

Relative Ambition and the Role of Wage Secrecy in Labor Contracts*

Tomer Blumkin[†] and David Lagziel[‡]

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ABSTRACT:

In this paper we study the properties of optimal labor contracts in an efficiency-wage setting with homogenous workers whose utilities depend both on their absolute and relative wages, compared to their co-workers. Assuming that relative wages carry a two-sided effect over workers incentives, we characterize necessary and sufficient conditions for wage dispersion and wage secrecy to be part of the optimal labor contract. We show the important role played by the extent of complementarity exhibited by the production function, and further demonstrate the robustness of our results to the incorporation of general equilibrium stability considerations.

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[†]Ben-Gurion University of the Negev, Beer-Sheva 8410501, Israel. e-mail: Tomerblu@bgu.ac.il.

[‡]Ben-Gurion University of the Negev, Beer-Sheva 8410501, Israel. e-mail: Davidlag@bgu.ac.il.

“...rank among our equals is, perhaps, the strongest of all our desires, and our anxiety to obtain the advantages of fortune is accordingly much more excited and irritated by this desire...”

—Adam Smith (1759), *The Theory of Moral Sentiments*, VI.I.4.

1 Introduction

Envy and competitiveness are core emotions at the human need to compare oneself to others. While competitiveness directs an individual to gain an advantage over others, envy dictates a basic desire to level a relative shortage. Essentially, the two emotions produce complementary effects - either downwards or upwards. In this paper we offer some insights into the repercussions of these elements (henceforth, referred to as *relative ambition*) through a natural economic setting.

Our problem begins with a simple principal-agent interaction. A partially-informed firm designs incomplete contracts such that employees receive fixed wages. With a slight deviation from the neoclassical model, we assume that the ex-ante homogeneous employees are subject to some form of relative ambition. Their utility functions depend on individual effort, personal wages, and on their counterparts' wages, as well. Namely, we assume that others' wages and enhanced relative ambition provoke an adverse effect over employees' incentives. Given a general CES production function, we address the problem of optimal labor contracts, focusing on the role played by two key parameters: (i) the extent of relative ambition exhibited by the workers; and, (ii) the degree of complementarity exhibited by the production function. In each aspect we offer a specific insight, explained as follows.

The first part concerns the variation in optimal incentives as employees' relative ambition intensifies. As long as ambition levels are low, employees pay little attention to others' wages, and the firm exercises a simple uniform-pay policy. This is anticipated in light of the presumed symmetry in production and workers' homogeneity. However, once relative ambition considerations become more manifest and employees are more concerned with their relative lot vis-a-vis their co-workers, a uniform-pay policy becomes increasingly costly. There is simply no way to efficiently incentivize an entire group of people, whenever their main concern is their ordinal ranking. A superior remuneration strategy involves wage dispersion which discriminates among ex-ante homogeneous employees. In essence, we prove that wage gaps are a natural reaction to the human need of competition.

Figure 1 captures this transformation through a single parameter γ that measures the level of relative ambition. If $\gamma = 0$, employees' utility is independent of others' wages. However, as γ increases, employees become more concerned with their relative wage, thus the optimal

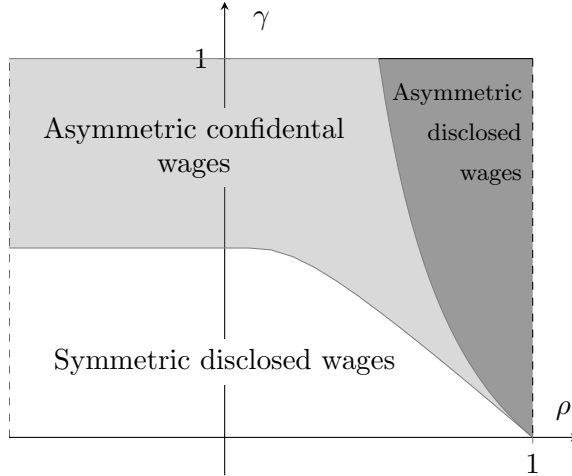


Figure 1: The two parameters $\rho \in (-\infty, 1]$ and $\gamma \in [0, 1]$ relate to the elasticity of substitution and the level of relative ambition, respectively. As long as envy and competitiveness levels are low (white area), the optimal contract dictates a disclosed symmetric wage policy, and all employees receives the same commonly-known wage. However, as emotions intensify (gray areas), the optimal wages become dispersed. When production tends to perfect substitution (dark gray area), the firm gains from full disclosure of the asymmetric wages. On the other hand, when production depends heavily on cooperation among employees (light gray area), the firm must exercise an ambiguous pay policy, where employees have a noisy assessment of their partners wages.

solution involves a discriminatory wage policy (gray areas).

The second part focuses on different levels of substitution in production. Under high level of complementarity, employees cooperation weighs heavily on production, and the firm must resort to a uniform compensation policy even in the backdrop of high-level relative ambition. Since the common solution of wage compression becomes increasingly costly, we propose a novel approach - the use of *secrecy*. We show that a firm can, and sometimes must, employ an undisclosed-wage policy, such that only the average wage of workers is common knowledge. In other words, the firm uses secrecy to reduce the wage benchmark that employees use to assess their relative reward. To differ, under high level of substitution in production, little cooperation is needed and the firm only gains from fully-disclosed wage-gaps to address the relative ambition concerns.

This insight is also presented in Figure 1. In case some wage dispersion is needed (gray areas), the level of substitution dictates how these gaps are implemented: full disclosure whenever the level of substitution is high (dark gray area), and a confidential-wage policy otherwise (light gray area).

In practice, one can track confidential-wage policies by comparing high- and low-tech

workers' contracts. In many high-tech companies employees are formally obligated under contract to refrain from disclosing their individual wages to other employees, while low-tech workers are usually paid a uniform, fixed, commonly-known wage. This seems to be in line with the commonly stipulated competitive attitude of employees in the high-tech industry.

The combined presentation of the two stated results is somewhat misleading since the two are, in fact, independent. First, the use of a confidential-pay policy is relevant as long as some form of relative ambition exists. Whether the employees are homogeneous or not, the firm can use confidentiality to reduce the employees wage benchmark and optimize incentives. The same result would hold even if wage dispersion follows from employees heterogeneity. Second, wage dispersion is a natural response to the employees' concerns about their relative pay. It goes to the core problem of optimal incentives for agents whose primary concern is their ordinal ranking, and it is irrelevant to any disclosure concerns.

In the last part of the paper, we extend the basic set-up to a general-equilibrium setting, with ex-ante and ex-post stability concerns and free entry. Our results indicate that secrecy is potentially beneficial to individuals' expected welfare, thus leading the interesting policy implications. Namely, we prove that fully-disclosed policies are not (necessarily) supported in equilibrium, since firms' have profitable deviations towards confidential wage policies, that are supported in equilibrium. Thus, a regulatory restriction to eliminate secrecy could give rise to suboptimal equilibria from the employees' view-point.

1.1 Related literature

Our theoretical analysis dwells on a voluminous strand in the labor economics literature, originating from the seminal study of Akerlof (1982). Akerlof focuses on the incompleteness of labor contracts and views employer-worker relations as a gift-exchange, where employers produce a gift in the form of a fair wage rate (i.e., wages exceeding a certain reference level reflecting market conditions and workers' perceptions). In exchange, employees reciprocate with a gift by exerting efforts exceeding the minimum contractible level.

A fundamental question in this theory concerns the determination of the reference level, which in turn, defines what constitutes a fair level of remuneration. Akerlof and Yellen (1990) suggest, for instance, that the reference point is a weighted average of the equilibrium wage under the standard neoclassical assumptions and the average wage within a reference group. The latter component alludes to the commonly perceived salient role played by comparability, or relative pay considerations, in forming workers' perceptions of fairness.

Pay inequality and relative remuneration considerations bear important implications for optimal labor contracts. Charness and Kuhn (2007) argue that workers' perception of fair-

ness, and consequently their motivation to exert effort, are shaped (to some extent) by relative concerns. These concerns provide a positive rationale for compensation practices such as wage compression and wage secrecy.

Akerlof and Yellen (1990) were the first to suggest the potential role of wage compression as a means to alleviate co-workers' equity concerns in an efficiency wage setting. More recently, Charness and Kuhn (2007) employed a reduced form gift-exchange framework, with heterogeneous workers (differing in productivity) whose effort choices are affected by their co-workers' wages. They explicitly demonstrate how profit-maximizing firms would respond to an increase in the responsiveness of workers to their co-workers' compensation by compressing wages.¹

Somewhat surprisingly there is a paucity in studies examining the desirability of incorporating wage secrecy arrangements in the optimal design of labor contracts. A notable exception is the study by Danziger and Katz (1997) that demonstrates how a wage secrecy convention can serve to facilitate risk shifting between firms and workers in response to productivity shocks. In the current paper, we offer a different rationale for wage secrecy, hinging on the latter's role in mitigating dis-incentivizing effects of relative pay concerns embedded in a canonical gift-exchange setting.

