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Incentive schemes, private information and the double-edged role of competition for agents[*]

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Abstract

This paper examines the effect of imperfect labor market competition on the efficiency of compensation schemes in a setting with moral hazard, private information and risk-averse agents. Two vertically differentiated firms compete for agents by offering contracts with fixed and variable payments. Vertical differentiation between firms leads to endogenous, type-dependent exit options for agents. In contrast to screening models with perfect competition, we find that existence of equilibria does not depend on whether the least-cost separating allocation is interim efficient. Rather, vertical differentiation allows the inferior firm to offer (cross-)subsidizing fixed payments even above the interim efficient level. We further show that the efficiency of variable pay depends on the degree of competition for agents: For small degrees of competition, low-ability agents are under-incentivized and exert too little effort. For large degrees of competition, high-ability agents are over-incentivized and bear too much risk. For intermediate degrees of competition, however, contracts are second-best despite private information.

JEL Classification: D82, D86, J31, J33

Keywords: Incentive compensation, screening, imperfect labor market competition, vertical differentiation, cross-subsidy

1 Introduction

In a competitive environment, compensation packages in labor contracts include variable pay not only to induce effort, but also to attract the most talented agents. With increasingly globalized markets, firms at varying stages of development and in industries of different maturity compete for highly talented agents. Against this backdrop, our paper examines how the degree of labor market competition between heterogeneous firms affects the design and efficiency of compensation packages.

Specifically, we consider a model where two firms compete to employ a risk-averse agent. The agent faces a moral hazard problem if hired and has private information on her productivity type. Besides, productivity is also firm-specific: We assume that both types of agents have higher productivity in one firm. Firms offer contracts that consist of a fixed wage and a share of the stochastic output in the form of a piece rate. From each firm's perspective, the agent's outside option is the contract offered by the competing firm, which is contingent on the expected output the agent can produce there. Hence, the productivity difference between the firms affects the agent's outside option and therefore captures the degree of labor market competition for agents in a fundamental way. We thus consider a model of competition between vertically differentiated firms for an agent in an environment with adverse selection, moral hazard and risk aversion.

Modelling the degree of competition via the productivity difference between firms allows us to analyze the effect of imperfect competition on the existence and characteristics of equilibrium labor market contracts. We derive two sets of results. With regard to contract characteristics, we find that the efficiency of compensation schemes is hump-shaped in the degree of labor market competition, and that three regions need to be distinguished:

First, for high degrees of competition between firms (i.e., for low degrees of vertical differentiation), the low-productivity agent type's labor contract is second-best efficient, but the piece rate in the high-productivity type's contract is above the second-best rate that equilibrates the inefficiencies of insufficient risk-sharing and insufficient effort at the margin. High types hence bear excessive risk. Standard results from screening with perfectly competing principals thus continue to hold in a region of high, but less than perfect competition. In this region, social welfare decreases in the degree of competition for agents.

Second, if competition for agents is low, the result is reversed: While the high type's contract is second-best efficient, the piece rate in the low type's contract is below the second-best rate. Thus, low types have inefficiently low effort incentives. This extends standard results from monopolistic screening to weak degrees of competition among firms. In this region, social welfare increases in the degree of labor market competition.

Third, for intermediate degrees of competition, the contracts for both agent types are second best. Here, private information on types has no impact, and the compensation contracts are equivalent to the case with only moral hazard and risk aversion. The basic intuition for this result is that second-best contracts differ across types because

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of the agents' risk aversion and differing productivity, and these diverging second-best contracts then fulfill the incentive-compatibility constraints of both types even with private information for intermediate labor market competition. From a normative point of view, our model hence suggests that intermediate labor market competition is optimal. From an empirical perspective, the model implies that incentive contracts become more high-powered when competition for agents gets fiercer.

Since the seminal paper by Rothschild and Stiglitz (1976) on adverse selection with perfect competition among principals, it is well-known that (pure strategy) equilibria may fail to exist when principals have an incentive to offer low agent types more than their expected output in order to reduce the inefficiency in the high types' contracts. As a consequence, most of the literature on competitive screening either assumes exogenous outside options or adds restrictive assumptions to ensure existence of equilibria (see the literature review below). We do not impose any such restriction, and we derive the following second set of results that seem to be novel in this respect.

First, and in contrast to perfect competition, we find that existence of equilibria does not require that offering each type her expected output is an equilibrium response (i.e., that the least-cost separating allocation is interim efficient, see Bénabou and Tirole, 2013). Rather the less productive firm (bad firm, henceforth) may well offer contracts that cross-subsidize the low type with expected output from the high type in equilibrium. While such a best response would impair existence of equilibria with perfect competition, the more productive (good) firm may still have an incentive to attract both agent types in our model. This result is thus a consequence of modelling vertically differentiated firms.

Second, a necessary condition for an equilibrium may be that the bad firm exerts even more competitive pressure on the good firm than with the cross-subsidy strategy just described: In equilibrium, the bad firm may need to offer the low type more than her expected output and the high type exactly her expected output, i.e., in total more than the two types' aggregate expected output. The reason is that, except for cases with particularly low competition, an equilibrium requires that *both* agent types are offered the same utility from both firms, and this may only be feasible if the bad firm offers more than total aggregate expected output to the two types. Again, this result is specific to vertical differentiation between firms.

The equilibrium strategies just described imply that existence of equilibria does not depend on whether the least-cost separating allocation is interim efficient or not. Still, our third result states that equilibria fail to exist for strong degrees of competition between firms when the probability of meeting a high-ability agent is high (which typically leads to the least-cost allocation not being interim efficient). This finding is in fact caused by the subsidizing element in the bad firm's strategy and the ensuing excess utility (i.e., utility beyond her expected output) offered to the low type: A subsidy becomes preferable if the probability of high types in the population is sufficiently large, since the efficiency-enhancing effect from the high type's contract then dominates

in the bad firm's profit function. However, if the good firm is not able to match the excessive utility offered to the low type without making losses, equilibria fail to exist. This scenario becomes more likely when we move towards perfect competition.

Our paper is related to two bodies of literature: The literature on screening with competing principals, and the recent applied work on incentive contracts in competitive labor markets in finance, corporations, academia etc. Regarding the first body of literature, our model combines adverse selection with imperfect competition for agents. A large literature on adverse selection starting with Rothschild and Stiglitz (1976), Wilson (1977), Miyazaki (1977) and Riley (1979) has been devoted to the question of existence of pure-strategy equilibria in models with adverse selection and perfect competition. Our results embed Rothschild and Stiglitz (1976) as a special case since a separating equilibrium requires that the participation constraint of the least efficient agent is binding. This is due to the fact that the agent types (i.e., their productivity levels) enter the firms' payoff functions directly (common values, see Maskin and Tirole, 1992). In models with perfect competition, as mentioned above, equilibrium existence requires that the least-cost separating allocation is interim efficient, so that there is no reason for cross subsidies. To ensure existence of equilibria, additional assumptions such as capacity constraints or other exogenous constraints are therefore usually imposed (see, e.g., Inderst and Wambach, 2001; Schmidt-Mohr and Villas-Boas, 2008) or additional stages where firms can offer or withdraw further contracts are introduced (Hellwig, 1987; Netzer and Scheuer, 2014). We do not resort to such restrictions and show that equilibria may nevertheless exist with imperfect competition.

