# Collective Wages and Incentive Contracts: On the Role of Envy and Worker Diversity*

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**Abstract**

In many countries, collective agreements tend to equalize wages across workers in the same sector and job. We analyze the impact of imposing wage equality on incentive contracts and firms' hiring policies. In our setting, an employer considers hiring two envious workers who differ only in their productivities. The employer offers the workers incentive contracts with identical fixed wages and potentially individualized bonuses. In this environment, we highlight the interaction between worker characteristics, optimal incentive contracts, and the employer's hiring policy. We find that, when the collective wage does not constrain the employer, fixed-wage equality implies bonus equality. Moreover, once the workers' sensitivity to disadvantageous inequality becomes sufficiently high, the optimal contract deters the low-productivity worker from accepting it, even if productivity differences between the workers are small. Finally, where the agreed-upon fixed wage binds the employer, bonus pay is tailored to the workers' productivity. In that case, the presence of social preferences allows the employer to exploit the intrinsic incentives arising from the workers' relative-income concerns. Furthermore, in this scenario, it is more likely that both workers will be hired.

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# 1 Introduction

In many countries, wages are set through collective bargaining. Such agreements are typically sectoral, whereby employers and labor unions agree on wage scales that may depend on occupational category, professional attributes, skill levels, and the like.[1] The agreed-upon standard wages usually serve as a lower bound, with actual wages often exceeding this level, resulting in a "wage cushion" (Cardoso and Portugal, 2005; Card and Cardoso, 2022). Nevertheless, in the majority of European countries, actual wages closely adhere to the standard wage across all workers subject to the agreement.[2] Card and Cardoso (2022, p. 7) point out that, in the US, "a union contract specifies a grid of wages for different jobs, and *all workers in the same job receive the same pay*"(italics in the original).

Notwithstanding the standardized wage schedules typical of collective wage agreements, legislators in many countries explicitly stipulate that such agreements may contain productivity-related variable-pay components. For example, in Germany work councils are explicitly allowed to set bonus schemes in collective wage agreements.[3] As evidenced by a recent surveys of the International Labour Organization (ILO), such institutional arrangements are in fact relevant also in a variety of countries with very different economic environments (International Labour Organization, 2023). For instance, in a highly industrial nation like Sweden, "[a]round two-thirds of white-collar workers in the private sector are covered by collective agreements with significant possibilities for performance related pay"(International Labour Organization, 2023, p. 87).[4] But also in a developing economy like Tunisia, "[f]or most workers [...], base wage plus guaranteed allowances and bonuses add up to practically the whole of regular take-home pay"(International Labour Organization, 2023, p. 93)

Motivated by these observations, we develop a stylized principal-agent model with moral hazard to study the impact of collective-wage agreements on firms' internal wage and hiring policies in the presence of a heterogeneous workforce. More specifically, we consider the labor relation between an employer who must adhere to a uniform base-wage standard and two workers working in close proximity to one another. These workers have identical social preferences, displaying *envy* towards each other's realized monetary pay-

[1]See, e.g., Bhuller et al. (2022) and Jäger et al. (2024). For the U.S., see https://www.opm.gov/policy-data-oversight/labor-relations/collective-bargaining-agreements. For France, see https://www.service-public.fr/particuliers/vosdroits/F78 or https://www.casd.eu/en/source/statistical-database-of-firms-collective-agreements.

[2]See Fig. 4 in WSI Collective Agreement Archive (2022) and Figs. 1, 3 in Delahaie et al. (2015) and Jäger et al. (2024), Fig. 4, particularly for Germany and Portugal.

[3]See https://www.gesetze-im-internet.de/betrvg/__87.html. For the general legal framework, see, e.g., Paragraph 87 of the German co-determination law. Another example is the UK, where a collective bargaining agreement allows an employer to retain sole discretion over the timing and amounts of, and reasons for, bonuses paid to employees (https://uk.practicallaw.thomsonreuters.com/w-018-0802?transitionType=Default&contextData=(sc.Default)&firstPage=true). For the specific regulation applied to public universities in Germany, see the 2002 reform of the Higher Education Act.

[4]For further studies on performance-related pay in the public sector, encompassing a broad set of countries, see also OECD (2005) and Hasnain et al. (2012). In addition, there is a broad variety of country- and industry-related studies on performance pay in the context of collective-wage agreements.

offs.[5] However, they differ in their respective non-contractible yet observable contributions to output.[6] The employer aligns objectives by means of individual incentive (bonus) contracts under the constraints that the fixed-wage component must be equal across workers and meet at least a collectively agreed-upon level.

We separately consider two scenarios, one in which the agreed-upon collective base-wage does *not* constrain the contract design beyond the requirement that it equally applies to both workers, and a second case where it does. We show that in the first case, the employer can extract rents from the workers, yet the equal-wage constraint compels her to also offer *identical* bonuses notwithstanding the workers' productivity differences. Since the *same* fixed wage must be used to extract *both* workers' information rents, the optimal contract entails an effort-distortion cost. In particular, the contract elicits suboptimal effort from the higher-productivity worker which is not fully compensated by the lower-productivity worker's supra-optimal effort. In addition, the workers' social preferences encompass agency costs related to the so-called *inequality* (or *envy*) *premium.* To avoid these costs, the employer may find it beneficial to design the optimal contract in a way that entices only the high-productivity worker to participate, thereby leaving the lower-productivity one unemployed. Accordingly, the optimal hiring policies in this environment depend on the interaction between the workers' social preferences and their productivity differences. If envy between workers is intense and hence entails large envy-premium costs, then imposing fixed-wage equality may prompt the employer to abstain from hiring the lower-productivity worker even when productivity differences are relatively minor. Substantial productivity differences between workers have the same effect even when envy is not that predominant.

When the agreed-upon lower bound on the fixed wage *effectively binds* the employer, the picture changes dramatically. As long as both workers earn a rent, fixed-wage equality is automatically attained. Under this circumstance, for "moderate" levels of envy, bonuses generally differ across workers in correspondence with their different productivities, raising the prospective pay inequality. This allows the employer to exploit the *incentive effect of envy* to elicit higher efforts from both workers. However, once envy is sufficiently intense, it becomes optimal to equalize the contracts across workers despite their productivity differences and the remaining informational rents. This continues to be the case once envy becomes intense enough to dissipate the (common) informational rents. Eventually, the scenario reverts to the previous one, where the optimal fixed wage exceeded the collectively agreed level and the optimal contracts were identical. However, under a binding collective wage, the employer is much more tolerant of envy than in the non-binding scenario. Intu-

[5]In line with most of the related literature we use the notion of "envy", which invokes an emotional interpretation. Some (including our own) papers use the more neutral notion of "inferiority aversion".

[6]Specifically, the productivity differences may depend on the employer's production technology, the workers' inherent skills or their abilities. While the workers' productivities are assumed to be known to the employer, they may or may not be fully transparent to the workers. To set ideas, consider programmers who are hired to write pieces of a code. Unlike his or her peers, the employer can typically assess a programmer's potential contribution to the final software most accurately and in advance. Similar scenarios apply in many productive environments such as health care, providers of social services, and the like.

itively, in the former case, employing only the high-productivity worker requires leaving him or her information rents, rendering this option much less attractive.

Previous theoretical work has investigated the impact of social (or other-regarding) preferences in the firm context using agency models with ex-post asymmetric information, yet its focus was on homogeneous workers (see, e.g., Bartling, 2011; Bartling and von Siemens, 2010; Demougin et al., 2006; Englmaier and Wambach, 2010; Grund and Sliwka, 2005; Kragl and Schmid, 2009; Neilson and Stowe, 2010). While most of this literature disregards financial constraints, a few earlier studies analyze the effects of liability limits on optimal incentive contracts for homogeneous workers with horizontal social preferences (Demougin and Fluet, 2003, 2006; Kräkel, 2016), thereby recognizing the profitable impact of envy in the presence of informational rents. This exact effect is also present in our companion paper (Kragl et al., 2023), where we employ a similar environment but with homogeneous workers. There we show that envy and the incentives it creates are key for the optimal design of organizations including wage-transparency policies.

Moral-hazard models that consider productivity differences among workers and within teams typically disregard social preferences.[7] An exception is Manna (2016) who employs an agency model with ex-ante asymmetric information to study the effects of envy towards boss and colleagues in a setting where workers differ with respect to their privately known productivity type. In the context of horizontal social preferences, Caserta et al. (2021) and Distefano (2024) also analyze an adverse-selection model where workers (but not the employer) are aware of their mutual skill differences and engage in surplus comparisons. Barigozzi and Manna (2020) use a screening model with differently productive workers to study how envy affects labour donation in mission- oriented organizations. Related to our setting with moral hazard, Awaya and Do (2022) recently study the impact of equal-pay constraints on work efforts, albeit in a different context where incentives are related to subjective peer evaluations.