Although our contribution is purely theoretical, we close this short literature review with a brief note on the related empirical literature. Relative pay reciprocity has been a subject of a large number of experimental studies (for a recent survey see Charness and Kuhn (2011)). Two main lines of research focus on the role played by 'vertical comparability' (with respect to past wages) and 'horizontal comparability' (with respect to peers' compensation). The latter strand of the literature is more relevant for our analysis. The broad picture is however mixed. Charness and Kuhn (2007), Fischer and Steiger (2009) and Hennig-Schmidt et al. (2010) find no effect of others' remuneration on the level of effort; whereas, Gächter and Thöni (2010), Cohn et al. (2011), Greiner et al. (2011), Ku and Salmon (2012) and Bracha et al. (2015) do find an effect.

The incentivizing role of relative pay has been examined outside the lab in several recent studies. Rege and Solli (2015) use the 2001 policy change in the on-line availability of Norwegian tax records to study how relative compensation affects workers' incentives. They find that the information shock increased job separation for low-earning workers relative to high-earning ones. Cullen and Perez-Truglia (2017) combined the same policy change with

¹The desirability of wage compression has been examined in several studies but in different contexts. For instance, Harris and Holmstrom (1982) examine wage compression as an insurance device, Frank (1984) derives wage compression from peers equity concerns, and Lazear (1989) focuses on the role of wage compression in enhancing cooperation amongst workers in tournaments.

a field experiment to show that higher perceived peer salary decreases effort and output, as well as retention. Notably these two studies allude to the role played by pay transparency in determining labor market outcomes. Our contribution would be in offering a potential theoretical explanation for the underlying mechanism at work.

1.2 Structure of the paper

The paper is organised as follows. In Section 2 we present the model along with the main assumptions. Section 3 depicts the main results for a single-firm problem, while Section 4 deals with the problems of ex-ante and ex-post stability in general equilibrium with free entry. In Section 5 we provide some concluding remarks.

2 The model

Consider a group of employees working for a single representative firm. The goal of the firm is to minimize costs, subject to a fixed level of production. For that purpose, the firm rewards employees through fixed individual payments. In turn, the (ex-ante) homogeneous employees strategically choose their private effort levels, taking into account their individual pay structure as well as those of their counterparts. In other words, the utility function of every employee depends on the relative wage, as the need to compare wages and the strategic reaction towards differential pay is a common feature, shared among all employees.

Since employees are concerned with their relative compensation, the utility-relevant wages are potentially kept secret. Namely, every employee is informed of his own pay, while the firm might not allow employees to share this information with others. The firm can exercise a *confidential-pay policy* as an additional tool, besides the ability to fix wages, in the quest for an optimal outcome. We capture this secrecy aspect by assuming that employees are matched into couples such that individual partners are used as *benchmarks*.

More formally, the process begins when all employees are matched into couples. For simplicity, we assume that there is a continuum of employees with a mass of 2, such that the total mass of couples is normalized to 1 (both values are given per a single firm). Next, the firm commits to a *feasible policy* $F \in \Delta \mathbb{R}_+^2$ which dictates the fixed wages of every matched couple. A feasible policy must sustain two conditions. First, the marginals must be identical to reflect the true distribution of wages among employees. Second, F is either a product distribution (i.e., independent marginals) or both coordinates are deterministically dependent (i.e., the realized wage of one employee uniquely determines the partner's wage).²

²We later discuss the implications of implementing a policy which allows for generally-dependent marginals.

A product distribution is considered a *confidential-pay policy* (CP policy) since partners' wages are independent, whereas the case of deterministically-dependent wages reflects an *observable-pay policy* (OP policy) among matched employees.³ Denote the set of feasible policies by \mathcal{F} .

Once wages are distributed according to F , the employees are privately informed of their realized pay. All employees possess the same utility function

$$U(e, w; w_p) = w - \frac{e^2}{2} + e[w - \gamma w_p],$$

where w and e are the employee's fixed wage and non-negative individual effort level, respectively; w_p is the wage of the employee's partner; and $\gamma \in [0, 1]$ is a measure of the employees' sensitivity towards their partners' income. Wage should be interpreted as real rates, an issue we revisit later when discussing the market equilibrium. For concreteness, we assume the existence of a single consumption good produced by the representative firm.

The output per matched couple, exerting efforts e and e_p , is determined by a CES production function $Q(e, e_p) = (\frac{1}{2}e^\rho + \frac{1}{2}e_p^\rho)^{1/\rho}$, where $\rho \leq 1$ (the notation $\rho = 0$ refers to the limit value, a Cobb-Douglas production function). The firm's total production is given by a strictly-positive, increasing, and weakly-concave function H over the aggregate production of all teams. Thus, assuming that the required production is exogenously fixed to X , the firm is confronted with the following cost-minimization problem,

$$\begin{aligned} \min_F C &= \min_{F \in \mathcal{F}} \mathbf{E}[w + w_p], \\ \text{s.t. } H(\mathbf{E}[Q(e, e_p)]) &\geq X > 0, \\ e &= \operatorname{argmax}_{\tilde{e}} \mathbf{E}[U(\tilde{e}, w; w_p)], \\ e_p &= \operatorname{argmax}_{\tilde{e}} \mathbf{E}[U(\tilde{e}, w_p; w)], \end{aligned}$$

where the expectation operator $\mathbf{E}[\cdot]$ represents the aggregation at the firm's level, and taken w.r.t. F .⁴ A direct optimization shows that $e = \max\{w - \gamma \mathbf{E}[w_p], 0\}$ and a similar equality holds for e_p . Notice the crucial difference between OP and CP policies in the eyes of the employees. Under an OP policy, every worker knows his partner's true wage w_p , whereas a CP policy suggests that employees only know their partners' expected wage based on F .

Reservation wage and minimal effort are fixed at zero in our model. This may seem unrealistic since zero-wage employees are, de-facto, not employed by the firm, and such

³An alternative way to consider the firm's strategy is through a two-stage decision process. First, the firm chooses a distribution over \mathbb{R}_+ , which dictates the wages of all employees before they are matched. Next, employees are either randomly matched to generate independent wages within couples (a CP policy), or employees are deterministically matched to produce an OP policy.

⁴Throughout the analysis, we use a simplified notation of $\tilde{X} = H^{-1}(X)$.

wages are not implementable due to minimum-wage legislation. Thus, we emphasize that the chosen base levels are a matter of a simplifying normalization. One can consider an alternative scenario where wage and effort are strictly positive, supported on some reservation levels, reflecting industry norms and/or pertinent legislation. More importantly, our set-up could be interrupted as a *bonus-plan model* eliciting extra efforts, rather than an entire compensation scheme. For the sake of simplicity, we abstract away from these elements, as the forces that apply under the following analysis would still hold given the updated setting.

2.1 The utility function and gift exchange

Our compensation structure (ruling out the possibility of piece-rate remuneration) hinges on the presumption that effort levels are private information, hence are neither observed, nor (ex-post) verified by the firm. In other words, we deal with incomplete labor contracts. For that purpose we divided the employees' utility function into two parts. The first is standard and measures the workers net payoff; namely, the compensation minus the disutility from the effort exerted. The second term of the utility function, $e[w - \gamma w_p]$, captures our notion of relative ambition, under incomplete contracts, through the concept of gift exchange (see Akerlof (1982)). Namely, for a fixed level of relative ambition, denoted by γ , the employee weighs-in his relative pay (compared to the partner's pay), and privately decides on the level of effort to exert. The range of γ suggests that the employees' preferences vary from no relative ambition ($\gamma = 0$) to full comparability ($\gamma = 1$).

There are several ways to interpret our gift-exchange term. Akerlof and Yellen (1990) considered an exogenous fair-wage benchmark, composed of "a weighted average of the wage received by the reference group and the market-clearing wage". Our term corresponds to theirs as $\gamma w_p = \gamma w_p + (1 - \gamma)0$, where the market clearing wage, in the absence of gift exchange, is indeed zero. A different interpretation could be found in Charness and Kuhn (2007). With a slight re-arrangement of $w - \gamma w_p$, we obtain $(1 - \gamma)w + \gamma(w - w_p)$, in line with Charness and Kuhn (2007) who studied a set-up where effort is a separable linear function of w and $w - w_p$.⁵ Our choice of a quadratic disutility from work induces linear response functions by the employees, thus providing a simple micro-foundation for their behavioral assumptions. Our utility function is also analogous to the one used by Blumkin et al. (2017). Similarly to Blumkin et al. (2017), the quadratic cost function could be replaced by a positive,

⁵The normalized weights, $1 - \gamma$ and γ , are a matter of technical simplification, rather than an essential one. An alternative approach would involve non-normalized positive weights $\gamma_1 w + \gamma_2(w - w_p)$, to produce similar results where high relative ambition is translated to an increase in γ_2/γ_1 . Moreover, one could consider a utility function where relative ambition vanishes in case of equal wages, i.e., $U(e, w; w_p) = w - \frac{e^2}{2} + \frac{e}{1-\gamma}[w - \gamma w_p]$. In this case, our analysis remains the same, while γ becomes irrelevant whenever $w = w_p$.

convexly-increasing, non-bounded function. The choice of a quadratic functional form is made for tractability purposes and does not limit the qualitative nature of our results.