Two more recent papers also consider competitive equilibria in markets with adverse selection: Tymula (2012) analyzes a model where firms can employ teams of two agents with unobservable ability. Each of the two team members can invest in own tasks and in activities improving the output of her teammate. Under perfect competition, incentive contracts for good types are excessively high-powered.[1] This prevents bad types from imitating and establishes a separating equilibrium, with assortative matching.

Most closely related to our work is the paper by Bénabou and Tirole (2013) who also consider imperfect labor market competition. In their model, horizontally differentiated firms compete in a Hotelling-framework for agents whose abilities are private information and who can perform two different tasks. While the first task is easily measurable, the second is not and contains elements of a public good. Besides abilities, agents also differ in their intrinsic motivation for performing the second task. Bénabou and Tirole (2013) also find that the impact of labor market competition on social welfare is hump-shaped, and that increasing competition for agents leads to excessively high-powered incentives for high-ability types. Since we analyze moral hazard and risk aversion instead of multi-tasking, we obtain a range of degrees of competition where all contracts are second best,

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[1]Also with perfect competition in a multi-task model, Moen and Rosen (2005) demonstrate that incentives may be too high-powered, thereby distorting relative incentives.

while this range shrinks to a point in Bénabou and Tirole (2013).[2] Most importantly, however, Bénabou and Tirole (2013) restrict attention to cases where the least-cost separating allocation is interim efficient, so that existence of equilibria is not an issue in their paper. By contrast, our most interesting equilibria characterizations refer to cases where this assumption does not hold, and where the bad firm's cross-subsidizing strategy determines the good firm's equilibrium contracts.

Related to our results, Jullien (2000) also finds that contracts can be efficient for intermediate types, while underproduction may occur for low types (to prevent high types from imitation) and overproduction for high types (to prevent low types from imitating). He considers an adverse selection model with continuous types and type-dependent reservation levels of utility. However, in his model, the type-dependent reservation levels of utility are given exogenously while they are endogenously derived from competition of vertically differentiated firms in our work.

The more applied work on labour market competition has gained increasing attention in the aftermath of the financial crisis, as a perceived need to offer high bonuses in order to retain "talents" before the onset of the crisis has frequently been followed by a poor actual performance in the financial industry afterwards. Thanassoulis (2011) considers moral hazard with respect to effort and risk-taking in a competitive market equilibrium. Variable payments then take on a double-edged role as they enhance effort and risk-taking incentives at the same time. As we do, he finds that fierce competition leads to inefficiently high-powered incentive contracts, but screening is not an issue in his model as managers learn their abilities only after contracting. In Acharya et al. (2013), agents invest efficiently in the absence of competition for workers, but poaching for talents leads to excessive risk-taking. Their model does not contain asymmetric information on types but focuses on the uncertainty that arises as managers can learn their types only over time.

Bannier et al. (2013) analyze the impact of screening contracts with imperfect labour market competition on risk-taking in portfolio management. They also assume that firms differ in their productivity and find that stronger competition leads to inefficiently high piece rates (or bonuses, in their parlance). However, our paper goes beyond their approach in many important respects: As the positive effects of higher effort are ignored in Bannier et al. (2013), bonuses can only have the negative effect of excessive risk-taking. Thereby, the benefits of higher competition are ignored, and competition is hence never too low. By contrast, one focus of our paper is the intermediate range of competition which is (second-best) optimal. Furthermore, the relationship between cross-subsidies and existence of equilibria, which is the key theoretical contribution of our paper, is not discussed in their paper. Finally, since they assume risk-neutral agents, they need to restrict the contract space by imposing limited liability in order to avoid

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[2]Albeit in a very different framework, Biglaiser and Mezzetti (1993) also find that screening does not lead to distortions in case of intermediate competition. However, competition is defined with respect to the agent types, the low-ability type may choose inefficiently high effort, and a pooling equilibrium arises for intermediate types.

first-best solutions which would otherwise emerge even with perfect competition.

Altogether, this literature supports the prevalent view that competition for agents induces excessively high-powered incentive contracts for sought-after talents. Too strong incentives relate to too much risk-taking in these models, which reduces the efficiency of labor market contracts. Our paper complements this literature by showing in a general setting with moral hazard, private information and heterogeneous firms that unduly high-powered incentives are only obtained for high degrees of competition and do not affect low-ability workers. In turn, we demonstrate that low-ability agents will be under-incentivized for low degrees of labor competition. Our setting with vertically differentiated firms is particularly suited to represent firms that compete at different stages of maturity or scientific and technological sophistication. Examples of such firms may indeed be found in the finance sector, but also in research-intensive areas such as the pharmaceutical industry or academia.

The remainder of the paper is organized as follows: Section 2 presents the model. Section 3 derives the good firms' best response function. Section 4.1 examines key insights into the bad firm's behavior, 4.2 characterizes the equilibria and Section 4.3 discusses the existence of equilibria. Section 5 analyzes the impact of labor market competition. We conclude in Section 6.

2   The model

Firms, agents and productivity.   In our model, two risk neutral firms $k \in \{G, B\}$ compete for a risk averse agent. The agent's ability type $i \in \{H, L\}$ is private information, and is H (high) with probability α and L (low) with probability $1 - \alpha$. The agent's effort e is unobservable, and the output of agent i when working for firm k is $\beta_k \theta_i e + \sigma Z$ where $\sigma > 0$, Z is a standard normally distributed random variable, and $\beta_k \in [0, 1]$ and $\theta_i > 0$ capture the productivity relative to the firm and the agent type, respectively. We assume that $\theta_H > \theta_L$ and $\beta_G = 1 > \beta_B = \beta$. Thus, expected output depends on the agent's type via θ_i, her effort e, and the firm she works for via β_k. The agent's risk aversion is represented by an exponential utility function with constant coefficient of absolute risk aversion ρ. The agent receives a payoff P_i^k, and e^2 is the effort cost that she faces when exerting effort e, so that her utility is $U(P_i^k - e^2) = 1 - \mathbf{e}^{-\rho(P_i^k - e^2)}$.