Empirically, the relevance of other-regarding preferences has been manifested in many studies, specifically through the emergence of peer effects. These have been shown to positively impact productive efforts and outcomes in various environments. Particularly pronounced are such effects under circumstances that are consistent with the presence of envy.[8] In our setting, it is the combination of social preferences and productivity differences that allows us to highlight how these features interact and how this interaction affects firms' optimal incentive contracts and hiring policies.

The remainder of the paper is organized as follows. In the next section, we present our economic environment. As a benchmark, in Section 3, we briefly discuss the scenario with symmetric information and self-regarding agents. Then, in Sections 4 and 5, we introduce the workers' and employer's respective optimization problems. In Section 6, we analyze the case where the collective wage does not constitute a binding constraint. In Section 7,

[7] In a perfect-information environment, Stark and Hyll (2011) identify a positive effect of envy for low-productivity workers.

[8] For a detailed discussion of this literature, see our complementary paper, Kragl et al. (2023).

we turn to the alternative case where it does. We discuss possible deviations from some of our main assumptions in Section 8. Finally, Section 9 presents conclusions and suggests some empirical and policy implications.

## 2 The Model

Consider a one-period environment in which a risk neutral employer (she) may employ one or two risk neutral workers (he), $i = H, L$, to perform a productive task. The workers differ only in their productivity $\theta_i$, whereby $\theta_H > \theta_L$. These productivity factors are observed by the employer.[9]

If employed, a worker's individual non-verifiable contribution to output, $Y_i$ depends on that worker's productivity as well as his privately known productive effort denoted by $e_i \in [0, \bar{e}]$, as follows:[10]

$$Y_i = \theta_i e_i \tag{1}$$

For both workers, effort cost is equally represented by an increasing and strictly convex function, $c(\cdot)$, with $c(0) = 0$, $c'(\cdot) > 0$, $c''(\cdot) > 0$. By imposing identical effort-cost functions, here we take the stand that attitudes towards hard work are universal and independent of individual productivity.

If employed, workers are in general other-regarding, as represented by worker $i$'s utility function:

$$U_i(W_i, W_j, e_i) = W_i - c(e_i) - \alpha \max\{W_j - W_i, 0\},\ i, j = H, L,\ i \neq j, \tag{2}$$

where $W_i$ and $W_j$ represent the workers' respective ex-post publicly known *total* wages. The parameter $\alpha \geqslant 0$ represents a worker's sensitivity to (disadvantageous) inequality, in the sequel referred to as the *intensity of envy*. Accordingly, the last term of the utility function reflects that worker's disutility associated with learning that his wage is lower than his co-worker's.

Two remarks on our utility specification are in order. Firstly, note that, in our formulation, income comparisons involve *only* ex-post realizations of gross-of-effort-cost wages. This represents the idea that social comparisons are based on ex-post *observables* rather than private information or beliefs. Accordingly, since effort is private information, workers do not consider the associated cost in their social comparison.[11] Secondly, we model the intensity of envy as being independent of the productivity difference. While this simplification may not always correspond to reality (see Breza et al., 2017), evidence shows that envy is pronounced also (and specifically) when workers are aware of such skill differences

[9] Clearly, this assumption rules out adverse selection scenarios.

[10] As our focus is on the effects of the exogenous standard-wage restriction, we abstract from productive synergies across these workers. In a complementary paper, we consider a setting with social preferences that encompasses productive synergies (see Kragl et al., 2023).

[11] Applied to the programmers' example in Footnote 6, it is a worker's contribution to the final software that varies rather than his effort cost.

(see, e.g., Ben-Ze'ev, 1992; Kim and Glomb, 2014). Furthermore, it is not self-evident that workers can well assess each other's skills, in particular when productivity differences are not the result of idiosyncratic "technical abilities" but rather stem from "soft" skills such as the ability to process information, patience, and the like (see, e.g., Deming and Silliman, 2024). In this sense, our formulation may be considered as an upper bound of the disutility generated by envy between heterogeneous workers.[12]

If unemployed, a worker's utility is set to be zero and no social comparison takes place. This reflects our focus on social comparisons that arise *within* organizational units where co-workers are the relevant reference group.[13]

Total output accrues to the employer and is given by:

$$Y = \delta_H Y_H + \delta_L Y_L = \delta_H \theta_H e_H + \delta_L \theta_L e_L, \tag{3}$$

where $\delta_i \in \{0, 1\}$ indicates whether a worker is employed ($\delta_i = 1$) or not ($\delta_i = 0$). While efforts and contributions to output are not verifiable, workers generate an individual, effort-related, verifiable signal, generically denoted by $s_i \in \{0, 1\}$, where the probability of observing a *favorable* signal is given by:

$$\Pr[s_i = 1|e_i] = p(e_i), \tag{4}$$

with $p(\cdot) \in [0, 1]$, $p(0) = 0$, $p(\bar{e}) = 1$, $p'(\cdot) > 0$, $p''(\cdot) \leqslant 0$.[14]

This specification is a common way of relating effort to some verifiable proxy thereof. Intuitively, in the programmers' example in Footnote 6, suppose that the employer can observe the number of coding mistakes made by a programmer. In that context, a favorable signal ($s = 1$) would emerge, say, when the programmer makes no mistake. Naturally, this is more likely to happen as a programmer increases effort (see Demougin and Fluet, 2001, p. 1749).

The signal is used by the employer to (potentially) individually align the workers' incentives, but the fixed wage must be identical for both. Accordingly, each worker is offered an incentive contract $(w, b_i)$, consisting of an *identical* fixed wage, $w$, and a potentially productivity-dependent bonus, $b_i$, paid when $s_i = 1$.

[12] In fact, appropriately rescaling the $\alpha-$parameter in our model would capture situations where envy is a decreasing function of worker heterogeneity. In Section 8.3, we discuss how our results extend to this case and further elaborate on the relation between productivity, output, and effort cost.

[13] There is plenty of evidence regarding the importance of social and physical proximity for the formation of reference groups. As noted by Obloj and Zenger (2017, p. 1), "the more proximate socially, structurally, or geographically are those to whom one socially compares, the larger the behavioral response."For an alternative specification in a very different economic environment, where social comparison occurs within a societal context, see Bental and Kragl (2021).

[14] Notice that observing each others' signals is observationally equivalent to our setting where workers observe each others' wage payments. In fact, workers are often aware of events triggering bonus payments within their collegial reference group even if they don't observe the actual payment. For example, in the context of university professors, colleagues tend to be aware of each other's progress on the publication process (e.g., R&R), research grants, or teaching evaluations.

The timeline of the model is as follows. First, the employer proposes each worker $i$ a publicly known take-it-or-leave-it contract, $(w, b_i)$. Then the workers decide whether to accept or reject the contract. When a worker accepts his contract, he privately chooses effort $e_i$. Otherwise, he obtains the alternative utility of zero. Finally, the employer obtains the output and pays the wages according to the contract.

## 3 Benchmark

As a benchmark, we consider the case where effort is contractible and agents are *self-regarding* ($\alpha = 0$). Under this circumstance and absent any exogenous wage constraint, the employer offers workers $H$ and $L$ individual contracts specifying the respectively optimal effort levels $e_H^*$ and $e_L^*$ and the associated wages $w_H^*$ and $w_L^*$ paid when the contracted effort is performed. Formally, the contract satisfies:

$$\begin{aligned} \max_{w_H, w_L, e_H, e_L} \quad & \theta_H e_H + \theta_L e_L - w_H - w_L \\ s.t. \quad & w_H \geq c\left(e_H\right) \\ & w_L \geq c\left(e_L\right) \end{aligned} \tag{0}$$

The optimal wages $w_H^*$ and $w_L^*$ compensate the workers exactly for their effort costs. The first-order conditions are then given by:

$$\begin{aligned} c'\left(e_H^*\right) = \theta_H \\ c'\left(e_L^*\right) = \theta_L \end{aligned} \tag{5}$$

Consequently, the *first-best solution* is obtained, in which the employer induces different effort levels corresponding to the workers' *marginal* productivities, i.e., in the optimal contract $e_H^* > e_L^*$ and, accordingly, $w_H^* > w_L^*$.
Imposing an *equal-wage constraint*, $w_H = w_L$, immediately implies that effort levels are equalized and satisfy:

$$c'\left(e^*\right) = \frac{\theta_H + \theta_L}{2} \tag{6}$$

This means that the employer implements a *uniform* effort level associated with the workers' *average* productivity. Note that, unlike in the moral-hazard scenario analyzed below (Subsection 6.1), this result would arise particularly in the presence of envy ($\alpha > 0$).

In the remainder of the paper, we turn to the moral-hazard case where effort is not contractible and an equal-wage constraint exists.