We assume that relative ambition has a two-sided effect: a relatively high wage sharpens incentives (competitiveness), while a relatively low wage weakens them (envy). To differ, asymmetries between upwards and downwards effects over incentives could arise, e.g., in case employees' possess a high level of envy with a low level of competitiveness (see Charness and Kuhn (2007) and Bracha et al. (2015)). Such asymmetries do not change the qualitative nature of our results. For example, the use of confidential-pay policy still confronts the problem of reducing employees' wage benchmark whenever employees are strictly concerned with envy, rather than competitiveness. For tractability reasons, we focus on the symmetric case in the analysis that follows. Note that previous experimental studies that tested the incentivizing effect of relative pay considered set-ups with heterogeneous workers. Heterogeneity in productivity may justify differential remunerations and mitigate the incentivizing role of relative pay. Indeed, Bracha et al. (2015) argue that, whenever workers are provided with some justifications underlying the differential compensation scheme, they tend to find it less disconcerting and accommodate it. Our framework that focuses on ex-post differential compensation of ex-ante identical workers is a natural setting in which relative pay concerns may arise and may bear incentivizing implications.

One final remark is in order before we turn to the analysis. The use of couples for benchmark purposes could be easily extended to teams of more than two employees and different sizes. Such modelling choices would carry limited influence over our analysis and conclusions. The forces that lead the interaction and, specifically, the externalities of wages would still apply in a general-team setting.

2.2 Complete contracts and the classical framework

Our choice to set focus on incomplete contracts and an employer-workers gift-exchange relationship draws on an extensive strand in the behavioural economics literature (see our discussion in the literature review) that examines, both theoretically and empirically, the potential incentivizing role of relative pay through the determination of a compensation reference level. While believing that this setting is a natural framework to explore the role of wage secrecy policies, we emphasize that our analysis can be readily extended to a complete-contract set-up.

For instance, consider an alternative utility function $U(e, w; w_p) = ew - C(e, w_p)$, where e denotes effort, and (w, w_p) denote the worker's and partner's wage rate (per unit of effort), respectively. Notice that the first term reflects a standard piece-rate remuneration scheme

based on observable effort levels, whereas the second term denotes the cost entailed by the worker in exerting productive effort. The cost function, C , is assumed to satisfy the following properties $C_e > 0$, $C_{ee} > 0$, $C_{w_p} > 0$, and $C_{ew_p} > 0$. The first two properties are standard and imply a positive and increasing marginal cost of effort. The last two properties capture a novel behavioural component, such that the cost of effort depends on the partner's level of remuneration. In particular, the worker's cost (both total and marginal) rises with the counterpart's wage rate, reflected both in the intensive margin (lower effort levels) and the extensive margin (lower utility which may push the dissatisfied worker to look for alternative job opportunities). With a few simple adjustments, all our qualitative results hold under the alternative specification. In other words, our results stem from the dependence of the workers' chosen effort levels on their partners' wages, and not driven by the incompleteness feature of the labor contract per se.

3 Main results

The first part of our analysis deals with the two extreme cases of the CES production function: perfect complements vs. perfect substitutes. Under the latter set-up, we prove that an observable-pay policy dominates any confidential one in terms of lower expected costs per unit of production. However, if γ is sufficiently high, then perfect complementarity yields the opposite outcome. Specifically, in case the production depends on the minimal amount of effort among the matched employees (a Leontief production function), the firm can use a confidential policy to reduce expected costs.

The driving force behind this result is the combination of perfect complements with the disutility from partners' wages. On the one hand, perfect complementarity requires high effort levels on the side of both employees simultaneously. On the other hand, the disutility from others' wages makes it extremely costly (prohibitively, in the limiting case where gamma goes to unity) to incentivize all employees at the same time using a fully disclosed compensation policy. Secrecy balances these two forces to produce an adequate number of high-wage matched employees, whose disutility from the expected average pay (and not their actual counterparts) is sufficiently low.

Theorem 1. *A confidential-pay policy is suboptimal in case of perfect substitutes. However, if $\gamma > \frac{1}{2}$, then an observable-pay policy is suboptimal in case of perfect complements.*

All proofs are deferred to the Appendix.

A key observation in the construction of the proof for the case of perfect complementarity is the role of *benchmarkers*. The latter refers to workers whose productive effort is sacrificed

by the firm (which offers them a relatively low remuneration), so as to reduce the benchmark of their productive counterparts, who are offered a relatively high level of compensation. By employing a confidential wage policy, the firm can reduce the measure of benchmarkers and, at the same time, entail a significant reduction in the benchmark wage rate.

To facilitate the interpretation of Theorem 1, one may abstract from our specific utility function and modelling choices, and consider a generic effort-response function $e(w, w_p)$ which dictates the optimal response of an employee. Starting with a standard set-up with no reference level ($\gamma = 0$, in our formulation), one expects an increasing and weakly concave effort level with respect to the individual wage. Taking into account the concave and symmetric production function, the optimal OP policy calls for wage compression. These assumptions and result arise naturally in the classic set-up, and completely change once relative ambition is embedded into the framework.

The existence of a reference point introduces a fixed cost to the firm's optimization problem. Namely, a worker exerts additional effort, above the base level, only if he is sufficiently compensated relative to the reference point (in our case, above γw_p). If the fixed cost is large enough, there are increasing returns to scale and the firm can do better by assigning the production to a subgroup of workers, thereby saving some of the fixed costs. The mathematical manifestation of a substantial fixed cost is reflected through an average-convexity property of the effort-response function. These sufficient conditions are summarized in Claim 1.

Claim 1. *Consider the case of perfect complements, and fix the employees' non-negative effort response function $e = e(w, w_p)$, where $e_w > 0 > e_{w_p}$. Given equal wages, assume that the effort function is increasing, and assume it is sufficiently convex (on average) in its first argument such that $e_w(w, w) > 2 \frac{e(w, w) - e(0, w)}{w}$. Then, the OP policy is suboptimal.*

Note that all monotonicity assumptions are quite orthodox in either framework. The response function increases in individual wage w , decreases in the partner's wage w_p , and increases in wages subject to equal pay. The key ingredient for our result is the convexity assumption which follows from the previously mentioned fixed cost, due to relative ambition and the use of partners as reference points.

A notable implication of the proof of Theorem 1 is that, under perfect substitutes, one can restrict attention to CP policies supported on only two wage levels. This observation relates to a broader result, given in Lemma 1, stating that the entire analysis could be restricted to at most two wage levels. The result is based on the concavity of the production function which allows us to contract wage levels and increase expected productivity. Note that the same contraction would be amplified by any convex cost function (of the firm), as it will

reduce expected costs.

Lemma 1. *For every finite ρ , any optimal policy, either confidential or observable, could be induced by at most two wage levels.*

Intuitively, one needs only two wage levels: a high level to elicit productive efforts and a low level to reduce the benchmark. Any wage dispersion, either within the group of workers that exert a positive effort level or amongst the pool of benchmarkers, can be reduced and save costs hinging on the concavity of the production function that dictates a symmetric compensation structure. The only deviation to a non-symmetric structure is due to the role of benchmark reduction, hence the separation between the two wage levels. Notably the latter property holds across the board and is independent of the degree of complementarity/substitutability between the effort levels.

Using Lemma 1, we can go beyond the two extreme cases of perfect complements and perfect substitutes, and extend Theorem 1 to any CES production function. Theorems 2 and 3 show that an ex-post discriminating and confidential policy cannot be optimal whenever employees are not zealous to compare wages. However, once relative ambition rises, the firm must employ some form of discrimination to reduce costs while motivating a sufficient amount of workers to produce X . The point at which the firm deviates from symmetric wages to non-symmetric ones depends on the level of complementarity among workers' production efforts, thus we split the results into two parts: $\rho \leq 0$ and $\rho \in (0, 1]$, considered in Theorems 2 and 3 respectively.

Theorem 2 relates to the case where levels of complementarity are relatively high, namely $\rho \leq 0$ (see Figure 2). It states that for low level of ambition (i.e., $\gamma \leq \frac{1}{2}$), wage dispersion is suboptimal and the firm should use a symmetric OP policy. However, if relative ambition rises (i.e., $\gamma > \frac{1}{2}$), then the firm should use a discriminating CP policy, where a proportion of employees receive a high wage, while others receive nothing.