Competition for agents.   Firms compete for the agent by simultaneously offering take-it-or-leave-it contracts $(F, w) \in \mathbb{R} \times [0, 1]$, where F is a fixed wage and w is a piece rate.[3]   The parameter β introduced above describes a simple form of vertical

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[3]Our model choice essentially follows Holmstrom and Milgrom (1987): Here, an agent controls the drift $\mu(t)$ in the time interval $[0, 1]$ of the process $\mathrm{d}Z = \mu(t)\mathrm{d}t + \sigma \mathrm{d}B$, where B is a standard Brownian motion. The agent is risk averse with constant absolute risk aversion. The principal observes the path $(Z_t)_{0 \leq t \leq 1}$ and compensation takes place at time 1 in form of a sharing rule $s((Z_t)_{0 \leq t \leq 1})$ with the sharing rule agreed at time 0. In this setup, the optimal drift choice is a constant drift μ and the optimal sharing

differentiation between the firms: Both agent types are more productive in the good firm than in the bad firm. As such, β captures the basic ingredient of competition for agents between the two firms. In particular, this modelling choice gives rise to a very simple representation of the two extreme cases of competition: We have perfect competition if $\beta = 1$, while we are in the simple case of monopolistic screening for $\beta = 0$.

Payoffs. Given the firms' compensation schemes, the agent's payoff P_i^k is given by

$$P_i^k := P_i^k(F, w, e) = F + w\left(\beta_k \theta_i e + \sigma Z\right).$$

As the error term Z is normally distributed, it follows from the moment-generating function of the normal distribution that the agent's expected utility is

$$\mathbb{E}\left[U(P_i^k - e^2)\right] = 1 - \mathbf{e}^{-\rho(F + w\beta_k\theta_i e - e^2 - \frac{\rho}{2}w^2\sigma^2)}.$$

Maximizing the agent's expected utility coincides with maximizing her certainty equivalent,

$$U_i^k(F, w, e) := F + w\beta_k\theta_i e - e^2 - \frac{\rho}{2}w^2\sigma^2. \tag{1}$$

The agent's effort choice is given by

$$e_i^k := e_i^k(w) = \operatorname*{argmax}_{e \geq 0}\left\{F + w\beta_k\theta_i e - e^2 - \frac{\rho}{2}w^2\sigma^2\right\} = \frac{1}{2}w\beta_k\theta_i.$$

Inserting into Equation (1) and simplifying yields

$$U_i^k(F, w) := U_i^k\left(F, w, \frac{1}{2}w\beta_k\theta_i\right) = F + \frac{w^2}{4}(\beta_k^2\theta_i^2 - 2\rho\sigma^2) \tag{2}$$

as the agent's certainty equivalent.[4] We define $\widehat{U}_i^k$ as the maximum certainty equivalent agent i can get from firm k, that is,

$$\widehat{U}_i^k := \max_{(F,w)\in\mathbf{\Omega}^k} U_i^k(F, w),$$

where $\mathbf{\Omega}^k$ denotes the set of contracts offered by principal k. Without loss of generality, we introduce the tie-breaking rule that both types accept the good firm's offer if $\widehat{U}_i^G = \widehat{U}_i^B$.

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rule is a linear function of Z_1, Holmstrom and Milgrom (1987, Theorem 7). Sung (2005) shows that the optimal sharing rule remains linear in a setup with moral hazard and adverse selection, see Section 2 and Theorem A.2 of Sung(2005). We therefore implicitly adopt the more involved setup of Holmstrom and Milgrom (1987), and consider a static model as introduced above, with the agent's payoff a linear function of the output. It should be noted, however, that our setting is slightly more general than the setting of Sung (2005) as it will turn out that, due to competition, the agents' reservation utilities are type-dependent in our setting, whereas Sung (2005) considers only the case of type-independent reservation utilities.

[4]In the following, we use the terms certainty equivalent and utility interchangeably.

Note that the marginal utility of the piece rate is higher for the high type, that is, the single-crossing property holds:

$$\frac{\partial^2 U_i}{\partial w \partial \theta_i} = w\beta_k^2 \theta_i > 0. \tag{3}$$

Finally, firm k's expected profit from agent i is

$$\Pi_i^k(F, w) := (1 - w)\beta_k \theta_i e_i^k - F = \frac{1}{2}(1 - w)w\beta_k^2 \theta_i^2 - F. \tag{4}$$

Sequence of events. The game can now be summarized as follows:

- *Stage 0*: Nature chooses the agent's type which becomes private information.

- *Stage 1*: Firms simultaneously offer take-it-or-leave-it contracts to the agent.

- *Stage 2*: Depending on her type, the agent chooses her utility-maximizing contract and her effort.

- *Stage 3*: Profits and payments are realized.

Complete information and the second-best piece rate. For later reference let us first consider the case without private information on types, so that risk aversion and moral hazard are the only concerns. In this case, each firm implements two second-best piece rates, which equilibrate the losses from inefficiently low effort and from insufficient risk-sharing at the margin. For each type, firm k maximizes profits as given in Equation (4) subject to the following binding participation constraint *(PC)* defined by the maximum utility $\widehat{U}_i^{\overline{k}}$ type i could get in the competing firm $\overline{k} \neq k$:

$$F + \frac{w^2}{4}(\beta_k^2 \theta_i^2 - 2\rho\sigma^2) = \widehat{U}_i^{\overline{k}}.$$

After substituting for F and simplifying, we obtain

$$\Pi_i(w) = \frac{1}{2}w\left(\beta_k^2 \theta_i^2 - \frac{w\beta_k^2 \theta_i^2}{2} - w\rho\sigma^2\right) - \widehat{U}_i^{\overline{k}},$$

and maximizing Π_i yields the second-best piece rate $w_i^{k,sb} = \frac{\beta_k^2 \theta_i^2}{\beta_k^2 \theta_i^2 + 2\rho\sigma^2}$. It is easily seen that $w_i^{k,sb}$ increases in the agent's type-dependent productivity θ_i and in the firm-dependent productivity β_k and decreases in the risk-aversion parameter ρ.

Welfare. In our model, different degrees of competition imply different allocations of the generated surplus between firms and workers. For welfare comparisons we apply the concept of Kaldor-Hicks efficiency, i.e., we consider an outcome as more efficient if those who are made better off could compensate those who are made worse off, so that a Pareto improvement could be achieved. We shall see that in any equilibrium, both worker types are employed by the good firm, and at least one piece rate is second-best. Thus, our welfare criterion effectively boils down to the degree of distortion in the piece rate that is not second-best.

3 The good firm's best response

In this section, we derive basic characteristics of the good firm's best response. For the most part, these features follow from general insights on monopolistic and competitive screening and are, therefore, fairly standard. We shall therefore keep our depiction in the text to a minimum while a rigorous proof is given in the Appendix. Those results that form the basis of our main contribution - the analysis of competitive effects between vertically differentiated firms - in Section 5 are summarized in Proposition 1.

