi^T = y(e_1^T, e_2^T) - c(e_1^T) - c(e_2^T) - \frac{1+2\eta e_2^T}{1+\eta e_2^T} \underline{u}_1$, and the (EC) constraint equals

$$-c(e_1^T) - c(e_2^T) - \frac{\eta e_2^T}{1+\eta e_2^T} \underline{u}_1 + \delta \left(y(e_1^T, e_2^T) - \underline{u}_1 \right) \geq 0 \tag{ECT}$$

First, note that, for a given e^T, π^T and the left hand side of (ECT) are decreasing in η. Now, we show that $\delta^T < \delta_1$ for $\eta \to 0$. At δ_1, (ECS2) is slack, thus (ECT) – which is the sum of (ECS1) and (ECS2) for $\eta \to 0$ – is slack as well. Thus, for $\delta^T \geq \delta_2$ and $\eta \to 0$, transparency allows us to increase e_1 without having to reduce e_2 (note that a reduction of e_2 might as well be optimal – then further increasing profits under transparency), implying that transparency is optimal in this case. Now, assume that $\delta < \delta_2$, hence both (ECS) constraints bind. Moreover, $e_2^S > e_1^S$ for $\eta \to 0$. Obviously, these levels also satisfy (ECT), hence $\pi^T \geq \pi^S$. Moreover, for $\eta \to 0$ the (uniquely) optimal implimentable effort levels under transparency are characterized by $e_1^T \geq e_2^T$ (see the proof to Proposition 3), thus (due to concavity of the profit function)

$$\pi^T > \pi^S$$

if $\delta < \delta_1$ and $\eta \to 0$.

Now, we show that secrecy can be optimal for large η. Because π^T is decreasing in η, it is bounded below by profits if $\eta \geq \bar{\eta}$, in which case $w_2^S = \underline{u}_1/(1-\delta)$ and

$$\pi^T = y(e_1^T) + y(e_2^T) - 2\underline{u}_1 - c(e_1^T) - c(e_2^T)$$

For this case, the (EC) constraint under transparency equals

$$-c(e_1^T) - c(e_2^T) + \delta\left(y(e_1^T) + y(e_2^T) - \underline{u}_1\right) \geq 0. \tag{2}$$

Since effort levels are characterized by

$$y_i - c'(e_i^T) + \lambda_{EC}\left[-c'(e_i^T) + \delta y_i\right] = 0$$

for $\eta \geq \bar{\eta}$, $e_1^T = e_2^T$. Now,

$$\pi^S = y(e_1^S) + y(e_2^S) - \underline{u}_1 - c(e_1^S) - c(e_2^S),$$

thus transparency dominates secrecy for $\delta < \delta_1$ if

$$\begin{aligned}&\left(y(e_1^T) - c(e_1^T)\right) - \left(y(e_1^S) - c(e_1^S)\right)\\ \geq &\underline{u}_1 + \left(y(e_2^S) - c(e_2^S)\right) - \left(y(e_2^T) - c(e_2^T)\right),\end{aligned}$$

which might or might not hold. As an example, note that one can show that with a quadratic cost and a linear output function, this condition is never satisfied. Then, there indeed exists a $\tilde{\eta}$ such that secrecy dominates transparency if $\eta > \tilde{\eta}$.

$\blacksquare$

Proof of Corollary 2.

As in the proof to proposition 4, we use the superscript "T" to denote effort under transparency, and "S" for effort under secrecy. Here, we focus on the case $\eta \geq \bar{\eta}$, hence $w_2 = \underline{u}_1/(1-\delta)$ and social comparison costs are absent under transparency (see the proof to Lemma A1).

Recall that, e_1^S is characterized by the binding (EC1) constraint,

$$-c(e_1^S) + \delta\left(y(e_1^S) - \underline{u}_1\right) = 0.$$

Moreover, $e_2^S = e^{FB}$ if $\delta \geq \delta_2$. Otherwise, e_2^S is characterized by the binding (EC2) constraint,

$$-c(e_2^S) + \delta y(e_2^S) = 0.$$

In any case, we have shown that

$$e_2^S > e_1^S.$$

In the proof to Proposition 4, we have also shown that, under transparency, the (EC) constraint for $\eta \geq \bar{\eta}$ equals

$$-c(e_1^T) - c(e_2^T) + \delta\left(y(e_1^T) + y(e_2^T) - \underline{u}_1\right) \geq 0,$$

and that $e_1^T = e_2^T$. We have also shown that e_1 is larger under transparency than under secrecy because future rents are re-allocated to increase the efficiency of the production process.

The change in e_2^T depends on the discount factor:

- If $\delta \in [\delta^T, \delta_1)$, $e_i^T = e^{FB}$, hence $e_2^T = e_2^S = e^{FB}$.
- If $\delta \in [\delta_2, \delta^T)$, $e_2^T < e_2^S = e^{FB}$.

- If $\delta < \delta_2$, $e_2^T < e_2^S$. This is because e_i^T is now characterized by

$$-c(e_i^T) + \delta \left(y(e_i^T) - \frac{u_1}{2} \right) = 0,$$

whereas e_2^S is characterized by

$$-c(e_2^S) + \delta y(e_2^S) = 0.$$

$e_2^T < e_2^S$ then follows from the concavity of $y(\cdot)$ and the convexity of $c(\cdot)$. ■