Theorem 2. *Fix $\rho \leq 0$. The symmetric observable-pay policy is optimal if and only if $\gamma \leq \frac{1}{2}$. If $\gamma > \frac{1}{2}$, then an ex-post asymmetric CP policy is optimal.*

The case characterized in Theorem 2 focuses on production functions exhibiting a relatively high degree of complementarity. In these cases the only feasible wage policy that induces a benchmark reduction is the confidential pay regime. Any discriminatory OP policy would imply that total output produced by the pair of workers would be zero (this reflects an extreme manifestation of the complementarity property - see our earlier discussion of the limiting Leontief case). With a confidential pay policy, the benchmark can be reduced prob-

abilistically and not for each pair across the board. In the backdrop of a sufficiently high degree of relative ambition this turns out to be the cost-minimizing strategy.

Theorem 3 focuses on the second part of $\rho \in (0, 1]$, showing that there are three possible solutions: a symmetric OP policy; an asymmetric OP policy; and an asymmetric CP policy. The variation between these three solutions is best exemplified by Figure 2. There exists a continuously-decreasing function, $\gamma_1(\rho)$, such that wage compression is optimal at (γ, ρ) if and only if $\gamma \leq \gamma_1(\rho)$ (this is consistent with the result of Theorem 2 in the sense that $\gamma_1(0) = \frac{1}{2}$). Alternatively, for $\gamma > \gamma_1(\rho)$, wage gaps become imminent due to the high-level of competitiveness. The firm implements wage dispersion either with secrecy, a CP policy, or without it, an OP policy. The distinction between the two is a function $\gamma_2(\rho)$ of the complementarity level, where relatively high complementarity (i.e., a low ρ) requires secrecy.

Theorem 3. *Fix $\rho \in (0, 1]$ and $\gamma \in [0, 1]$. There exist two continuously-decreasing functions γ_1 and γ_2 such that the confidential-pay policy is optimal if and only if $\gamma_1(\rho) < \gamma < \gamma_2(\rho)$. Moreover, the symmetric observable-pay policy is optimal if and only if $\gamma \leq \min\{\gamma_1(\rho), \gamma_2(\rho)\}$; and the asymmetric observable-pay policy is optimal if and only if $\gamma \geq \max\{\gamma_1(\rho), \gamma_2(\rho)\}$.*

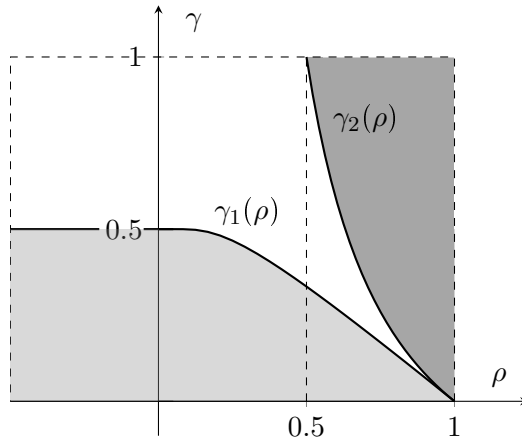


Figure 2: Optimal policies as a function of γ and ρ : light gray area = symmetric OP policy; white area = asymmetric CP policy; dark gray area = asymmetric OP policy. The proof of Theorem 3 also shows that $\gamma_1(0) = 0.5$, $\gamma_2(0.5) = 1$, and $\gamma_1(1) = \gamma_2(1) = 0$.

4 Equilibrium analysis - stability and implementation

4.1 Partial equilibrium

The partial equilibrium analysis is straightforward and based on a fixed number of firms, not greater than half the number of employees (recalling that a single firm employs a mass of 2 employees). Under such conditions, all firms strive to maximize profit. By presumption that prices are normalized to unity and that wage rates are denoted in real terms, the profit is given by $X - C_{\gamma,\rho}(X)$ where $C_{\gamma,\rho}$ is the minimal cost given (γ, ρ) . Previous results indicate that $C_{\gamma,\rho} = \alpha_{\gamma,\rho}H^{-1}(X)$ is a linear function of $H^{-1}(X)$. To eliminate trivial solutions (i.e., no production or an unbounded level of production), one can assume that H is strictly-concave such that the maximum-profit problem, $\max\{X - \alpha_{\gamma,\rho}H^{-1}(X)\}$, has a finite positive solution. Therefore, all firms would follow the previous analysis to minimize costs, while the production level is determined according to a maximum-profit condition. In particular, the characterization of the optimal pay policy and the necessary and sufficient conditions for the optimality of a CP policy, stated in Theorems 2 and 3, continue to hold under the partial equilibrium regime.

4.1.1 Policy implications

Our preceding analysis (Theorem 2) shows that, for $\gamma > 0.5$ and under perfect complementarity, firms would resort to a CP policy, in equilibrium. An interesting question is whether regulating pay transparency, which takes the form of restricting firms to OP policies, would be beneficial for workers. A straightforward computation reveals that such regulation would actually be harmful for all sides.

Observation 1. *Consider the case of perfect complementarity and, for tractability, fix $H(k) = k^{1/2}$. For every $\gamma > 0.5$, workers' ex-ante utility is higher under the optimal CP policy than under the optimal (restricted) OP policy.*

4.2 General equilibrium

Thus far we have confined our analysis to a simple partial equilibrium framework, in which the number of firms was fixed. Namely, incumbent firms were not threatened by potential entrants that might dissipate their rents. In addition, a key feature of our analysis was the desirability of confidential pay structures, that resulted in ex-post payoff differences amongst ex-ante identical workers. However, in the presence of free entry, workers can renegotiate their contracts with their current employer as long as firms derive positive rents. These rents ensure that employees have a credible threat to switch to an alternative firm that offers a

more generous remuneration. Moreover, even in the absence of rents (i.e., whenever firms earn zero profits), workers who end up with a lower remuneration level would try to renegotiate their wages, since the superior possibility of switching remains feasible and credible. In this section, we incorporate these stability considerations into account. In particular, we show that our key insights carry over to the extended general equilibrium setting.

To guarantee these stability notions, the wage policy must maximize employees' expected utility, subject to two conditions: (i) the firm's profit is non-negative; and (ii) every realized wage weakly exceeds the expected utility minus the transaction costs associated with switching a firm.⁶ Thus, given that all firms guarantee an expected utility of \tilde{U} , the single-firm maximization problem is reformulated as follows,

$$\begin{aligned} \max_F \mathbf{E}[U(e, w; w_p)] &= \max_{F \in \mathcal{F}} \mathbf{E} \left[w - \frac{e^2}{2} + e[w - \gamma w_p] \right], \\ \text{s.t. } H(\mathbf{E}[Q(e, e_p)]) &\geq \mathbf{E}[w + w_p], \\ U(e, w_0; \mathbf{E}[w_p]) &\geq \tilde{U} - T, \quad \forall w_0 \in \text{Supp}(w), \end{aligned}$$

where all expected values are taken w.r.t. the pay policy F , the value $T > 0$ denotes the transaction cost associated with switching a firm, and (e, e_p) are determined as before. The new optimization problem ensures that no firm would be able to attract employees by offering them a higher expected utility. Such a deviation would either be non-profitable (violating the first constraint) or turn out to be ex-post unstable as it would induce a positive measure of employees to renegotiate their terms (violating the second constraint). The objective function essentially imposes an ex-ante stability condition which suggests that all firms, in equilibrium, produce the same expected utility for workers. Thus, an equilibrium (à la Nash) induces a fixed point with respect to the objective function, and the solution for the above optimization must be \tilde{U} .

To simplify our exposition, we will focus on the case of perfect complementarity in production and, for tractability, fix $H(k) = k^{1/2}$. Clearly, any strictly-concave function H which ensures a positive finite level of production would apply as well. Another technical issue revolves around the existence of an equilibrium. For OP policies, the problem is straightforward since there is one possible profile to consider. Under symmetry in production within and across teams with free entry and workers' homogeneity, the optimal OP policy will specify a uniform wage rate. Therefore, one can derive the maximal wage from the first constraint (as the second becomes redundant) and solve the optimization problem. On the other hand, CP policies are more challenging. Note that the objective function is convex while the first

⁶These costs may capture search frictions, costs of negotiating the new wage contract and the uncertainty due to the ex-ante stochastic compensation policy associated with switching to an alternative employer.

constraint is concave, so the previously-used compression argument fails. Thus, we must work with general wage distributions, and it is unclear whether a solution to the problem exists.⁷ To avoid technical issues of existence (which are beyond the scope of this paper) we assume that CP policies are supported on a finite number of bounded wage levels, such that the above problem could be embedded in a compact set (finite dimension, closed, and bounded).

Recall that in the partial equilibrium framework, we have shown that a CP policy dominates an OP regime in case γ is sufficiently high (i.e., $\gamma > 1/2$ in Theorem 1). Similarly, in the following theorem we provide a sufficient condition for the non-existence of an OP policy equilibrium due to firms' profitable deviation towards a CP policy, whereas a CP-policy equilibrium exists.