In the following, we assume without loss of generality that workers choose the good firm when both firms offer contracts that yield the same expected utility.[5] A firm's best-response function (omitting the firm's index k) to exogenously given reservation utilities $\widehat{U}_L, \widehat{U}_H \in \mathbb{R}_+$ when assuming that the firm attracts the agents in a tie-break is given by

$$\max_{F_H, w_H, F_L, w_L} \Pi(F_H, w_H, F_L, w_L) = \alpha \left(\frac{1}{2}(1 - w_H)w_H \beta_k^2 \theta_H^2 - F_H \right) \mathbf{1}_{\{U_H(F_H, w_H) \geq \widehat{U}_H\}}$$
$$+ (1 - \alpha) \left(\frac{1}{2}(1 - w_L)w_L \beta_k^2 \theta_L^2 - F_L \right) \mathbf{1}_{\{U_L(F_L, w_L) \geq \widehat{U}_L\}}, \quad (5)$$

subject to

- $U_L(F_L, w_L) \geq U_L(F_H, w_H)$ _(ICCL)_,

- $U_H(F_H, w_H) \geq U_H(F_L, w_L)$, _(ICCH)_.

The indicator function $\mathbf{1}_A$ takes value 1 if A holds and 0 otherwise. Hence, the indicator functions above express that an agent type will be hired if the utility offered weakly exceeds the utility proposed by the competitor. This is the case for the good firm by assumption, while the weak inequality in the indicator functions for the bad firm must be replaced by a strict inequality. The incentive compatibility constraints, _(ICCL)_ and _(ICCH)_, ensure that each type picks the contract designed for her.

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[5]This assumption just simplifies the exposition as the good firm would marginally outbid the bad firm anyway due to its productivity advantage.

From each firm's perspective, the utilities offered by the competing firm determine the agents' exit options, and these exit options need to be endogenized in Section 4 in order to derive the equilibrium configurations from both firms' best responses. Both best-response functions are given by Equation (5), but it is worthwhile to consider each of them separately in more detail. For the good firm, we fully specify the best response function by assuming that the good firm hires both agent types, and we will prove later that this is indeed the case in equilibrium. The bad firm's equilibrium behavior is in many respects similar to the case of perfect competition, and even though it will never hire an agent in equilibrium, we will see how the bad firm's behavior influences the equilibrium contracts offered by the good firm.

If the good firm wants to attract both types, its best-response function can be written as[6]

$$\max_{F_H, w_H, F_L, w_L} \Pi(F_H, w_H, F_L, w_L)$$
$$= \alpha \left(\frac{1}{2} (1 - w_H) w_H \theta_H^2 - F_H \right) + (1 - \alpha) \left(\frac{1}{2} (1 - w_L) w_L \theta_L^2 - F_L \right) \quad (6)$$

subject to the following constraints:

- $U_H(F_H, w_H) \geq \widehat{U}_H^B,$ (PCH),

- $U_L(F_L, w_L) \geq \widehat{U}_L^B,$ (PCL),

- $U_H(F_H, w_H) \geq U_H(F_L, w_L),$ (ICCH),

- $U_L(F_L, w_L) \geq U_L(F_H, w_H)$ (ICCL).

The following properties simplify the analysis:

Lemma 1. *In the good firm's best response* $(F_H^*, w_H^*), (F_L^*, w_L^*),$

1. $w_H^* \geq w_H^{sb}$ *and* $w_L^* \leq w_L^{sb}$;

2. *If* $w_L^* < w_L^{sb}$, *then:* (i) $w_H^* = w_H^{sb}$; (ii) (ICCH) *and* (PCL) *are binding, while* (iii) (ICCL) *is non-binding*;

3. *If* $w_H^* > w_H^{sb}$, *then:* (i) $w_L^* = w_L^{sb}$; (ii) (ICCL) *and* (PCH) *are binding, while* (iii) (ICCH) *is non-binding*.

The proof is given in Appendix A.1.

That at least one of the piece rates is second best is explained as follows: If the good firm offers two second-best piece rates and holds both agents on their exit options, the low type has an imitation incentive, whenever

$$U_L(F_H, w_H) > U_L(F_L, w_L) = \widehat{U}_L^B,$$

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[6]In the following, we delete the firm's index k whenever we refer to the good firm but label the bad firm throughout with a B.

which can be rewritten as

$$\widehat{U}_H^B - \frac{\theta_H^4(\theta_H^2 - \theta_L^2)}{4(\theta_H^2 + 2\rho\sigma^2)^2} > \widehat{U}_L^B,$$

i.e., when the difference in the utilities the bad firm offers to the high and low types is sufficiently large. In turn, the high type has an imitation incentive, whenever

$$U_H(F_L, w_L) > U_H(F_H, w_H) = \widehat{U}_H^B,$$

which can be rewritten as

$$\widehat{U}_L^B + \frac{\theta_L^4(\theta_H^2 - \theta_L^2)}{4(\theta_L^2 + 2\rho\sigma^2)^2} > \widehat{U}_H^B,$$

i.e., when the utility difference, $\widehat{U}_H^B - \widehat{U}_L^B$, offered by the bad firm is sufficiently small. If the high type has an incentive to imitate, then there is no reason for the good firm to deviate from the second-best piece rate for the high type (part 2 of the Lemma) and likewise if the low type has an incentive to imitate (part 3 of the Lemma). As usual, the incentive compatibility constraint is binding only for the agent type who has an imitation incentive, and the participation constraint is always binding for the one without imitation incentive. The participation constraint for the type who has an imitation incentive may be either binding or non-binding.

Applying Lemma 1, we can express the good firm's maximization problem as a function of just one variable: the piece rate offered to the type whose (ICC) is slack. The following proposition then shows that the contracts offered by the good firm, in particular the efficiency distortions relative to the second-best piece rates, depend on the *difference* in utilities the two types are offered by the bad firm, not on the actual level of the respective offers. Denoting this difference by $\Delta\widehat{U}^B := \widehat{U}_H^B - \widehat{U}_L^B$, we thus characterize the good firm's best response function in terms of $\Delta\widehat{U}^B$. Essentially, Proposition 1 below states that three situations can arise, depending on the size of $\Delta\widehat{U}^B$: If $\Delta\widehat{U}^B$ is sufficiently small, then the piece rate for the low type is smaller than the second-best piece rate (Region 1); if $\Delta\widehat{U}^B$ is too large, then the piece rate for the high type is greater than the second-best piece rate (Region 3), and in-between, the piece rates for both types are second-best (Region 2). These situations are depicted in Figure 1. Our findings are supported by Jullien (2000), who, in a setting with continuous types, shows that the properties of the best response depend on the steepness of the type-dependent reservation utilities. A formal derivation, detailed expressions for the respective piece rates and the proof of Proposition 1 are given in Appendix A.1.

In the following, let $\Delta\widehat{U}_1^B = U_H(0, w_L^{sb}) - U_L(0, w_L^{sb})$ and $\Delta\widehat{U}_2^B = U_H(0, w_H^{sb}) - U_L(0, w_H^{sb})$.