## 4 Workers' Problems

Consider a generic worker $i = H, L$, where workers $j$ is his co-worker Provided both workers accept their respective contract, each faces the following contingent payoff matrix:

| | $s_j = 0$ | $s_j = 1$ |
|---|---|---|
| $s_i = 0$ | $w, w$ | $w, w + b_j$ |
| $s_i = 1$ | $w + b_i, w$ | $w + b_i, w + b_j$ |

Accordingly, for given $(w, b_i, b_j)$ and given co-worker effort $e_j$, worker $i$ chooses effort $e_i$ to maximize expected utility:

$$\max_{e_i} \; w+p(e_i)\,b_i-c(e_i)-\alpha\left[p(e_j)\left(1-p(e_i)\right)b_j+p(e_i)\,p(e_j)\max\{(b_j-b_i),0\}\right], i \neq j \quad (7)$$

Given the equality-constraint on the fixed wage, the maximization problem (7) reflects two possible realizations of the signal pair $(s_i, s_j)$ where the envy element of worker $i$'s utility becomes (potentially) effective: first, when $(s_i = 0, s_j = 1)$ so that worker $j$ obtains the bonus but worker $i$ does not, and second, when $(s_i = 1, s_j = 1)$, i.e., both workers obtain the bonus, provided that $b_j > b_i$. The corresponding first-order condition associated with problem (7) is:[15]

$$p'(e_i)\,b_i - c'(e_i) - \alpha\left[-p(e_j)p'(e_i)\,b_j + p'(e_i)\,p(e_j)\max\{(b_j-b_i),0\}\right] = 0 \qquad \text{(IC)}$$

In the sequel, we identify worker $j$ with the high-productivity worker $H$ and worker $i$ with the low-productivity worker $L$. Note that, with $\theta_H \geq \theta_L$, the employer will never find it optimal to set $b_H(e_H, e_L) < b_L(e_H, e_L)$ and induce $e_H < e_L$ (see the proof of Proposition 2 in the Appendix). Accordingly, $b_H(e_H, e_L) \geq b_L(e_H, e_L)$, which implies from condition (IC):

$$\begin{aligned} b_L(e_H, e_L) &= \frac{c'(e_L)}{p'(e_L)(1+\alpha p(e_H))} \\ b_H(e_H, e_L) &= \frac{c'(e_H)}{p'(e_H)} - \alpha p(e_L) b_L(e_L, e_H) \end{aligned} \qquad \text{(ICLH)}$$

In the above system of equations, we have $\frac{\partial b_L(e_H,e_L)}{\partial \alpha} < 0$ and $\frac{\partial b_H(e_H,e_L)}{\partial \alpha} < 0$. Accordingly, the respective bonuses required to induce a given level of effort are decreasing in the workers' propensity for envy. Analogously, ceteris paribus, higher intensities of envy induce workers to exert greater efforts in an attempt to avoid *not* earning the bonus. For the case of homogeneous workers, these implicit work incentives emerging from workers' social preferences are well known as the *incentive effect of envy* (see, e.g., Grund and Sliwka, 2005; Demougin and Fluet, 2006; Kragl and Schmid, 2009).

[15] Note that the second-order conditions are satisfied for both workers.

Finally, worker $L$ participates if the contracts $(w, b_L)$ and $(w, b_H)$ together with the effort levels $(e_H, e_L)$ satisfy:

$$w + p(e_L) b_L - c(e_L) - \alpha [p(e_H)(1 - p(e_L)) b_H + p(e_L) p(e_H)(b_H - b_L)] \geq 0 \qquad \text{(PCL)}$$

Similarly, worker $H$ accepts if:

$$w + p(e_H) b_H - c(e_H) - \alpha p(e_L)(1 - p(e_H)) b_L \geq 0 \qquad \text{(PCH)}$$

The above constraints show that, when a constraint is binding and $\alpha > 0$, the employer needs to compensate the workers for the prospects of pay inequality to induce participation. The respective last terms in the workers' expected utilities then represent the *envy premium.* In the agency literature considering homogeneous workers, this extra wage cost is known as the *inequality premium* and is shown to reduce optimal efforts and profits under unlimited liability (see, e.g., Grund and Sliwka, 2005; Demougin and Fluet, 2006; Kragl and Schmid, 2009).

## 5 Employer's Problem

In the following, we introduce the employer's profit-optimization problem, again initially assuming that both workers are employed, i.e., $\delta_H = \delta_L = 1$, and that $b_H \geq b_L$.

$$\begin{aligned} \max_{w, b_H, b_L, e_H, e_L} \quad & \theta_H e_H + \theta_L e_L - 2w - p(e_H) b_H - p(e_L) b_L \\ s.t. \quad & \text{(ICLH), (PCH), (PCL),} \\ & w \geq \bar{w} \qquad \text{(CW)} \end{aligned} \qquad \text{(I)}$$

According to problem (I), the employer needs to consider the incentive-compatible bonuses defined by the equation system (ICLH) as well as the participation constraints (PCL) and (PCH). The last constraint (CW) prescribes the lower bound on the workers' contractual (equal) fixed salary imposed by the collectively agreed-upon wage, which we denote by $\bar{w}$.

In the following, we solve this problem for two scenarios. In the first one (Section 6), $\bar{w}$ is sufficiently low so that (CW) is slack and can hence be ignored.[16] Below we refer to this scenario as a *non-effective collective wage.* In the alternative scenario, analyzed in Section 7, we turn to the case where condition (CW) gets binding, i.e., the collective wage $\bar{w}$ is *effectively* constraining the fixed wage set by the employer at least when $\alpha = 0$.

[16] Note that, to keep the model simple, we postulated a zero outside option for the workers in (PCH) and (PCL) and initially do not impose non-negativity on $\bar{w}$. Consequently, in the model, constraint (CW) can be slack only if $\bar{w}$ is negative. This should be regarded as a normalization which can obviously be adjusted by assuming a sufficiently large outside option relative to $\bar{w}$.

# 6 Non-Effective Collective Wage

In this section, we assume that the lower bound on the fixed wage which the employer must meet, $\bar{w}$, is slack, i.e., the employer can extract rents from workers. In other words, the fixed wage emerging from the optimal contract is sufficiently large to meet the collectively agreed-upon fixed wage.

The employer chooses $(w, b_H, b_L)$ in order to maximize expected profit subject to (ICLH), (PCH), and (PCL):

$$\Pi(e_H, e_L, w, b_H, b_L, \delta_H, \delta_L) = \delta_H \theta_H e_H + \delta_L \theta_L e_L - \delta_H (w + p(e_H) b_H) - \delta_L (w + p(e_L) b_L) \quad (8)$$

Note that the employer may find it optimal to choose a contract structure that induces only worker $H$ to participate. In the next subsection, we focus on the case where both workers accept the contract, i.e., $\delta_H = \delta_L = 1$. Thereafter, we analyze the employer's optimal hiring decision, i.e., we reconsider whether and under which circumstances hiring both workers is optimal in the first place.

## 6.1 Incentive Contracts

To derive the optimal incentive contracts, we solve the employer's problem (I), assuming that condition (CW) is slack. The solution, formalized in the following proposition, shows that an employer who finds it optimal to hire both workers offers them the *same* incentive contract despite their different productivity levels.

**Proposition 1** *Suppose that the collective wage $\bar{w}$ is such that condition (CW) is slack. Let the employer be faced by the triplet $(\alpha, \theta_H, \theta_L)$ and suppose that inducing both workers to participate is optimal. Then i) neither worker earns a rent and ii) the employer offers both of them the same incentive contract $\left(w^U, b^U\right) = \left(w\left(\alpha, \theta_H, \theta_L\right), b\left(\alpha, \theta_H, \theta_L\right)\right)$.*

**Proof.** See Appendix. ■

The intuition of the above result can be best explained starting with self-regarding workers ($\alpha = 0$). In particular, imposing fixed-wage equality implies that the employer cannot attain the first-best outcome even in this case (see Section 3). From the employer's perspective, any attempt to extract the rent of one worker requires that, at the optimum, the other worker's rent must also be extracted. To see this, note that as the workers' effort-cost functions are identical, condition (IC) entails that extracting both rents forces the employer to offer identical bonus schemes. Accordingly, instead of inducing different efforts reflecting the workers' *marginal* productivities (see equation system (5) in Section 3), the employer implements a uniform effort level associated with the workers' *average* productivity, coinciding with the corresponding benchmark case (see equation (6)). In that case, the low-productivity worker works "too much" while the high-productivity worker's effort is "too small". Notably, the presence of envy exacerbates effort distortions. In particular, the *envy premium* increases the employer's wage cost (see the second line of the employer's problem (II) in the Appendix) and prompts the employer to induce *lower* efforts for *both* workers, resulting in reduced profits.