Theorem 4. *In the case of perfect complements and given a positive transaction cost, there exists a weakly-decreasing function, $\frac{1}{2} \leq \gamma(T) < 1$, such that for every $\gamma > \gamma(T)$ there exists no observable-pay policy equilibrium. Moreover, there exists $T^* > 0$ such that for every $T \geq T^*$ and every $\gamma > \gamma(T^*)$, a confidential-pay policy equilibrium exists.*

The rationale underlying the sufficient condition stated in Theorem 4 relies on two key insights. First, as in the partial-equilibrium setting, the optimality depends again on the degree of relative ambition. With a higher degree of relative ambition, a firm offering an OP policy (with uniform wage rates) would elicit lower levels of effort and consequently produce lower levels of output. Constrained by the zero profit condition, the latter implies that the maximized utility, under an OP policy, is decreasing in the degree of relative ambition. A switch to an alternative CP policy would serve to mitigate the relative ambition disincentivizing effect, and therefore raise the workers' expected utility. Thus, when the degree of relative ambition is sufficiently high, a CP policy prevails over an OP policy. For example, in the limiting case where the parameter gamma converges to unity, an OP policy elicits no effort and therefore no positive utility, hence it is dominated by a CP policy for any positive level of transaction costs.

The second insight relates to a main feature of the CP policy - wage dispersion. Workers with realized low wages reduce the 'benchmark' faced by their highly remunerated peers, thereby contributing to efforts and output. The presence of transaction costs limits the

⁷The set of probability distributions over $[0, \infty)$ is not necessarily compact, and the expectation functional need not be continuous. There is the possibility of reverting to a weak* topology, namely the vague topology, along with radon measures that guarantee tightness (i.e., vanishes at infinity; see Theorems 5.19-5.22 in Kallenberg (2002)). However, since this is not a mathematical paper dealing with modern methods in functional analysis, we revert to a simpler framework, without loss of *economic* generality.

scope of wage dispersion, thus limiting the potential gains from a switch to a CP policy. In the absence of transaction costs, for instance, wage dispersion cannot hold in equilibrium. That is, in a frictions-less environment with zero transaction costs, the only pay policy that would be ex-post stable is an OP policy. However, if transaction costs are bounded away from zero, a CP policy becomes ex-post stable and can potentially sustain in equilibrium. The higher the transaction costs are, the larger the gains from switching to a CP policy. Thus, for a given degree of relative ambition and if transaction costs are sufficiently high, a CP policy prevails over an OP one.

4.2.1 Policy implications

As done in the context of partial equilibrium, we revisit the welfare implications of pay transparency regulations under the general equilibrium set-up. A straightforward observation that follows from the combination of the two parts of Theorem 4 is that for sufficiently high degree of relative ambition and large enough transaction cost, there exist only CP policy equilibria.

Observation 2. *For every $T \geq T^*$ and every $\gamma > \gamma(T^*)$, the only existing equilibria are confidential-pay policy ones.*

In the proof of Theorem 4 we have shown that an OP policy equilibrium does not exist due to a profitable deviation towards a CP policy. It therefore follows that a regulatory restriction which prohibits the use of pay secrecy clauses in wage contracts has a potential detrimental effect on workers' welfare. To see this consider the setting described in Observation 2, with a regulatory restriction of wage secrecy, such that firms are obligated to publish wages. Once CP policies become infeasible, the only supported equilibrium is the previously-unattainable suboptimal OP policy profile, which imposes an expected welfare loss to workers.

Observation 3. *For every sufficiently high transaction cost and relative ambition, the exclusion of CP policies lowers workers' expected utility.*

5 Concluding remarks

Our paper provides a positive explanation for a pay secrecy convention to arise in equilibrium. The key insight of our analysis hinges on the combination of the relative ambition exhibited by workers and the complementarity of the production function. A worker cares about the level of remuneration of a subset of her peers, which serves as her reference group and are complementary to her in the production process. The firm is employing a confidential pay

policy to strike a balance between the desire to pay those in the reference group a high wage in order to elicit high productive efforts (by virtue of the complementarity) and the need to pay those workers a low wage in order to mitigate the dis-incentivizing effect of relative ambition. The idea underlying the wage secrecy policy is to use the workers outside the reference group as benchmarks, serving to reduce the expected wage of the workers in the reference group without actually doing so. In our set-up, the worker's reference group was comprised of the members of her production team.

Clearly, a worker's reference group may be defined more broadly. Considering the employees' social network, one can assume that a worker's reference group is comprised of a weighted average of adjacent peers, where closer peers are weighted more heavily than others. Our set-up is, in essence, a specific version of this concept since only team members are positively weighted. Though the general set-up is left for future research, the key feature that would maintain our qualitative insights is that, as a whole, the reference group would exhibit sufficient complementarity with respect to the worker's productive effort.

Somewhat surprisingly, pay secrecy, which is often described as a strategic tool used by employers to improve their bargaining position in wage negotiations and as a means to mitigate the potentially demoralizing effect of pay gaps on employees,⁸ may actually improve employees' welfare. In particular, in case relative ambition considerations are sufficiently manifest, we demonstrate that in a general equilibrium setting with free entry (which implies full dissipation of firms' rents), a confidential pay policy would maximize the ex-ante utility of workers, as it serves to mitigate workers' relative ambition concerns.

Our focus in the paper was on the efficiency enhancing features of pay secrecy. Most of the popular debate on the desirability of pay transparency, however, revolves around equity aspects. A notable example is the ongoing public discourse on executive excessive pay (that hogged the limelight in the early 90's), which was the trigger for legislation mandating the disclosure of this information in financial statement of publicly traded firms and setting salary caps on executive levels of remuneration. More recently, the issue of pay transparency has resurfaced, in the context of gender pay gaps, where transparency has been suggested as a means to address persistent gender inequities in the labor market.⁹

To the extent that executives' high compensation schemes reflect economic rents (po-

⁸In a recent study of employees at the University of California, Card et al. (2012) find that giving workers access to a database listing the salary of their peers, results in a decrease in job satisfaction among those with relatively low wages. Relatedly, Perez-Truglia (2015) used the previously-mentioned Norwegian tax-records policy change to find that income transparency increased the satisfaction gap between low- and high-earning individuals by more than 20%.

⁹A recent exposure of e-mails by executives in Sony Pictures revealed substantial gender wage variation in wage contracts signed with top stars in the Film industry in Hollywood.

tentially driven by poor corporate governance) and gender gaps in the film industry are a byproduct of gender-based discrimination, pay transparency should be promoted as a means to reduce inequities without entailing efficiency costs (or better, mitigating those). Our analysis demonstrates, however, that pay secrecy may be desirable on efficiency grounds. Thus, determining the optimal extent of pay transparency involves resolving an equity-efficiency trade-off, which in our case is captured by the choice between an OP and a CP policy.

Our analysis can be extended in several directions. We focus on a setting with an incomplete labor contract, which naturally lends itself to the notion of relative ambition due to the reference-dependent pay structure. A natural extension would be to consider a setting where remuneration can be based on observable effort levels. The possibility to observe efforts may hinder the efficiency gains from implementing a secrecy policy regime, so it would be more natural to consider a setting with heterogeneous workers differing in productivity.

Another source of heterogeneity that could be promising for extending our analysis would be a variation in relative ambition across workers. This would enrich the set of compensation schemes available to the firm, as the composition of teams would matter both under the OP policy and the CP policy regimes. In the former case, a fundamental question would revolve around segregation, namely, whether to allocate workers into homogeneous teams (in term of relative ambition) or heterogeneous ones. The less competitive types may serve as efficient bench-markers for their more competitive peers, for instance. Under a CP policy regime, one can apply different secrecy standards to different groups of workers that vary in the degree of relative ambition (as suggested by our analysis to be the optimal choice, indeed). The applicability of the above analysis can be exemplified in the context of gender. In light of the well documented empirical evidence on gender differences in the degree of ‘competitiveness’, gender homogeneous teams could potentially reduce expected costs to a firm. That is, although workers are homogeneous (barring their gender-related ‘competitive’ attitude) and assuming that ant-discrimination legislation rules out any wage differences between genders, allocating workers into gender-homogeneous teams would prove superior when the production function of the team exhibits a sufficiently high degree of complementarity.

The gender example may also provide a testable implication of our model. We predict that CP policy with secrecy arrangements will be desirable when the degree of relative ambition is sufficiently strong. Thus, we expect to see that secrecy arrangements would be more prevalent in male dominated industries and to a lesser extent in female dominated ones.

One final potential avenue for extension, would be to relax our assumption of statistical independence and allow for different marginals, so that under a CP policy regime, workers may update their beliefs regarding the benchmark in a Bayesian fashion. We conjecture

that due to the gift exchange component in the utility function, this enrichment of the set of compensation schemes available to the firm under a CP policy regime would serve to mitigate the ‘renegotiation-proofness’ binding constraint that ensures ex-post stability.