Proposition 1. *In the good firm's best-response function, the piece rates depend on the utility difference $\Delta\widehat{U}^B$ the two agent types are offered by the bad firm. The following two regions can be distinguished:*
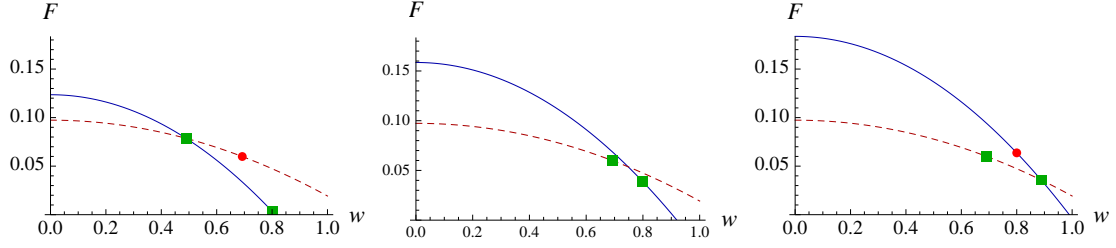
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Figure 1: Best responses of good firm. In each graph, the solid (dashed) line denotes the high (low) type's indifference curve for different combinations of fixed wages and piece rates, given an exit option $\widehat{U}_i^B$. Utilities are greater for points to the northeast of the indifference curves. Rectangles denote contracts from the good firm's best response, a point denotes the second-best contract that is infeasible because of the imitation incentive. Left: Region 1(b); middle: Region 2; right: Region 3(b) of Proposition 1.

Region 1 *If $\Delta\widehat{U}^B < \Delta\widehat{U}_1^B$, then the piece rate for the high type is second best, $w_H^* = w_H^{sb}$, and* (PCL) *is binding. The piece rate for the low type is below second best, $w_L^* < w_L^{sb}$, and determined by:*

(i) *the first-order condition of the good firm's maximization problem, in which case the high type's participation constraint,* (PCH), *is non-binding;*

(ii) *the binding* (PCH) *otherwise.*

Both $\Delta\widehat{U}^B$ and w_L^* are greater in Region 1(b) than in Region 1(a), and w_L^* is strictly increasing in $\Delta\widehat{U}^B$ in Region 1(b). Social welfare is increasing in $\Delta\widehat{U}^B$.

Region 2 *If $\Delta\widehat{U}^B \in \left[\Delta\widehat{U}_1^B, \Delta\widehat{U}_2^B\right]$, then both piece rates are second best.*

Region 3 *If $\Delta\widehat{U}^B > \Delta\widehat{U}_2^B$, the low type's piece rate is second best and* (PCH) *is binding. The piece rate for the high type is above second best, $w_H^* > w_H^{sb}$, and determined by:*

(i) *the first-order condition of the good firm's maximization problem, in which case the low type's participation constraint,* (PCL), *is non-binding;*

(ii) *the binding* (PCL) *otherwise.*

Both $\Delta\widehat{U}^B$ and w_H^* are greater in Region 3(a) than in Region 3(b) and w_H^* is strictly increasing in $\Delta\widehat{U}^B$ in Region 3(b). In Region 3, social welfare is decreasing in $\Delta\widehat{U}^B$.

Region 1 represents the case where the utility difference offered to the low type and the high type by the bad firm is small. In this region, the high type would imitate the

low type when contracting with the good firm if two second-best contracts with binding participation constraints were offered (Figure 1, left). In other words, she would prefer a contract with a lower piece rate than the one actually designed for her.

In order to reduce the high type's imitation incentive, the good firm therefore offers the low type a piece rate below the second-best rate, hence distorting her effort incentive. However, only if $\Delta\widehat{U}^B$ is very small will the offered contracts equilibrate at the margin the loss from the distortion in the low type's contract and the loss from the high type's information rent (Region 1(a)). This is because the firm only benefits from offering an inefficiently low piece rate to the low type as long as this helps to reduce the high type's information rent. Whether or not the participation constraint is binding depends on $\Delta\widehat{U}^B$: The larger $\Delta\widehat{U}^B$, the weaker is the high type's imitation incentive, so that her information rent shrinks. Once *(PCH)* becomes binding for sufficiently high $\Delta\widehat{U}^B$, so that her information rent vanishes, w_L is determined by this binding *(PCH)*-constraint instead (Region 1(b)).[7]

As the low type is under-incentivized throughout Region 1, any increase in her piece rate would increase social welfare. In Region 1(b), w_L^* is indeed increasing in $\Delta\widehat{U}^B$, so that higher $\Delta\widehat{U}^B$ leads to higher welfare. In Region 1(a), in contrast, the high type's participation constraint is non-binding and the low type's piece rate is determined by equilibrating the low type's efficiency loss with the high type's information rent at the margin. The piece rate w_L^* is hence invariant to changes in $\Delta\widehat{U}^B$.

For intermediate values of $\Delta\widehat{U}^B$ (Region 2), neither type can benefit from imitating the other even when both are held on their exit options (Figure 1, middle). Thus, offering two second-best piece rates is compatible with two binding participation constraints. The reason is that the firm will offer different piece rates anyway as the trade-off between effort incentives and risk aversion is type-specific. Thus, in Region 2 inefficiencies arise only from moral hazard and risk aversion, and incomplete information poses no further restrictions.

Region 3 is essentially the opposite of Region 1. Here, the difference in the two types' exit options expressed by $\Delta\widehat{U}^B$ is so high that the low type would imitate if two second-best contracts with binding participation constraints were offered (Figure 1, right). Therefore, the contract for the high type is inefficiently high-powered in order to reduce the low type's information rent. Similar to Region 1, there are two subcases. For very high imitation incentives (large $\Delta\widehat{U}^B$), the low type's participation constraint is non-binding, and the degree of inefficiency hence independent of $\Delta\widehat{U}^B$. Otherwise, the distortion in the high type's contract increases in $\Delta\widehat{U}^B$.

It is worth pointing out what would happen in our model if agents were risk-neutral, that is $\rho = 0$. Then, irrespective of firm type and agent type, all second-best piece rates would be first best, i.e., $w_i^{k,sb} = 1$. In this case, risk-sharing is not an issue,

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[7]Any piece rate below would reduce the efficiency of the low type's contract, but would not allow to offer a lower overall remuneration to the high type. Consequently, the piece rate for the low type is higher in Region 1(b) than in Region 1(a).

since incentives are fully aligned if agents receive their individual outputs, and fixed payments are negative (franchising). As a consequence, Region 2 would collapse to one point, namely where $\Delta \widehat{U}^B = U_H(0,1) - U_L(0,1)$. Thus, the existence of a whole region of (intermediate) degrees of competition, which is immune to adverse selection, can be attributed to agents' risk aversion.