As a result of the above distortions, the employer may find it optimal to forgo the services of the low-productivity worker if the productivity of his peer is sufficiently larger or when envy plays a significant role. This is analyzed in the next subsection.

## 6.2 Profits and Hiring Decision

Above we have considered the case where hiring both workers ($\delta_L = 1$ and $\delta_H = 1$) is optimal. We now analyze whether, from the employer's viewpoint, hiring one or both workers is optimal in the first place. By hiring just one worker, the employer avoids the agency costs arising from the workers' social preferences (envy premium). Furthermore, the loss arising from the effort distortion induced by the identical contracts disappears. It is therefore obvious that, if only one worker is to be hired, then it will be the high-productivity one. As we show below, hiring just the high-productivity worker becomes optimal when either $\alpha$ is sufficiently large or the productivity advantage of that worker is sufficiently pronounced. In this case, the employer's problem reduces to the generic moral-hazard problem with one (possibly envious) worker, where envy becomes however irrelevant. To illustrate the effects of envy and productivity differences on the optimal profits and the ensuing hiring decision, we make use of a parametric analysis and graphical depiction.[17]

To simplify the exposition, we assume that even when only one worker is hired, that worker's optimal fixed wage still exceeds the lower wage bound $\bar{w}$. The associated optimal profits and the ensuing hiring decision are illustrated in Figure 1 where the horizontal lines represent the employer's profits when hiring only the high-productivity worker, for $\theta_H = 3$ (lower line) and $\theta_H = 5$ (upper thick line).[18] The downward-sloping curves show the profits, as functions of $\alpha$, for the scenario analyzed above, where both workers are employed, holding $\theta_L = 2$ in both cases. Altogether, the solid curves depict the optimal profits, $\Pi^U(\theta_H, \theta_L)$, incorporating the optimal hiring decision while the dashed curves represent the respective sub-optimal profits, $\pi^U(\theta_H, \theta_L)$, resulting from the non-optimal hiring decision. As can be seen, for the lower value of $\theta_H$ the employer finds it optimal to keep both workers as long as $\alpha < \alpha^c(3, 2)$. Once the intensity of envy exceeds that value, it is better for the employer to forgo the services of the $L$-worker.[19] For the higher value

[17]The parametric environment used for all figures specifies $c(e_i) = -(\ln(1 - e_i) + e_i)$ and $p(e_i) = e_i$, $e_i \in [0, 1], i = H, L$.

[18]Throughout the paper, in our discussion regarding the effects of envy and worker heterogeneity, we vary the productivity of the high-productivity worker while keeping that of the low-productivity worker fixed. Analogous results emerge in the reverse case.

[19]Notice that, at $\alpha^c(\theta_H, \theta_L)$, there is a discontinuity in the optimal fixed wage, whereby the fixed wage offered to the $H$-worker falls below the one offered to both workers. Recall that we assumed the lower-wage bound to remain slack also for the former fixed wage. If this were not the case, the following section shows that the employer would be forced to leave the high-ability worker some rent. As a result the horizontal line would shift down, move $\alpha^c(\theta_H, \theta_L)$ to the right, and make the employer more tolerant toward envy.

of $\theta_H$ the critical envy intensity is reduced to $\alpha^c(5,2)$ since the benefit of employing only the $H$-worker has increased.[20] As a matter of fact, increasing $\theta_H$ further would imply that even at $\alpha = 0$ the employer prefers to employ only the high-productivity worker.

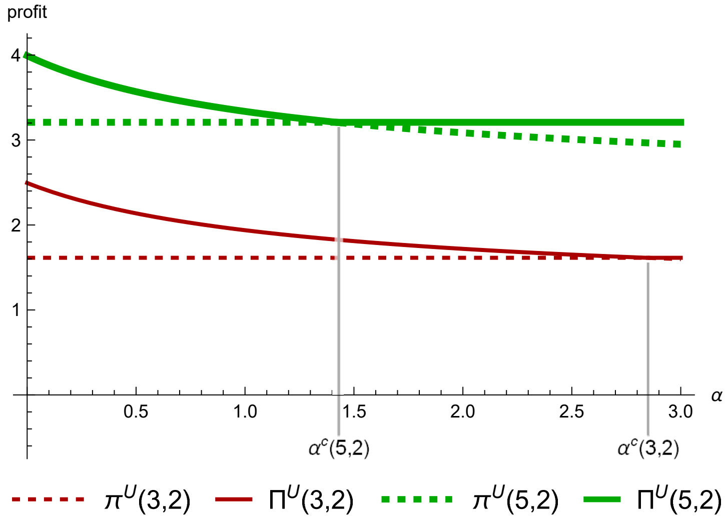


Figure 1: Optimal Hiring under a Non-Effective Collective Wage

## 7 Effective Collective Wage

In this section, we analyze the case where the lower bound on the joint fixed wag $\bar{w}$ may be constraining the optimal contract, i.e., condition (CW) in the employer's problem (I) may be binding.[21]

For simplicity, in the remainder, we set $\bar{w} = 0$. Notice that, consistent with Footnote 16, constraint (CW) is then binding in the *absence* of social preferences ($\alpha = 0$), and Proposition 1 no longer holds. Instead, workers earn information rents when $\alpha = 0$ and beyond.[22] As shown in the following, the optimal contractual and hiring structures are in this scenario dramatically different from those under a non-effective collective wage. In particular, they depend on the difference in workers' productivities and the intensity of envy. In the sequel, we first analyze the impact of these parameters on the workers' rents and thus the employer's wage costs and then derive the optimal incentive contracts. Subsequently, we study the employer's profits and determine the optimal hiring decision under an effective collective wage.

[20] The values are $\alpha^c(3,2) = 1.43$ and $\alpha^c(5,2) = 2.85$.

[21] For evidence, see Footnote 2. In the context of our hypothetical programmers' example (Footnote 6), it seems that, at least in Germany, collective wages may also effectively be binding for IT workers (see https://www.igmetall.de/tarif/besser-mit-tarif/tarif-wirkt-it-ler-bekommen-erstmals-einheitlich-mehr-gel).

[22] As is well-known, in the presence of lower-wage constraints such rents may arise under moral hazard because workers have private information on their actions; see, e.g., Laffont and Martimort (2002, Ch. 4.3).

## 7.1 Incentive Contracts and Information Rents

Reconsider problem (I) and initially assume that $\alpha = 0$. The employer's problem is then equivalent to a scenario with two separate independent workers. As is well-known, the optimal fixed wage is then zero and workers earn positive information rents. Technically, in that case, conditions (PCH) and (PCL) are slack while condition (CW) is binding. Unlike in the case of a non-effective collective wage, the workers' different productivities induce the employer to offer them *different* incentive contracts in this case. When $\alpha > 0$, workers interact via their other-regarding preferences, and the corresponding optimal incentive contracts depend on the specific productivities of workers and their propensity to envy. In particular, the contracts reflect the emergence and dissipation of workers' rents, illustrated in Figure 2.

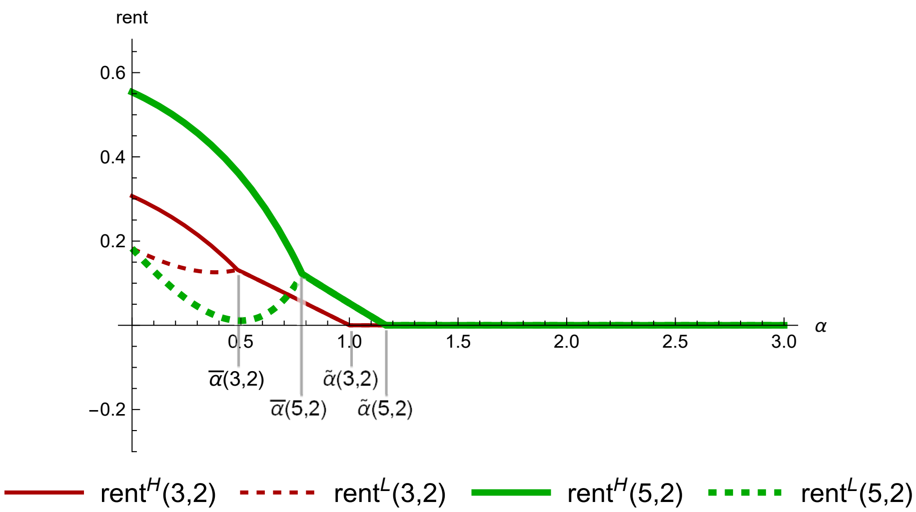


Figure 2: Worker Rents under an Effective Collective Wage

Using the functional specification of Footnote 17 and the parameters underlying Figure 1, Figure 2 plots the workers' rents whereby the low-productivity worker ($\theta_L = 2$) is matched with different high-productivity workers. In particular, the thick (outer) curves refer to the case of large productivity differences ($\theta_H = 5$) while the thin (inner) curves represent the case when productivities are more similar ($\theta_H = 3$). In either case, the solid curves depict the rents for the respective high-productivity worker and the dashed curves those of the low-productivity worker. Notice that the curves for *both* workers depend on the match combination. In particular, the low-productivity worker's rent is much smaller when paired with a $\theta_H = 5$-worker (thick dashed curve) as compared to being paired with a $\theta_H = 3$-worker (thin dashed curve).[23] Once envy is sufficiently intense, at $\overline{\alpha}(\theta_H, \theta_L)$ both