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Appendices

Theorem 1. *A confidential-pay policy is suboptimal in case of perfect substitutes. However, if $\gamma > \frac{1}{2}$, then an observable-pay policy is suboptimal in case of perfect complements.*

Proof. We start with the case of perfect complements such that $Q(e, e_p) = \min\{e, e_p\}$. Take an OP policy where every matched couple is paid w and w_p w.p. 1. Due to the complementarity, it would be suboptimal to pay different wages, thus $w = w_p$, and $e = e_p = w(1 - \gamma)$. Since $\gamma = 1$ is a trivial case, assume $\gamma \in (\frac{1}{2}, 1)$. This alternation is without loss of generality since the aggregate level of production is fixed. Thus, $\mathbf{E}[Q(e, e_p)] = w(1 - \gamma) = \tilde{X}$ and $C = 2w = \frac{2\tilde{X}}{1-\gamma}$.

Now, fix a CP policy where every employee receives either a wage of w w.p. $p \in (0, 1)$, or nothing, otherwise.¹⁰ There is a probability of p^2 for a couple to be productive, hence $\mathbf{E}[Q(e, e_p)] = p^2(w - \gamma wp) = \tilde{X}$ and $C = 2pw = \frac{2\tilde{X}}{p(1-\gamma p)}$. Comparing the expected costs leads to the following sufficient condition $p(1 - \gamma p) > 1 - \gamma$. If p is sufficiently close to 1 (specifically, in case $p > \frac{1}{2\gamma}$), then the LHS of the inequality is decreasing, while $p = 1$ yields an equality. Thus, for $p > \frac{1}{2\gamma}$ and $\gamma > \frac{1}{2}$, the result follows.

We move on to the case of perfect substitutes such that $Q(e, e_p) = \frac{1}{2}e + \frac{1}{2}e_p$. Take an OP policy where every matched couple is paid (w, w_p) w.p. 1. A straightforward constrained optimization shows that asymmetric pay of either $w = 0$ or $w_p = 0$ is the optimal OP policy for every γ . This outcome is intuitive since costs and production are linear and asymmetric wages bypass the problem of comparison among employees. Therefore, we need to show that any CP policy produces an expected cost of at least $2\tilde{X}$, given production level \tilde{X} , since an OP $(w, 0)$ -policy has an expected total cost of $2\tilde{X}$.

Take a CP policy F . Recall it is ex-ante symmetric w.r.t. all employees, thus they maintain the same benchmark of $\mathbf{E}[w] = \mathbf{E}[w_p]$. Denote $a = \gamma\mathbf{E}[w]$. The expected production and cost are given by $\tilde{X} = \mathbf{E}[(w - a)\mathbb{1}_{\{w \geq a\}}]$ and $C = 2\mathbf{E}[w]$. Define $Y = w - a$ and $q = \Pr(Y \geq 0)$. Let $Y_+ = \max\{Y, 0\}$ and $Y_- = \min\{Y, 0\} = Y - Y_+$ be the non-negative and non-positive parts of Y . Therefore, $\tilde{X} = \mathbf{E}[Y_+]$. In simple terms, the expected production equals the expectation of the marginal distribution above a .

Define an atomic distribution $\tilde{F} \in \Delta\mathbb{R}_+$ over the two values $\frac{\mathbf{E}[Y_+]}{q} + a$ and $\frac{\mathbf{E}[Y_-]}{1-q} + a$ (if $q = 1$, consider only the first term) with probabilities q and $1 - q$, respectively. The distribution \tilde{F} is, essentially, a contraction of F 's marginals on the two sides of a , preserving the expected value $\mathbf{E}[w]$ and the probabilities of being above or below the benchmark a . Specifically, the expectation w.r.t. \tilde{F} equals $\mathbf{E}[Y] + a = \mathbf{E}[w]$. Thus, an implementation of \tilde{F} , as a wage distribution with a random matching of employees, yields the same expected production of $\tilde{X} = \mathbf{E}[Y_+]$, and the same expected cost of $C = 2\mathbf{E}[w]$. So, the random implementation of \tilde{F} is equivalent to F , and (without loss of generality) we can restrict any CP policy to atomic marginal distributions supported on two values, above and below the benchmark level.

Consider an atomic distribution F' such that $w_i \geq 0$ is reached w.p. p_i , where $i = 1, 2$ and $p_1 + p_2 = 1$. Following the previous statement, let $\mu = w_1p_1 + w_2p_2$ be the expected value according to F' , and assume that $w_1 < a = \gamma\mu \leq \mu \leq w_2$. Note that w_1 -wage employees exert no effort, thus it is suboptimal to offer them a positive wage, and we can assume that $w_1 = 0$. An implementation of F' as a CP policy yields an expected production of

¹⁰Throughout the proof, we assume that fixed wages and probabilities meet the production requirement.

$X = (w_2 - a)p_2 = w_2(1 - \gamma p_2)p_2$, and an expected cost of $C = 2w_2p_2 = \frac{2\tilde{X}}{1-\gamma p_2}$. Hence, we need to verify that $\frac{2\tilde{X}}{1-\gamma p_2} \geq 2\tilde{X}$ or, equivalently, $\gamma p_2 \geq 0$. The last inequality is strict by the use of a CP policy (i.e., $p_2 > 0$) whenever $\gamma > 0$, and otherwise we get an equality, thus concluding the proof. \blacksquare

Claim 1. *Consider the case of perfect complements, and fix the employees' non-negative effort response function $e = e(w, w_p)$, where $e_w > 0 > e_{w_p}$. Given equal wages, assume that the effort function is increasing, and assume it is sufficiently convex (on average) in its first argument such that $e_w(w, w) > 2\frac{e(w, w) - e(0, w)}{w}$. Then, the OP policy is suboptimal.*

Proof. Under the Leontief production function $Q(e, e_p) = \min\{e, e_p\}$ and given the monotonicity properties of e , the optimal OP policy dictates equal wages such that $e(w, w) = X$ and $C = 2w$. Consider a CP policy where every employee receives either a wage of w w.p. $p \in (0, 1)$, or nothing, otherwise. The expected production is $p^2e(w, wp) + (1-p^2)e(0, wp) = X$ and the expected cost is $C(w, p) = 2wp$. Note that the optimal OP solution is embedded in the CP analysis for $p = 1$, so it is sufficient to show that the expected cost is increasing at $p = 1$, which implies that a strict CP policy where $p < 1$ is superior.

The equation $p^2e(w, wp) + (1 - p^2)e(0, wp) - X = 0$ defines w as an implicit function of p . Hence,

$$w'(p) = -\frac{2pe(w, wp) + wp^2e_{w_p}(w, wp) - 2pe(0, wp) + w(1 - p^2)e_{w_p}(0, wp)}{p^2e_w(w, wp) + p^3e_{w_p}(w, wp) + p(1 - p^2)e_{w_p}(0, wp)}.$$

Differentiating the expected cost, plugging in $w'(p)$, and taking $p = 1$, we get

$$\begin{aligned} [2w'(p)p + 2w]_{p=1} &= \frac{-4e(w, w) - 2we_{w_p}(w, w) + 4e(0, w)}{e_w(w, w) + e_{w_p}(w, w)} + 2w \\ &= \frac{-4e(w, w) + 4e(0, w) + 2we_w(w, w)}{e_w(w, w) + e_{w_p}(w, w)} \\ &> \frac{-4e(w, w) + 4e(0, w) + 4e(w, w) - 4e(0, w)}{e_w(w, w) + e_{w_p}(w, w)} = 0, \end{aligned}$$

where the inequality follows from the conditions over e . Note that the denominator is strictly positive by the assumption that $e(w, w_p)$ is increasing, subject to equal wages. So, the expected cost is increasing at $p = 1$, and the result follows. \blacksquare

Lemma 1. *For every finite ρ , any optimal policy, either confidential or observable, could be induced by at most two wage levels.*

Proof. Fix ρ and consider a CP policy F which marginals are supported on more than two values. Since it is ex-ante symmetric, all employees maintain the same benchmark of $\mathbf{E}[w] = \mathbf{E}[w_p]$. Denote $a = \gamma\mathbf{E}[w]$ and define the two random variables $Y = w - a$ and $Y^p = w_p - a$. We follow the standard \pm notation for $Y_+ = \max\{Y, 0\}$ and for $Y_- = \min\{Y, 0\}$ such that $Y = Y_- + Y_+$. The expected production and cost are given by $\tilde{X} = \mathbf{E}[Q(Y_+, Y_+^p)]$ and $C = 2\mathbf{E}[w]$, respectively.