4   Equilibrium

For analyzing the equilibrium configuration, we proceed as follows: In Section 4.1, we discuss properties of the bad firm's best response that hold in equilibrium. Section 4.2 extends to conditions for the equilibrium behavior of both firms and characterizes the set of equilibria. In Section 4.3, we analyze how the existence of equilibria depends on the degree of competition, β, and the distribution of high and low types, expressed by α and $1 - \alpha$, respectively.

4.1   Preliminaries on the bad firm's equilibrium behavior

The bad firm's best response, although in general given by Equation (5), can be made more explicit by taking into account the special role of the bad firm. In contrast to the good firm and similar to the case of perfect competition, the bad firm earns zero expected profit in equilibrium, and will generally compete as fiercely as possible by offering both types at least their full expected output.

When analyzing the bad firm's behavior in the following, we will exclude contracts that offer both types more than their expected output. Such a contract pair is weakly dominated as the bad firm would face losses with either type. Still, these contract offers would be part of an equilibrium as long as the good firm makes weakly positive profits when matching them. When excluding these implausible and weakly dominated strategies, however, we need to avoid elimination of dominated strategies that are limits of undominated strategies. The reason is the same as in the simplest case of Bertrand competition with constant marginal costs: Marginal-cost prices are weakly dominated by all higher prices,[8] but are nevertheless equilibrium strategies as they are limits of undominated strategies, and because one would otherwise destroy the unique equilibrium in pure strategies.

We hence introduce the following assumption:[9]

Assumption 1. *Weakly dominated strategies are excluded, except those that are limits of undominated strategies.*

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[8]With marginal-cost prices, profits are zero regardless of the competitor's behavior. With prices above marginal costs, profits are positive whenever all competitors set higher prices, and zero otherwise.

[9]Simon and Stinchcombe (1995) use the same criterion and call the resulting equilibria *limit admissible*. Limit admissibility is required for infinite games; otherwise one could just exclude all weakly dominated strategies.

The following Proposition summarizes properties of the bad firm's equilibrium behavior, which helps to streamline the analysis.[10]

Proposition 2. *Suppose that, in the good firm,* (PCH) *and* (PCL) *are binding in equilibrium. Then, (i) the bad firm offers the low type a second-best piece rate, while the piece rate in the high type's contract is distorted upwards; (ii)* (ICCLB) *is binding while* (ICCHB) *is non-binding; (iii) the bad firm offers the high type her expected output, and the low type at least her expected output.*

If (PCH) *is not binding, then the bad firm offers the low type a second-best piece rate and at least her expected output. The high type is offered at most her expected output.*

Note first that, when any participation constraints are slack, the bad firm's behavior is not uniquely determined and the best response cannot be characterized in such detail. We show in Section 4.2 that *(PCL)* is in fact binding in equilibrium. [11]

Parts (i) and (ii) of Proposition 2 are well-known from screening with perfect competition: If the bad firm offers two second-best piece rates to the agents and adjusts the fixed wages such that the zero-profit condition holds, the low type will have an imitation incentive. The bad firm therefore offers only the low type her second-best piece rate, but distorts the high type's piece rate upwards to reduce the low type's imitation incentive (part (i), see analogously Region 3 in the good firm's best response where competition is high). Clearly, the low type's incentive compatibility constraint *(ICCLB)* is binding, while *(ICCHB)* is non-binding (part (ii)).

While parts (i) and (ii) are standard results, part (iii) points to a key insight on the bad firm's equilibrium behavior that distinguishes our model with vertically differentiated firms from models with perfect competition, and also from models with horizontally differentiated firms (Bénabou and Tirole, 2013). To develop this insight step by step, define a contract pair with the following features as *least-cost separating allocation* (LCA), see Bénabou and Tirole (2013): Each agent type gets her expected output, the low type's incentive compatibility constraint, *(ICCL)*, holds with equality, so that the distortion in the high type's contract is minimum. Such a contract pair can only be a best response if the LCA is *interim efficient*, that is, if there exists no other incentive compatible contract pair where the firm breaks even and which Pareto dominates the LCA. For perfect competition, it is well-known that equilibria in pure strategies fail to exist if the LCA is not interim efficient, and the same result emerges in our model for $\beta = 1$. In other words, whenever the best response function of a firm

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[10] *(ICCLB)* and *(ICCHB)* refer to the incentive compatibility constraints of the low and the high type, respectively, in the contracts offered by the bad firm.

[11]Further, observe that a non-binding *(PCH)* corresponds to Region 1(a) in the good firm's best response. Here, the equilibrium behavior of the good firm resembles monopolistic screening and, hence, refers only to the case of low competition. In this case, *(PCL)* is binding, which determines the properties of the offer to the low type, while the bad firm's offer to the high type is not uniquely specified, but a contract with the specifications of the first section of the Proposition is contained in the set of best responses.

entails that one agent type is offered more than her expected output, an equilibrium fails to exist. Consequently, Bénabou and Tirole (2013) restrict attention to the cases where the LCA is interim efficient in their model in order to circumvent the problems of existence of equilibrium.

Part (iii) of Proposition 2 states that this is different in our model with vertically differentiated firms since existence of equilibria does not hinge on whether the LCA is interim efficient or not. We first explain why the bad firm may have incentives to offer the low type more than her expected output and, at the same time, the high type exactly her expected output. Of course, this implies that the bad firm would not break even when attracting both types. In the next subsection, we discuss why such a behavior may well be part of an equilibrium, and why there may exist no equilibrium in which both types are offered their output, as would be the case in the LCA.

There are two reasons why the bad firm's best response may entail to offer the low type more than her expected output. Recall that we assume in the first section of Proposition 2 that *(PCH)* and *(PCL)* are binding, so that both agent types get the same utility in either firm. If the LCA is not interim efficient, then the bad firm has an incentive to offer the low type more than her output, since this decreases the distortion in the piece rate for the high type required to avoid imitation by the low type. This *cross-subsidy* then allows the bad firm to offer contracts that yield higher utility for both agent types, and the LCA can thus not be part of the best response when it is not interim efficient.

A second reason arises in Region 3(a) of the good firm's best response function, where *(PCL)* is non-binding (see Proposition 1). Then, the bad firm has the following profitable deviation: It slightly improves its offer to the low type such that she still prefers the good firm. As this reduces the low type's imitation incentive, the bad firm can improve the efficiency in the contract for the high type. And as long as the low type still prefers the good firm (i.e., as long as *(PCL)* is non-binding), the higher efficiency in the high type's contract can be used to increase her utility and earn positive profits at the same time. We shall see shortly that this profitable deviation yields the result that *(PCL)* needs to be binding in equilibrium, and we can now turn to equilibrium characterization by considering the behavior of both firms.

4.2   Equilibrium characterization

Propositions 1 and 2 state properties of the good and bad firms' best response functions, respectively. From this, we can derive the following additional equilibrium properties.