[23] As is evident from Figure 2, reducing $\theta_L$ pushes the rent of the $L$-worker down. In particular, for $\theta_H = 5$, if $\theta_L$ is sufficiently small, for some value of $\alpha$ the $L$ -worker's rent become negative, in which case that worker would not participate. In such cases, the employer is forced to adjust the $L$ -worker's contract to keep the rent at 0. This constraint on the $L$ -worker's contract affects also the $H$-worker. Eventually, as $\alpha$ continues to increase, the $L$-worker's rent becomes positive and the situation reverts to the one shown in Figure 2. To keep the figure easy to read, we focus on the case where rents of both workers are positive throughout.

workers' rents become equalized. Increasing envy even further reduces both workers' rents until it reaches the level denoted by $\widetilde{\alpha}(\theta_H, \theta_L)$, where rents are simultaneously exhausted. Notably, both of these critical envy propensities are higher when the workers' productivity difference is larger, i.e., $\overline{\alpha}(5,2) > \overline{\alpha}(3,2)$ and $\widetilde{\alpha}(5,2) > \widetilde{\alpha}(3,2)$.[24]

The consequences for the optimal contracts are as follows. As long as rents are present, the optimal fixed wage is identical for both workers at $\overline{w}$. However, when the workers' rents differ, the contracts are *different*, whereby the bonus of the high-productivity worker is larger. Once rents become equal, the contracts become identical too, just as in the non-effective collective-wage case. As discussed in the next subsection, as $\alpha$ increases further, the contracts remain identical, whereby the fixed wage eventually turns positive, and Proposition 1 applies. Proposition 2 formally summarizes the optimal contracts for the cases where rents are positive.

**Proposition 2** *Let $\bar{w} = 0$ and let the employer be faced by the triplet $(\alpha, \theta_H, \theta_L)$ with $\theta_H > \theta_L$. Then, under the optimal contracts, i) at $\alpha = 0$, the high-productivity worker's bonus, effort, and rent are larger than those of the low-productivity worker. Furthermore, under reasonable conditions and provided both workers keep earning rents, ii) there exists a value $\overline{\alpha}(\theta_H, \theta_L) > 0$, such that for $0 < \alpha < \overline{\alpha}(\theta_H, \theta_L)$, the high-productivity worker's bonus, effort, and rent are larger than those of the low-productivity worker and, at $\alpha = \overline{\alpha}(\theta_H, \theta_L)$, the workers' bonus, efforts and rents are equalized. iii) There exists a value $\widetilde{\alpha}(\theta_H, \theta_L) > \overline{\alpha}(\theta_H, \theta_L)$ such that for $\overline{\alpha}(\theta_H, \theta_L) < \alpha < \widetilde{\alpha}(\theta_H, \theta_L)$, the workers' bonuses and efforts are equalized and, at $\widetilde{\alpha}(\theta_H, \theta_L)$, their rents become zero.*

**Proof.** See Appendix. ■

### 7.2 Profits and Hiring Decision

Based on the foregoing discussion of the optimal contracting structures, we now illustrate the effects of envy and productivity differences on the optimal profits and the ensuing hiring decision under an (initially) effective collective wage in Figure 3.

In line with Figure 1, the solid curves in Figure 3 depict the optimal profits, $\Pi^L(\theta_H, \theta_L)$, as functions of $\alpha$ for $\theta_H = 3$ (lower curve) and $\theta_H = 5$ (upper thick curve), keeping $\theta_L = 2$. For the sake of comparison, all figures are drawn for the same range of $\alpha$-values. The dashed curves again represent the sub-optimal profits, $\pi^L(\theta_H, \theta_L)$, which in the given cases correspond to the respective profits generated when only the high-productivity worker is employed. In the given example, it is optimal to keep both workers engaged throughout.[25]

The figure shows the dramatic impact an effective collective wage has on profits. In contrast to the case where the collective wage is ineffective, higher intensities of envy are associated with *higher* profits as long as rents are positive, i.e., $\alpha < \widetilde{\alpha}(\theta_H, \theta_L)$. This

[24]The respective values are $\overline{\alpha}(3,2) = 0.49, \overline{\alpha}(5,2) = 0.78, \widetilde{\alpha}(3,2) = 1.01$, and $\widetilde{\alpha}(5,2) = 1.17$.

[25]If the productivity differential is sufficiently large, the envy premium becomes eventually so high as to annul the advantage of having both workers engaged.

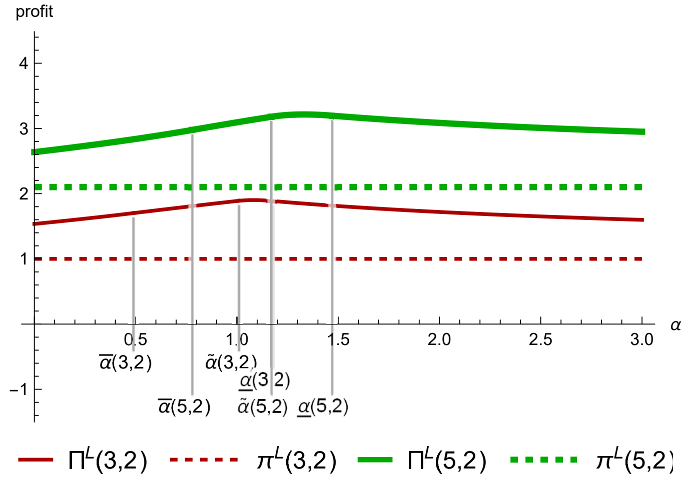


Figure 3: Optimal Hiring under an Effective Collective Wage

reflects the employer's ability to induce higher effort at the expense of the workers' rents (see also Kragl et al., 2023). Intuitively, as explained in Subsection 4, envious individuals work harder for any payment to decrease the chances of falling behind (*incentive effect of envy*). Once rents are exhausted at the respective $\widetilde{\alpha}(\theta_H, \theta_L)$-values, the regime changes. Initially, further increases in $\alpha$ force the employer to offer contracts that respect both the lower bound on the collective wage and the binding participation constraints until $\alpha$ reaches the value $\underline{\alpha}(\theta_H, \theta_L)$.[26] Beyond that point, higher envy is associated with ever increasing envy premia. To satisfy the participation constraints, this leads to positive fixed wages, rendering the collective wage non-effective. In fact, for $\alpha > \underline{\alpha}(\theta_H, \theta_L)$, the (solid) profit curves for the two-worker case in Figure 3 are identical to the ones shown in Figure 1 where the collective wage is never effective in the first place.

Notably, opposite to the case where the collective wage is never effective, the relative advantage of having both workers employed becomes *larger* as $\theta_H$ increases. To understand this result, recall that in either scenario hiring both workers yields exactly the same profit once condition (CW) is no more binding, i.e., when envy becomes sufficiently large ($\alpha > \underline{\alpha}(\theta_H, \theta_L)$). When there is no effective lower wage bound (Figure 1), employing only the high-productivity worker allows the employer to induce the first-best effort of that worker and obtain the corresponding first-best profit. In contrast, under an effective collective wage (Figure 3) employing only that worker entails high information rents, suboptimal effort, and reduced profit. Accordingly, the one-worker option becomes significantly less attractive, thereby making the employer more tolerant towards envy occuring (only) in the two-worker case.[27] Consequently, while under a non-effective collective wage the envy occuring between workers and the high-productivity level are *substitutes* from the employer's viewpoint, they become *complements* under an initially binding collective wage. The foregoing manifests itself as an *increased tolerance towards envy* on the side

[26]The respective values are $\underline{\alpha}(3, 2) = 1.18$ and $\underline{\alpha}(5, 2) = 1.47$.

[27]This property holds also when the cutoff points under an effective lower bound are finite.

of the employer under an effective collective wage. This emphasizes the distinct effects of social preferences, depending on whether the collectiuve wage is effective or not.

# 8 Discussion

In this section, we turn to our main assumptions and discuss whether and to what extent changing some of them might affect our main results.

## 8.1 Different Social Preferences

In line with our model's focus on *envy* there is widespread evidence that envy is of major relevance in the workplace (Vecchio, 2000, 2005; Duffy et al., 2008, 2021). Our preference specification also reflects the widely held view that disadvantageous inequality matters more than advantageous inequality. In fact, Fehr and Schmidt (1999) and many others find envy to be stronger than compassion in the context of inequality aversion (for a meta-analysis, see Nunnari and Pozzi, 2022). Nevertheless, our results extend to broader specifications of other-regarding preferences.