Denote $q = \Pr(Y > 0)$. Define an atomic distribution \tilde{F} such that

$$W = \begin{cases} \frac{\mathbf{E}[Y_+]}{q} + a, & \text{w.p. } q, \\ \frac{\mathbf{E}[Y_-]}{1-q} + a, & \text{w.p. } 1 - q, \end{cases}$$

for $W \sim \tilde{F}$ (in case $q = 1$, consider only the first term). The distribution \tilde{F} is, essentially, a contraction of F 's marginals on the two sides of a , which preserves several key values. Namely, for $Y^w = W - a$, it follows that

$$\begin{aligned} \Pr(Y_+^w > 0) &= \Pr(W > a) = q = \Pr(w > a) = \Pr(Y_+ > 0); \\ \mathbf{E}[W] &= q \left[\frac{\mathbf{E}[Y_+]}{q} + a \right] + (1 - q) \left[\frac{\mathbf{E}[Y_-]}{1-q} + a \right] = \mathbf{E}[w]; \\ \mathbf{E}[Y_+^w] &= \mathbf{E}[(W - a)_+] = q \left[\frac{\mathbf{E}[Y_+]}{q} + a - a \right] = \mathbf{E}[Y_+]; \\ \mathbf{E}[Y_+^w | Y_+^w > 0] &= \frac{\mathbf{E}[Y_+^w]}{\Pr(Y_+^w > 0)} = \frac{\mathbf{E}[Y_+]}{\Pr(Y_+ > 0)} = \mathbf{E}[Y_+ | Y_+ > 0]. \end{aligned}$$

Thus, an implementation of \tilde{F} , as a wage distribution with a random matching of employees, preserves the expected cost along with $\mathbf{E}[Y_+]$ and a .

Now, fix a realization of Y^p and observe the expected production $\mathbf{E}[Q(Y_+, Y_+^p)]$.

$$\mathbf{E}[Q(Y_+, Y_+^p)] = (1 - q)\mathbf{E}[Q(Y_+, Y_+^p) | Y_+ = 0] + q\mathbf{E}[Q(Y_+, Y_+^p) | Y_+ > 0] \quad (1)$$

$$\leq (1 - q)\mathbf{E}[Q(Y_+, Y_+^p) | Y_+ = 0] + qQ(\mathbf{E}[Y_+ | Y_+ > 0], Y_+^p) \quad (2)$$

$$= (1 - q)\mathbf{E}[Q(Y_+^w, Y_+^p) | Y_+^w = 0] + qQ(\mathbf{E}[Y_+^w | Y_+^w > 0], Y_+^p) \quad (3)$$

$$= (1 - q)\mathbf{E}[Q(Y_+^w, Y_+^p) | Y_+^w = 0] + q\mathbf{E}[Q(Y_+^w, Y_+^p) | Y_+^w > 0] \quad (4)$$

$$= \mathbf{E}[Q(Y_+^w, Y_+^p)], \quad (5)$$

where Eqs. (1) and (5) follow from the law of total expectation; Ineq. (2) follows from the concavity of the CES function and Jensen inequality; Eq. (3) follows from the preserving qualities of W and Y^w ; and Eq. (4) follows from the fact that $Y_+^w | Y_+^w > 0$ is constant. A similar computation holds for Y^p . Therefore, the random implementation of \tilde{F} dominates F (potentially weakly) by preserving the expected cost and increasing production. We conclude our analysis of CP policies. Since any OP policy is based on a deterministic matching of

employees, it is optimal to uniquely implement the most efficient couple's wage-combination, thus maintaining at most two wage levels and the result follows. \blacksquare

Theorem 2. *Fix $\rho \leq 0$. The symmetric observable-pay policy is optimal if and only if $\gamma \leq \frac{1}{2}$. If $\gamma > \frac{1}{2}$, then an ex-post asymmetric CP policy is optimal.*

Proof. The computation is trivial for $\gamma \in \{0, 1\}$, thus we consider $\gamma \in (0, 1)$. We begin by explicitly writing the expected cost, in terms of production, for every policy. By Lemma 1 we can restrict ourselves to, at most, two pay levels. Note that the observable policy must be symmetric, since the overall production is set to zero once at least one agent is effortless. The expected cost and production from a symmetric OP policy and a CP policy (where a positive wage w is paid w.p. p) are:

$$\begin{aligned} Q_{\text{OP}} &= \left[\frac{1}{2}(w - \gamma w)^\rho + \frac{1}{2}(w - \gamma w)^\rho \right]^{1/\rho} = w(1 - \gamma) = \tilde{X}, \\ C_{\text{OP}} &= 2w = \frac{2\tilde{X}}{1 - \gamma}, \\ Q_{\text{CP}} &= p^2 \left[\frac{1}{2}(w - \gamma wp)^\rho + \frac{1}{2}(w - \gamma wp)^\rho \right]^{1/\rho} = p^2 w(1 - \gamma p) = \tilde{X}, \\ C_{\text{CP}} &= 2pw = \frac{2\tilde{X}}{p(1 - \gamma p)}, \end{aligned}$$

similarly to the proof of Theorem 1. Note that the symmetric OP policy is nested in the CP policy given $p = 1$. Hence, the optimal policy is reached by maximizing the denominator of C_{CP} , and the CP policy is optimal whenever $p < 1$. Optimizing $p(1 - \gamma p)$ w.r.t. $p \in (0, 1]$, we get that the optimal probability is $p = \min\{\frac{1}{2\gamma}, 1\}$. Thus, the CP policy is optimal if and only if $\gamma > 1/2$, as needed. \blacksquare

Theorem 3. *Fix $\rho \in (0, 1]$ and $\gamma \in [0, 1]$. There exist two continuously-decreasing functions γ_1 and γ_2 such that the confidential-pay policy is optimal if and only if $\gamma_1(\rho) < \gamma < \gamma_2(\rho)$. Moreover, the symmetric observable-pay policy is optimal if and only if $\gamma \leq \min\{\gamma_1(\rho), \gamma_2(\rho)\}$; and the asymmetric observable-pay policy is optimal if and only if $\gamma \geq \max\{\gamma_1(\rho), \gamma_2(\rho)\}$.*

Proof. The computation for $\gamma = 0$ is trivial, showing that a symmetric OP policy is optimal. Thus, we consider $\gamma \in (0, 1]$. Differing from Theorem 2, we also need to consider a non-symmetric OP policy where one agent receives a positive wage of w , while the other receives nothing. The expected cost and production from such a policy are $Q_{\text{OP-Asym}} = \left[\frac{1}{2}(w - \gamma \cdot 0)^\rho + \frac{1}{2} \cdot 0 \right]^{1/\rho} = \frac{w}{2^{1/\rho}} = \tilde{X}$ and $C_{\text{OP-Asym}} = w = 2^{1/\rho} \tilde{X}$. Recall, from Theorem 2, that the symmetric OP policy yields an expected cost of $C_{\text{OP-Sym}} = \frac{2\tilde{X}}{1-\gamma}$. On the other

hand, the expected production and cost of a CP policy, where a wage of w is paid w.p. $p > 0$, are given by

$$\begin{aligned} Q_{\text{CP}} &= p^2 Q(w - \gamma wp, w - \gamma wp) + 2p(1 - p) Q(w - \gamma wp, 0) \\ &= p^2 w(1 - \gamma p) + 2p(1 - p) \frac{w - \gamma wp}{2^{1/\rho}} \\ &= wp(1 - \gamma p) \left[p + 2^{1-1/\rho}(1 - p) \right] = \tilde{X}, \end{aligned}$$

and $C_{\text{CP}} = 2pw = \frac{2\tilde{X}}{(1-\gamma p)[p+2^{1-1/\rho}(1-p)]}$. In case $\rho = 1$, we get $C_{\text{CP}} = \frac{2\tilde{X}}{1-\gamma p}$, and the asymmetric OP policy is superior for every $\gamma > 0$. Thus, define $\gamma_1(1) = \gamma_2(1) = 0$, and henceforth assume that $\rho \in (0, 1)$.

First, we study the function $h_{\gamma,\rho}(p) = (1 - \gamma p) [p + 2^{1-1/\rho}(1 - p)]$. Denote the probability that maximizes $h_{\gamma,\rho}$ (and minimizes C_{CP}) by $P_{\gamma,\rho}$. Since $h_{\gamma,\rho}(p)$ is a parabolic function, it follows that $P_{\gamma,\rho} = 1$ if and only if $h'_{\gamma,\rho}(1) \geq 0$. The sign of $h'_{\gamma,\rho}(1) = 1 - 2^{1-1/\rho} + \gamma(2^{1-1/\rho} - 2)$ is crucial for our analysis since the symmetric OP policy is embedded in the CP policy, and the policies coincide in case $P_{\gamma,\rho} = 1$.

Define $\gamma_1(\rho)$ based on the indifference curve $h'_{\gamma,\rho}(1) = 0$. The LHS of $h'_{\gamma,\rho}(1) = 0$ is continuous and decreasing in γ and ρ , so every feasible (γ, ρ) above the curve maintains $h'_{\gamma,\rho}(1) < 0$ such that the CP policy is superior to the symmetric OP policy, as needed. The properties of $h'_{\gamma,\rho}(1)$ along with the values $\gamma_1(0) = 1/2$ and $\gamma_1(1) = 0$ assure that the function γ_1 is well-defined and continuously-decreasing.