Proposition 3. *In equilibrium, (i) (PCL) is binding; (ii) the good firm employs both types.*

In Section 4.1, we saw that the bad firm has a profitable deviation whenever *(PCL)* is non-binding and that this profitable deviation involves offering the low type more than her expected output. Thus, there is no equilibrium in Region 3(a) of the good

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firms's best response function. Recall that such a subsidy impairs existence of equilibria with perfect competition, in which case equilibria in pure strategies fail to exist if the LCA is not interim efficient. By contrast, with imperfect competition, the subsidy is required in our model whenever *(PCL)* would otherwise be non-binding in the good firm's best response.[12] That *(PCL)* is binding in equilibrium imposes a lower bound on the utility the bad firm offers the low type, and this lower bound may even exceed the low type's utility derived from the cross-subsidy in the interim efficient allocation.

For part (ii) of Proposition 3, recall that in many monopolistic screening models the high type's information rent is eliminated by offering just one contract when the probability of meeting a low type, $(1 - \alpha)$, is below a certain threshold (e.g. Section 2.2 of Salanié, 2005). Thus, it may be surprising that, even when competition disappears, that is for $\beta = 0$, the good firm always hires both types. The reason is as follows: As $(1 - \alpha) \to 0$, the piece rate w_L in the low type's contract converges to 0 as well, and so does hence the high type's information rent since the two types' utilities are the same for $w_L = 0$. Thus, offering two contracts or just one contract yields identical profits for $(1 - \alpha) = 0$, while offering two contracts is strictly superior for $(1 - \alpha) > 0$. In the proof in the Appendix, we show that the claim also holds for $\beta > 0$, because in equilibrium the bad firm will never make an offer to the low type that is unprofitable to match for the good firm.

We are now prepared to turn to a complete analysis of the properties that need to hold in equilibrium. We already know that the bad firm offers both types at least their expected output,[13] cross-subsidizes the low type if the LCA is not interim efficient, and needs to offer the low type a utility such that *(PCL)* is binding in the good firm's best response. These requirements jointly set a *lower bound* on the minimum utility the bad firm offers the low type in equilibrium. At the same time, the good firm's willingness to compete sets an *upper bound*. If the upper bound is below the lower bound, there is no pure-strategy equilibrium, while we have multiple equilibria if it is strictly above.

In order to derive these bounds and the range of equilibria, we need to make the bad firm's best response explicit. In equilibrium, the bad firm's best response satisfies

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[12]This notion of subsidy does not imply that the bad firm breaks even on average with both types (in contrast to the *cross-subsidy*). Rather, it is an "empty" offer to the low type that allows to improve the offer to the high type as long as the bad firm is never called upon this offer.

[13]In the case where *(PCH)* is non-binding (Region 1(a)), such a contract specification is contained in the bad firm's best response set. Since the exact specification of the high type's contract has no effect on the good firm's best response, we take this particular contract specification as given in concrete calculations, but it should be stressed that this has no effect on the good firm's best response, existence of equilibria and impact of competition.

$$U_L^B(F_L^{B,*}, w_L^{B,*}) = \widehat{U}_L^G = \widehat{U}_L^B \tag{7a}$$

$$F_H^{B,*} = \frac{1}{2}(1 - w_H^{B,*})w_H^{B,*}\beta^2\theta_H^2 \tag{7b}$$

$$w_H^{B,*} \text{ such that } U_L^B(F_H^{B,*}, w_H^{B,*}) = \widehat{U}_L^G. \tag{7c}$$

Equation (7a) states that *(PCL)* is binding, $\widehat{U}_L^G = \widehat{U}_L^B$. The expression for $F_H^{B,*}$ in (7b) implies that the high type receives her expected output, and the expression for $w_H^{B,*}$ in (7c) says that *(ICCLB)* is binding. Further, the piece rate for the low type is second best as any other piece rate is weakly dominated.

Summing up, a pure-strategy equilibrium requires that the best responses of the good and the bad firm are simultaneously given by Equation (6) and Equations (7a)–(7c), respectively, and that the good firm's expected profit from each agent is non-negative. We hence need to establish under which conditions the best responses are given by Equation (6) and Equations (7a)–(7c).

For this, we can express an entire equilibrium configuration via one variable, such as $\widehat{U}_L^B$, the utility the low type is offered by the bad firm: Given $\widehat{U}_L^B$, we can determine $\widehat{U}_H^B$ such that the low type does not imitate and such that the high type receives her expected output in the bad firm. The binding *(PCL)* and $\Delta\widehat{U}^B$ then determine the best response by the good firm, which allows us to derive lower and upper bounds for $\widehat{U}_L^B$. Any $\widehat{U}_L^B$ within this range is associated with an equilibrium configuration. The bounds given in Proposition 4 depend only on the model's parameters, and they hence allow to fully characterize the equilibrium configuration. But as they are contingent on all parameters (that is, $\alpha, \beta, \rho, \sigma, \theta_L$ and θ_H), displaying the full expressions is not enlightening in this context.

Proposition 4. *There exist bounds $\underline{U}_L^B$ and $\overline{U}_L^B$ such that $\widehat{U}_L^B \in [\underline{U}_L^B, \overline{U}_L^B]$ gives rise to an equilibrium. Any $\widehat{U}_L^B \notin [\underline{U}_L^B, \overline{U}_L^B]$ does not constitute an equilibrium.*

The minimum utility $\underline{U}_L^B$ the bad firm must offer to the low type is given by

$$\underline{U}_L^B = \min\left[\max\left(\widehat{U}_{L,LCA}^B, \widehat{U}_{L,CS}^B, \widehat{U}_{L,PCL}^B\right), \max\left(\widehat{U}_{L,LCA}^B, \widehat{U}_{L,PCH}^B\right)\right], \tag{8}$$

where

- $\widehat{U}_{L,LCA}^B = \dfrac{\left(w_L^{B,sb}\right)^2}{4}\beta^2\theta_L^2$ *prevents the bad firm from profitably attracting the low type; it follows from the least-cost separating allocation, where each type receives exactly her expected output,*

- $\widehat{U}_{L,CS}^B$ *is derived from the contract that prevents the bad firm from profitably attracting the high type;*[14]

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[14]Subscript "CS" denotes "cross-subsidy".

- $\widehat{U}^B_{L,PCL}$ *is the smallest utility that makes* (PCL) *binding;*

- $\widehat{U}^B_{L,PCH}$ *is the smallest utility that makes* (PCH) *binding.*

The maximum utility $\overline{U}^B_L$ *the bad firm can offer to the low type is given by*

$$\overline{U}^B_L = \min\left(\widehat{U}^B_{L,\max}, \widehat{U}^B_{L,no\ imi.}\right),$$

where

- $\widehat{U}^B_{L,\max}$ *denotes the greatest utility to be offered to the low type that is still profitable for the good firm,*

- $\widehat{U}^B_{L,no\ imi.}$ *is the greatest utility such that* (ICCLB) *is binding.*

As a consequence note that an equilibrium exists only if $[\underline{U}^B_L, \overline{U}^B_L] \neq \emptyset$, that is, if $\underline{U}^B_L \geq \overline{U}^B_L$.