Consider initially the case of *inequality aversion* where workers dislike any deviation from the equitable payoff distribution, i.e., are *both* envious and compassionate. Recall that our main results stem from two particular effects of social preferences on the employer's profits. On the one hand, envy implies inequality-premium costs whenever workers earn no rents. The additional presence of compassion would further enlarge this premium. On the other hand, when workers earn rents, envy implies an incentive effect that may benefit the employer. This effect is still present, though smaller, for inequality averse workers provided that falling behind has a greater utility effect than that of forging ahead.

Similarly, our results extend to the case of *competitive* workers. Such workers still dislike downward deviations from the equitable payoff distribution, yet derive utility from upward deviations. Provided that also in this case disadvantageous inequality has a greater utility effect, such preferences also yield positive, though smaller, inequality-premium costs when no rents are paid (and turn into a discount otherwise). The incentive effect is even stronger for competitive workers. Altogether, the foregoing would clearly make hiring both workers more likely.

## 8.2 Different Sources of Heterogeneity

In our model, the workers' heterogeneity manifests itself only through their productivity differences and consequently their respective contributions to output. Another common way to formalize productivity differences in agency models is through differences in effort-cost functions (see, e.g., Holmström and Milgrom, 1991, and many others). Absent further constraints, this strategy is observationally equivalent to modeling productivity differences in production functions. However, as it turns out, in our setting, the two specifications are quite different. In fact, the consequences of this subtle difference on the optimal contracts in our setting implies that the usual observational equivalence does not hold under all circumstances (see Proposition 1). We consider environments where a worker's particular contribution to output depends on the employer's production technology rather than the worker's inherent skills or abilities. In such a context, we find it more plausible that employers can *ex ante* infer productivity levels, say by screening, rather than be in the position to assess workers' effort cost, which is private information.

Another source of heterogeneity that might emerge from idiosyncratic productivities concerns differences in the workers' outside options. For this to be relevant in our setting, such differences need to be observable by the employer. Should that be the case, a higher outside option of the high-productivity worker would reduce his relative advantage in generating higher profits. Yet the essence of our model results would not be affected. When the collective wage is not binding, such a difference in outside options would entail higher wage costs. In particular, the fixed wage must be adjusted to satisfy the high-productivity worker's outside option, thereby entailing a rent for the low-productivity worker, which cannot be offset by the beneficial incentive effects of envy. When the collective wage is binding, then with a larger outside option, the rent of the high-productivity worker is exhausted for lower intensities of envy than in our setting. As a result, the range of $\alpha$-values for which the employer finds it beneficial to hire both workers is also larger, which makes our discussion above even more likely to apply. In our model, we however abstract from outside-option differences since the general observability of alternative offers is not obvious. In particular, such offers are typically quite firm- and context-dependent and may involve personal considerations and thus private information to various extents.[28]

## 8.3 Productivity Differences and Envy

In the context of the aforementioned rich discussion on the role of envy in the workplace, the question arises whether workers' tolerance of pay differentials may depend on productivity differences. For example, Breza et al. (2017) find that differences in flat daily wages have no negative morale effects when productivity differences are *observed ex ante.* However, even in the context of the simple technologies relevant to that paper, productivity differences turned *not to be observable* by co-workers in some tasks. In that case, pay disparities *do* have significant morale effects.[29] Furthermore, as Deming and Silliman (2024) note, productivity differences may arise due to "soft" skills such as the ability to process information or patience, which are less likely to be observable by co-workers.

How worker awareness of productivity differences might affect social preferences, the perception of pay inequality, and optimal incentive contracts is not straightforward. There is evidence that envy is not only still present if workers are aware of mutual productivity differences but may in fact arise *because of* these differences, leading in some cases workers

[28] An analogous discussion emerges in the literature about switching costs where some benefits characterizing a given economic relationship do not automatically extend to other relationships.

[29] We thank Guido Friebel for raising this issue in the context of the SIOE 2023 conference in Frankfurt.

to sabotage their high-productivity peers (see, e.g. Ben-Ze'ev, 1992; Kim and Glomb, 2014).

Suppose however that, as indicated by Breza et al. (2017), productivity differences increase workers' tolerance towards pay differentials. One way to model this is making workers' propensity for envy a decreasing function of such heterogeneity. In fact, such a formulation would amount to a simple rescaling of our fixed envy parameter representing an accordingly adjusted tolerance for envy. As long as the incentive effect of envy is present, our results would qualitatively carry over. In the limit, where productivity differences are large enough to exclude the peer from a worker's reference group, such a model would revert to the self-regarding case. Notably, this limit case is analogous to perfect wage secrecy or a spatial separation of other-regarding workers, discussed in our companion paper (Kragl et al., 2023).

### 8.4 Workforce Selection

To represent challenges of firms facing a given heterogenous labor force, the workers' productivity distribution is taken as given in our environment. Another interesting question arises when considering how firms select their workforce composition in the first place. Notably, our results imply that, under a binding collective wage, firms may benefit from hiring low- and high-productivity workers jointly because it allows them to exploit the incentive effect of envy. In particular, holding average productivity fixed, increasing the productivity spread between workers increases the range of envy intensities for which the contracts are different, and, in that range, increases profits.[30] When the intensity of envy is sufficiently large, it is envy that is important while the extent of productivity differences turns out to matter little. This insight is one aspect that may contribute to understanding the benefits of a more diverse workforce.[31]

### 8.5 Restricting the Span of Incentive Contracts

Given our model setup without productive synergies, we naturally focus on individual bonus contracts. From a theoretical viewpoint, the employer could in principle offer group bonuses, whereby contingent bonuses are always identical for both workers, thereby avoiding the realization of envy-premium cost altogether. Instead, large rent payments may apply due to the associated freeriding. We disregard such contracts in the current paper because it is *precisely* the behavioral response generated by envy which we are interested in. In fact, as we have shown in Section 7.2, the employer benefits from this particular behavioral response arising only under individual incentive pay. Moreover, in light of the

[30]We thank Simon Dato for suggesting this exercise.

[31]Referring one more time to our programmers' example from Footnote 6, Heath et al. (2023) find that open-source-software projects benefit across a variety of project outcomes when the team increases its diversity.

prominent freeriding issues under group bonuses, individual incentives are the norm rather than the exception in real-world incentive contracts.[32]

## 9 Conclusion

This paper considers employment relationships affected by moral hazard and envy between workers. Employers face a workforce with given heterogeneous productivities. In designing wage contracts, they are constrained by collective agreements that uniformly apply to all workers. These agreements specify a lower bound to workers' fixed wages and moreover standardize the contracts by requiring that fixed wages be equal across workers within one firm.

We first consider a scenario where the collective wage does not constitute a binding lower bound. Then forcing employers to offer standardized fixed wages across differently productive workers prompts them to standardize contracts altogether, that is to also equalize bonuses.[33] As a result, higher-productivity workers are induced to exert "too little" effort, which is moreover not fully compensated by their lower-productivity peers' "too high" effort. To avoid such effort distortion, even in the absence of social preferences, employers find it worthwhile to forgo the services of low-productivity workers when the output contribution of their high-productivity peer is sufficiently large. The presence of envy exacerbates effort distortions because of the additional envy-premium costs arising when both workers are employed. In fact, when workers are envious, employers prefer to hire only high-productivity workers even if the output contribution of their low-productivity peers is quite close. We also show that the impact of social preferences is very different when the common lower-wage bound is effectively constraining the optimal fixed wage. In fact, employers in that case *benefit* from the workers' relative-income concern by exploiting the incentive effect of envy that induces workers to increase effort at the expense of their informational rents. As a result, the presence of social preferences raises the likelihood of both workers being hired.

The envy effects analyzed in our paper have potential empirical implications. Specifically, in our environment, unemployment is more likely when the collective-wage agreement is not effective since, in that case, employers may prefer a more homogeneous workforce to avoid the potential cost related to social comparison and envy. Along the same lines, one would expect employed workers to be more similar in their qualifications when the wage constraint is not effective while higher diversity should be more common when it is. Ceteris paribus, the latter case is more likely to apply in tight labor markets characterized by higher levels of agreed-upon collective wages. This is consistent with the intuition that

[32]See our companion paper for the tradeoffs arising when productive synergies exist and also group bonuses are appropriate and allowed (Kragl et al., 2023).

[33]This finding is consistent with an OECD study showing that wage-setting practices account for the fact that wage inequality is much less pronounced *within* rather than across firms (see OECD, 2021, Ch. 2).

in tighter labor markets employment levels are higher, particularly for low-productivity workers.