We move on to γ_2 . The asymmetric OP policy is (weakly) superior to the CP policy if and only if $2^{1/\rho-1} h_{\gamma,\rho}(P_{\gamma,\rho}) \leq 1$. A computation of $P_{\gamma,\rho}$ yields $P_{\gamma,\rho} = \frac{2^{1/\rho-1} - 1 - \gamma}{2\gamma(2^{1/\rho-1} - 1)}$. In case, $\gamma \geq 2^{1/\rho-1} - 1$, it follows that $P_{\gamma,\rho} \leq 0$, which means that positive wages are not distributed and production is impossible. Thus, any (γ, ρ) above the curve $\gamma = 2^{1/\rho-1} - 1$ is irrelevant for a CP policy, and we can henceforth restrict ourselves to the area below the curve.

Denote $t = 2^{1-1/\rho}$, and plug $P_{\gamma,\rho} = \frac{1-t-t\gamma}{2\gamma(1-t)}$ into the function $2^{1/\rho-1} h_{\gamma,\rho}(p)$:

$$\begin{aligned} 2^{1/\rho-1} h_{\gamma,\rho}(P_{\gamma,\rho}) &= 2^{1/\rho-1} [1 - \gamma P_{\gamma,\rho}] \left[2^{1-1/\rho} + P_{\gamma,\rho}(1 - 2^{1-1/\rho}) \right] \\ &= t^{-1} \left[1 - \gamma \frac{1-t-t\gamma}{2\gamma(1-t)} \right] \left[t + \frac{1-t-t\gamma}{2\gamma(1-t)} (1-t) \right] \\ &= t^{-1} \left[1 - \frac{1-t-t\gamma}{2(1-t)} \right] \left[t + \frac{1-t-t\gamma}{2\gamma} \right] \\ &= t^{-1} \left[\frac{1}{2} - \frac{-t\gamma}{2(1-t)} \right] \left[\frac{t}{2} + \frac{1-t}{2\gamma} \right] \\ &= \frac{1}{4} \left[1 + \frac{t\gamma}{1-t} \right] \left[1 + \frac{1-t}{t\gamma} \right]. \end{aligned}$$

Thus, $2^{1/\rho-1} h_{\gamma,\rho}(P_{\gamma,\rho}) = 1$ iff $\frac{t\gamma}{1-t} = 1$. The last equality translates to $\gamma = 2^{1/\rho-1} - 1$, which is exactly the curve that defines the non-positive probability-restriction $P_{\gamma,\rho} = 0$.

Define $\gamma_2(\rho) = 2^{1/\rho-1} - 1$ and note that $\gamma_2(0.5) = 1$, $\gamma_2(1) = 0$. We now need to show that below the curve, the CP policy is superior to the asymmetric OP policy. Given $p > 0$, the function $2^{1/\rho-1}h_{\gamma,\rho}(p)$ is point-wise decreasing in ρ and γ . Thus, the function $2^{1/\rho-1}h_{\gamma,\rho}(P_{\gamma,\rho}) = \max_{p \in (0,1]} [2^{1/\rho-1}h_{\gamma,\rho}(p)]$ is decreasing in both arguments, by virtue of an envelope argument. Let $S = \{(\gamma, \rho) \in [0, 1]^2 : 2^{1/\rho-1}h_{\gamma,\rho}(P_{\gamma,\rho}) \leq 1\}$ be the set of points (γ, ρ) such that asymmetric OP policy is superior to the CP policy. Hence, for every $(\gamma, \rho) \in S$, it follows that $(\gamma', \rho') \in S$ where $\gamma' \geq \gamma$ and $\rho' \geq \rho$. By the continuity and the monotonicity of $2^{1/\rho-1}h_{\gamma,\rho}(P_{\gamma,\rho})$, we establish that γ_2 is continuously-decreasing and, given ρ , the CP policy is optimal if and only if $\gamma_1(\rho) < \gamma < \gamma_2(\rho)$, as required. Note that the second part of the theorem follows directly from the definition of γ_1 and γ_2 . \blacksquare

Theorem 4. *In the case of perfect complements and given a positive transaction cost, there exists a weakly-decreasing function, $\frac{1}{2} \leq \gamma(T) < 1$, such that for every $\gamma > \gamma(T)$ there exists no observable-pay policy equilibrium. Moreover, there exists $T^* > 0$ such that for every $T \geq T^*$ and every $\gamma > \gamma(T^*)$, a confidential-pay policy equilibrium exists.*

Proof. We begin our proof with the first part of the theorem. Fix $T > 0$ and a symmetric profile of OP policies where workers' expected utility is \tilde{U} . As mentioned, wage compression is evident under OP policies, which guarantees ex-post stability and eliminates the second constraint of the optimization problem. Moreover, the first constraint must be binding as one would increase w to maximize the goal function. Thus, we can extract $w = \frac{1-\gamma}{4}$ and plug into the expected utility to get

$$\mathbf{E}[U(e, w; w_p)] = \frac{1-\gamma}{4} + \frac{(1-\gamma)^4}{32}.$$

The latter is a non-negative decreasing function w.r.t. γ , such that $\lim_{\gamma \rightarrow 1} \mathbf{E}[U(e, w; w_p)] = 0$.

We shall prove that any firm has a profitable deviation by constructing a specific CP policy. For that purpose, consider a policy of two wage levels, 0 and w , w.p. $1-p$ and p , respectively. The stability problem, subject to the mentioned profile, is

$$\begin{aligned} \max_{w > 0, p \in [0, 1]} \quad & wp + p \frac{(w - \gamma wp)^2}{2}, \\ \text{s.t.} \quad & 0 \geq 2wp - [p^2(w - \gamma wp)]^{1/2}, \\ & T \geq \tilde{U}. \end{aligned}$$

Henceforth assume that the first constraint is binding. Notice that this problem incorporates a (limited) CP regime and, without loss of generality, any optimal OP policy. Again, we can extract $w = \frac{1-\gamma p}{4}$ and plug into the expected utility to get

$$\mathbf{E}[U(e, w; w_p)] = \frac{p(1-\gamma p)}{4} + \frac{p(1-\gamma p)^4}{32}.$$

Denote the last function by $G(p, \gamma)$, such that $G(1, \gamma) = \tilde{U}$. Note that $G(p, \gamma)$ is a polynomial in p and in γ on a compact set $[0, 1]^2$, so it is uniformly bounded and a solution exists.

If $G(1, \gamma) > T$, then the second constraint of the limited CP problem cannot hold. Therefore, a necessary condition for deviating is $G(1, \gamma) \leq T$. Moreover, if $G(1, \gamma) < T$ and the problem above dictates an optimal probability $p_\gamma < 1$, then there exists a CP policy that dominates the optimal OP policy. A sufficient condition for $p_\gamma < 1$ is $\frac{\partial G(1, \gamma)}{\partial p} < 0$. Evidently, $\frac{\partial G(p, \gamma)}{\partial p} = \frac{1-2\gamma p}{4} + (1-\gamma p)^3 \left[\frac{1-5\gamma p}{32} \right]$, and the condition holds for $\gamma \geq 0.5$.

We are left with the problem of estimating γ such that $G(1, \gamma) < T$. The function $G(1, \gamma)$ is decreasing in γ , and $G(1, 1) = 0$. Hence, for every $T > 0$, we can define a value $\gamma_T < 1$ such that the inequality $G(1, \gamma) < T$ holds if and only if $\gamma > \gamma_T$. The monotonicity of $G(1, \gamma)$ suggests that γ_T also decreases in T , until T is sufficiently large such that $\gamma_T \leq 0$. Define the function $\gamma(T) = \max\{0.5, \gamma_T\}$. For every $\gamma > \gamma(T)$, the optimal probability is bounded away from 1 and the optimal OP policy falls short of the upper bound T , proving the existence of a CP policy superior to the optimal OP policy, as needed.

We turn to the second part of the theorem, proving the existence of a symmetric CP policy equilibrium, given a fixed finite number of bounded wage levels. We do so by solving the problem while (momentarily) ignoring the second constraint of ex-post stability. The assumptions over wages impose a compact set in the euclidean space, while the objective function is continuous, and a solution exists for every $\gamma \geq 0$. Denote the workers' maximal expected utility (uniformly for all possible values of γ) by \tilde{U} , and consider a profile of policies where all firms follow the same optimal policy. Fix $T^* = \tilde{U}$ such that the second constraint holds uniformly for every γ . Clearly, all firms are optimizing w.r.t. the given problem, and no firm has an incentive to deviate, establishing an equilibrium. In addition, the first part of the theorem shows that for $\gamma > \gamma(T^*)$ the optimal policy is not OP policy, and $\gamma(T)$ is weakly decreasing in T , so the statement holds for every $\gamma > \gamma(T^*)$ and every $T > T^*$, as needed. ■