The foregoing leads also to potential policy implications. Typically, imposing universal high collective wages is supposed to generate unemployment. By contrast, in our environment the opposite may emerge. As we have shown, effective collective wages encourage employers to hire low-productivity workers and exploit the incentive effect of envy. Accordingly, increasing the power of labor unions to raise collective wages may *reduce* unemployment since some labor markets may switch from situations in which the collective wage was not effective to a situation where it is. In these markets, workers are then paid information rents at the expense of profits, and the aforementioned labor-market effects on diversity and employment emerge.

Finally, we attempt to extrapolate our findings to the societal level. Following the literature, more egalitarian societies (typically European countries) are associated with more envious or inequality averse social attitudes in comparison to, for example, the U.S. (see, e.g., Alesina et al., 2004; Corneo, 2001; Bénabou and Tirole, 2006). Under this interpretation and somewhat paradoxically, for any given productivity distribution and level of the collective wage (effective or not), our model indicates that the detrimental role of envy in the former societies makes them more likely to be characterized by relatively higher unemployment rates.

# Appendix

We start the analysis by stating the following observations:

**Observation 1** $b_H(e_H, e_L) \geq b_L(e_H, e_L)$ *implies* $e_H \geq e_L$.

**Proof.** Using the equation system (ICLH), the assumption can be rewritten as

$$(1+\alpha p(e_H))\frac{c'(e_H)}{p'(e_H)} \geq (1+\alpha p(e_L))\frac{c'(e_L)}{p'(e_L)}. \tag{A.I}$$

The result follows by noting that since $c''(e) > 0$ and $p'(e) > 0$, $(1+\alpha p(e))\frac{c'(e)}{p'(e)}$ is increasing in $e$. ■

**Observation 2** *If* $c(e)$ *is strictly convex, the function*

$$f(e) := p(e)\frac{c'(e)}{p'(e)} - 2c(e) \tag{A.II}$$

*is increasing in* $e$.

**Proof.** The derivative of $f(e)$ can be written as

$$f'(e) = -\frac{p(e)\,c'(e)\,p''(e)}{(p'(e))^2} + \frac{p(e)\,c''(e)}{p'(e)} - c'(e). \tag{A.III}$$

The first element is non-negative. The last two can be expressed as

$$ec''(e)\left[\frac{p(e)}{ep'(e)}-\frac{c'(e)}{ec''(e)}\right], \tag{A.IV}$$

which is positive since the concavity of $p(e)$ implies $\frac{p(e)}{ep'(e)} \geq 1$ and the strict convexity of $c(e)$ implies $\frac{c'(e)}{ec''(e)} < 1$. ■

Using the two observations, we can establish the following.

**Claim 1** *With $b_H(e_H, e_L) \geq b_L(e_H, e_L)$, conditions (PCL) and (PCH) imply:*

$$\begin{aligned} p(e_H) b_H(e_H, e_L) - c(e_H) - \alpha p(e_L)(1-p(e_H)) b_L(e_H, e_L) &\geq p(e_L) b_L(e_H, e_L) - c(e_L) \\ &-\alpha\left[p(e_H)(1-p(e_L)) b_H(e_H, e_L) + p(e_L) p(e_H)(b_H(e_H, e_L) - b_L(e_H, e_L))\right] \end{aligned} \tag{A.V}$$

**Proof.** Rearranging (A.V) and using (ICLH) yields

$$(1+\alpha) p(e_H)\frac{c'(e_H)}{p'(e_H)} - c(e_H) \geq (1+\alpha) p(e_L)\frac{c'(e_L)}{p'(e_L)} - c(e_L). \tag{A.VI}$$

The result follows from Observations 1 and 2. ■

**Claim 2** *Claim 1 implies that the employer sets the wage $w$ sufficiently high to just induce the participation of worker $L$, i.e.,*

$$w = -\left[p(e_L) b_L(e_H, e_L) - c(e_L) - \alpha\left(p(e_H) b_H(e_H, e_L) - p(e_H) p(e_L) b_L(e_H, e_L)\right)\right]. \tag{A.VII}$$

As a result, and using (A.VII), the employer faces the following maximization problem:

$$\begin{aligned} \max_{e_H, e_L} \quad & \theta_L e_L + \theta_H e_H - p(e_L) b_L(e_H, e_L) - p(e_H) b_H(e_H, e_L) \\ & -2\left[c(e_L) - p(e_L) b_L(e_H, e_L) + \alpha\left(p(e_H) b_H(e_H, e_L) - p(e_H) p(e_L) b_L(e_H, e_L)\right)\right] \\ & s.t. \quad \text{(ICLH)}, \text{(A.VI)} \end{aligned} \tag{II}$$

**Proof of Proposition 1.** i) Suppose that, at the optimal contract, condition (A.VI) does not bind. Then the employer maximizes (II) s.t. (ICLH) only. Substituting the latter into the objective function, simplifying, and taking the derivative with respect to $e_L$ yields:

$$\theta_L + \frac{1+\alpha(3+2\alpha) p(e_H)}{1+\alpha p(e_H)} \frac{\partial}{\partial e_L}\left[p(e_L)\frac{c'(e_L)}{p'(e_L)}\right] - 2c'(e_L) \tag{A.VIII}$$

As the coefficient of the derivative in the second term is larger than 1, Observation 2 implies that the expression in (A.VIII) is positive and bounded away from 0. Accordingly, $e_L$ should strictly increase, thereby strictly increasing $b_L(e_H, e_L)$ and strictly decreasing $b_H(e_H, e_L)$. At the point where $b_L(e_H, e_L) = b_H(e_H, e_L)$, $e_L = e_H$, and the wages of both workers become equal, just satisfying the participation constraints, which proves part ii) of the proposition.[34] ■

**Proof of Proposition 2.**

**Preliminaries** Let $\theta_H > \theta_L$ and let $\overline{w} = 0$. Suppose that $w \geq \overline{w}$ is binding. Then the employer's objective is to maximize:

$$\begin{aligned} \Pi := \quad & \Pi\left(e_H, e_L; \theta_H, \theta_L, \alpha\right) = \theta_L e_L + \theta_H e_H - p\left(e_L\right) b_L - p\left(e_H\right) b_H, \text{ whereby} \\ b_L := \quad & b_L\left(e_H, e_L; \theta_H, \theta_L, \alpha\right) = \tfrac{c'(e_L)}{p'(e_L)(1+\alpha p(e_H))}, \\ b_H := \quad & b_H\left(e_H, e_L; \theta_H, \theta_L, \alpha\right) = \tfrac{c'(e_H)}{p'(e_H)} - \alpha p(e_L) b_L\left(e_H, e_L; \theta_H, \theta_L, \alpha\right), \end{aligned}$$

and subject to

$$\begin{aligned} p\left(e_L\right) b_L - c(e_L) - \alpha\left[p(e_H)\left(1 - p\left(e_L\right)\right) b_H + p\left(e_L\right) p\left(e_H\right)\left(b_H - b_L\right)\right] &\geq 0, \\ p\left(e_H\right) b_H - c(e_H) - \alpha p(e_L)\left(1 - p\left(e_H\right)\right) b_L &\geq 0. \end{aligned}$$

Let $e_L^*(\alpha) := e_L^*(\theta_H, \theta_L, \alpha)$ and $e_H^*(\alpha) := e_H^*(\theta_H, \theta_L, \alpha)$ be the maximizers of $\Pi$ and let $\Pi^*(\alpha) := \Pi\left(e_H^*(\alpha), e_L^*(\alpha); \theta_H, \theta_L, \alpha\right)$. Furthermore, let $p_L^*(\alpha) := p\left(e_L^*(\alpha)\right)$, $p_H^*(\alpha) := p\left(e_H^*(\alpha)\right)$, $b_L^*(\alpha) := b_L\left(e_H^*(\alpha), e_L^*(\alpha); \theta_H, \theta_L, \alpha\right)$, and $b_H^*(\alpha) := b_H\left(e_H^*(\alpha), e_L^*(\alpha); \theta_H, \theta_L, \alpha\right)$. Suppose that, at the optimum, the participation constraints are not binding.

Under the above conditions, the second-order conditions require that at $e_L^*(\alpha)$ and $e_H^*(\alpha)$:

$$\begin{aligned} & \Pi^*_{e_L e_L} < 0, \\ & \Pi^*_{e_H e_H} < 0, \\ & \Pi^*_{e_L e_L} \cdot \Pi^*_{e_H e_H} - \left(\Pi^*_{e_L e_H}\right)^2 > 0, \end{aligned}$$

whereby $\Pi^*_{e_L e_L} := \frac{\partial^2 \Pi}{\partial e_L^2}, \Pi^*_{e_H e_H} := \frac{\partial^2 \Pi}{\partial e_H^2}$, and $\Pi^*_{e_L e_H} := \frac{\partial^2 \Pi}{\partial e_L \partial e_H}$.
Furthermore, let $\Pi_{e_L \alpha} = \frac{\partial^2 \Pi}{\partial e_L \partial \alpha}$ and $\Pi_{e_H \alpha} = \frac{\partial^2 \Pi}{\partial e_H \partial \alpha}$.

**Assumption 1** *If* $e_L^*(\alpha) < e_H^*(\alpha)$, *then* $\Pi^*_{e_H e_H} < \Pi^*_{e_L e_L}$.

**Assumption 2** $\Pi^*_{e_L e_H} < 0$.[35]

**Proposition 2 i)** *At* $\alpha = 0$, *the high-productivity worker's bonus, effort, and rent are larger than those of the low-productivity worker.*

**Proof.** Given our assumptions on $c(\cdot)$ and $p(\cdot)$, the results follows immediately from the assumption that $\theta_L < \theta_H$.

[34] A similar argument holds if $c(e)$ is convex (allowing $c''(e) = 0$) but $p(e)$ is strictly concave.

[35] Intuitively, Assumption 1 requires that at larger effort levels the profit becomes "more concave" and Assumption 2 implies that the marginal effect either worker's effort has on profits decreases when the effort of the other worker increases. For the specification used in the paper, Assumption 2 always holds and a sufficient condition for Assumption 1 to hold is $e_H^* > \frac{\alpha - 1}{\alpha}$.

**Proposition 2 ii)** *Provided both workers keep earning rents, there exists a value* $\overline{\alpha}(\theta_H, \theta_L) > 0$*, such that for* $0 < a < \overline{\alpha}(\theta_H, \theta_L)$*, the high-productivity worker's bonus, effort, and rent are larger than those of the low-productivity worker and, at* $a = \overline{\alpha}(\theta_H, \theta_L)$*, the workers' bonus, efforts and rents are equalized.*

**Proof.** Notice that the effect of $\alpha$ on $e_L^*(\alpha)$ and $e_H^*(\alpha)$ is given by:

$$\begin{bmatrix} \frac{de_L^*(\alpha)}{d\alpha} \\ \\ \frac{de_H^*(\alpha)}{d\alpha} \end{bmatrix} = -\frac{1}{\Pi^*_{e_L e_L} \cdot \Pi^*_{e_H e_H} - \left(\Pi^*_{e_L e_H}\right)^2} \begin{bmatrix} \Pi^*_{e_H e_H} & -\Pi^*_{e_L e_H} \\ \\ -\Pi^*_{e_L e_H} & \Pi^*_{e_L e_L} \end{bmatrix} \begin{bmatrix} \Pi^*_{e_L \alpha} \\ \\ \Pi^*_{e_H \alpha} \end{bmatrix}$$

It can be shown that:

$$\begin{aligned} \Pi_{e_L\alpha} &= 2p_H \tfrac{c'_L}{(1+\alpha p_H)^2} + 2p_L \tfrac{c''_L p'_L - c'_L p''_L}{\left(p'_L\right)^2} \tfrac{p_H}{(1+\alpha p_H)^2}, \\ \Pi_{e_H\alpha} &= 2p_L \tfrac{p'_H}{p'_L} \tfrac{c'_L}{(1+\alpha p_H)^2} (1 - \alpha p_H) \end{aligned}$$

**Claim 2.1** $\Pi^*_{e_L\alpha} > 0$ *and as long as* $e_L^*(\alpha) < e_H^*(\alpha)$*,* $\Pi^*_{e_L\alpha} > \Pi^*_{e_H\alpha}$*.*

**Proof.** The first part is obvious, given our assumptions on $c(\cdot)$ and $p(\cdot)$. The second part follows from the assumption that $e_L^*(\alpha) < e_H^*(\alpha)$, implying that at $e_L^*(\alpha)$ and $e_H^*(\alpha)$, $p_H^* > p_L^*$, whereas $p_H^{*\prime} < p_L^{*\prime}$ and $(1 - \alpha p_H^*) < 1$. Moreover, the second element of $\Pi^*_{e_L\alpha}$ is positive.

**Claim 2.2** *Given Assumptions 1 and 2,* $\frac{de_L^*(\alpha)}{d\alpha} > \frac{de_H^*(\alpha)}{d\alpha}$*.*

**Proof.** The result follows from the second-order conditions, the assumptions and claim 1. In particular, $-\Pi^*_{e_H e_H} \cdot \Pi^*_{e_L\alpha} > 0$ and $-\Pi^*_{e_H e_H} \cdot \Pi^*_{e_L\alpha} > -\Pi^*_{e_L e_L} \cdot \Pi^*_{e_H\alpha}$. Furthermore, $\Pi^*_{e_L e_H} \cdot \Pi^*_{e_L\alpha} < 0$ and $\Pi^*_{e_L e_H} \cdot \Pi^*_{e_L\alpha} < \Pi^*_{e_L e_H} \cdot \Pi^*_{e_L\alpha}$.

**Claim 2.3** *By Proposition 2 i) and Claim 2.2, there exists an* $\overline{\alpha}(\theta_H, \theta_L)$ *such that at* $\overline{\alpha}(\theta_H, \theta_L)$*,* $e_L^*(\overline{\alpha}(\theta_H, \theta_L)) = e_H^*(\overline{\alpha}(\theta_H, \theta_L))$*.*

**Proof.** As $e_L^*(0) < e_H^*(0)$ and $e_L^*(\cdot)$ increases strictly more rapidly, or decreases strictly more slowly with $\alpha$ than $e_H^*(\cdot)$, there exists a point $\overline{\alpha}(\theta_H, \theta_L)$ at which $e_L^*(\overline{\alpha}(\theta_H, \theta_L)) = e_H^*(\overline{\alpha}(\theta_H, \theta_L))$, implying the equalization of bonuses and rents.[36] As long as $0 \leq \alpha < \overline{\alpha}(\theta_H, \theta_L)$, $e_L^*(\alpha) < e_H^*(\alpha)$, $b_L^*(\alpha) < b_H^*(\alpha)$ and the high-productivity worker's rent is larger.

**Proposition 2 iii)** *There exists a value* $\widetilde{\alpha}(\theta_H, \theta_L) > \overline{\alpha}(\theta_H, \theta_L)$ *such that for* $\overline{\alpha}(\theta_H, \theta_L) < \alpha < \widetilde{\alpha}(\theta_H, \theta_L)$*, the workers' bonuses and efforts are equalized and, at* $\widetilde{\alpha}(\theta_H, \theta_L)$*, their rents become zero.*

**Proof.** First, note that for any pair of effort levels $(e_1, e_2)$ such that $e_1 > e_2$, it is never optimal to induce $e_L = e_1$ and $e_H = e_2$, since reversing the assignment increases profits while keeping costs at the same level. Accordingly, for any $\alpha$, $e_L^*(\alpha) \leq e_H^*(\alpha)$. Given Claim 2.2, once $\alpha = \overline{\alpha}(\theta_H, \theta_L)$, $e_L^*(\cdot)$ cannot fall below $e_H^*(\cdot)$.

[36] Assuming that $c'/p'$ is strictly convex, is a sufficient condition guaranteeing that $\frac{de_L^*(\alpha)}{d\alpha} - \frac{de_H^*(\alpha)}{d\alpha}$ is bounded away from 0 at $e_L^* = e_H^*$.

Finally, for $\alpha > \overline{\alpha}(\theta_H, \theta_L)$, the (common) rent is given by

$$R^*(\alpha) \quad := \quad p^*(\alpha)\, b^*(\alpha)\left[1 - \alpha\left(1 - p^*(\alpha)\right)\right] - c^*(\alpha)\,,$$

where $c^*(\alpha)$ denotes the effort cost at the optimal effort $e^*(\alpha)$. Accordingly, it can be shown that

$$\frac{dR^*(\alpha)}{d\alpha} \quad = \quad \left[\frac{\theta_H+\theta_L}{2}\left(1-\alpha\left(1-p^*(\alpha)\right)\right) - \frac{1}{(1+\alpha p^*(\alpha))}\right]\frac{de^*(\alpha)}{d\alpha} - p^*(\alpha)\,\frac{c'^*(\alpha)}{p'^*(\alpha)}\frac{1-p^*(\alpha)}{(1+\alpha p^*(\alpha))^2}.$$

Using the employer's FONC under the assumption that both workers provide the same effort and earn rents, it can also be shown that $\frac{de^*(\alpha)}{d\alpha} > 0$. Accordingly, for any $p^*(\alpha) < 1$, a sufficiently large $\alpha$ renders $\frac{dR^*(\alpha)}{d\alpha} < 0$. Consequently $R^*(\alpha)$ becomes negative, which proves the existence of $\widetilde{\alpha}(\theta_H, \theta_L)$. ■

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