The candidates for the lower bound, $\underline{U}^B_L$, are determined by the minimum utilities the bad firm needs to offer so that the good firm's best response prevents the bad firm from profitably attracting an agent type. The first maximum expression determines the lower bound when *(PCH)* is binding.The second term determines the lower bound when *(PCH)* is non-binding (Region 1(a)).

Assume first that *(PCH)* is binding. Among the boundary candidates, $\widehat{U}^B_{L,LCA}$ is the low type's utility with her second best piece rate when both types receive their expected output. This, however, is the lower bound for an equilibrium if and only if the LCA is interim efficient and if, for these offers, *(PCL)* is binding in the good firm's best response. In this case, the bad firm could attract the low type if it offered a utility smaller than $\widehat{U}^B_{L,LCA}$. The second candidate, $\widehat{U}^B_{L,CS}$, is determined (via the binding *(ICCLB)*) from the contract that prevents the bad firm from profitably attracting the high type (by using the cross-subsidizing strategy explained in Section 4.1). Hence, if $\widehat{U}^B_L$ were smaller than $\widehat{U}^B_{L,CS}$, then the bad firm could profitably attract at least the high type. Finally, if the bad firm offered less than $\widehat{U}^B_{L,PCL}$ to the low type, *(PCL)* would be non-binding in the good firm's best response.

Summing up, the bad firm needs to offer the low type more than her expected output in equilibrium whenever $\underline{U}^B_L$ is not given by $\widehat{U}^B_{L,LCA}$. Which parameter constellations lead to $\widehat{U}^B_{L,LCA}$ being lower than $\widehat{U}^B_{L,PCL}$ or $\widehat{U}^B_{L,CS}$, will be the focus of Section 4.3.

In the case that *(PCH)* is non-binding (Region 1(a)), the minimum utility to be offered to the high type is irrelevant, as she cannot be attracted by a profitable deviation, anyway. Hence, any cross-subsidizing strategy to attract the high type is ineffective, which allows to lower the bound from $\widehat{U}^B_{L,CS}$ either to $\widehat{U}^B_{L,LCA}$ or to the level where *(PCH)* becomes binding.

We now turn to the upper bound for the low type's utility in the bad firm, which we denote by $\overline{U}_L^B$. There are two candidates for this upper bound: $\widehat{U}_{L,\max}^B$ is the maximum utility the bad firm may offer such that the good firm can still earn non-negative profits from the low type. Since this utility level is contingent only on the good firm's zero profit condition, it is independent of both the productivity ratio of the firms, β, and the type distribution, α. Lastly, for any $\widehat{U}_L^B > \widehat{U}_{L,\text{no imi.}}^B$, the low type has no imitation incentive in the bad firm. Then, offering the low type more than total expected output is weakly dominated, so that there can be no equilibrium in which the low type would have no imitation incentive in the bad firm and gets more than her expected output at the same time. Note that the first candidate for the upper bound, $\widehat{U}_{L,\max}^B$, refers to the good firm's behavior, while the second candidate, $\widehat{U}_{L,\text{no imi.}}^B$, refers to the bad firm's behavior.

If $\overline{U}_L^B < \underline{U}_L^B$, there is no equilibrium in pure strategies while for $\overline{U}_L^B > \underline{U}_L^B$ there are multiple equilibria which differ by the utility the bad firm offers to the low type. In order to analyze the impact of equilibrium selection on the good firm's profit and social welfare, we define the excess utility offered to the low type, i.e., $\widehat{U}_L^B - \underline{U}_L^B$, as *competitive pressure*, where $\widehat{U}_L^B \in [\underline{U}_L^B, \overline{U}_L^B]$. The following proposition provides insights into competitive pressure and its relation with the good firm's profit and social welfare.

Proposition 5. *(i) The good firm's profit is decreasing in competitive pressure, i.e., in $\widehat{U}_L^B - \underline{U}_L^B$.*
(ii) A certain competitive pressure may be socially optimal.

For part (i) note that increasing $\widehat{U}_L^B$ reduces the expected profit earned from the low type, but increases the efficiency in the high type's contract. In the proof of Proposition 5, we show that the first effect always dominates, so that the profit is indeed decreasing in competitive pressure. Part (ii) follows directly from the fact that, since $\Delta \widehat{U}^B$ is decreasing in competitive pressure (see Equation (23) in the appendix), it may well be that Region 2 of Proposition 1, where social welfare is greatest, is attained only for some $\widehat{U}_L^B > \underline{U}_L^B$. Hence, for given β, it may be necessary that the bad firm exerts some competitive pressure on the good firm for reaching Region 2.

Let us emphasize that *competitive pressure* refers to the bad firm's choice of $\widehat{U}_L^B$ for given β (and hence to equilibrium selection), whereas the *degree of competition* captured by β is exogenously given in our model. The impact of β on the efficiency of (selected) equilibrium contracts will be examined in Section 5.

4.3 Discussion of equilibrium existence

In this section, we illustrate how existence and efficiency of equilibria depend on the exogenous parameters of the model. Figure 2 gives information about the equilibrium configuration as a function of α (the percentage of high types, on the vertical axis) and β (the degree of competition, on the horizontal axis). In the left graph of Figure 2, the
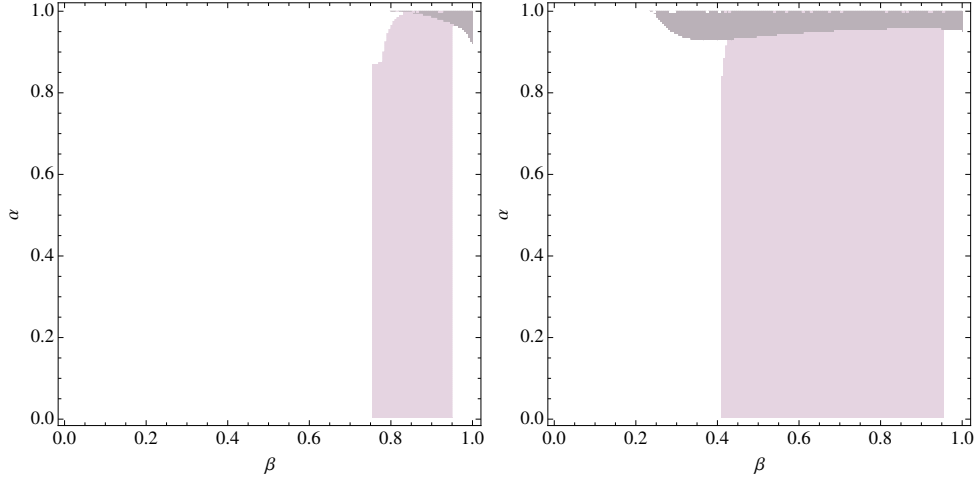
Figure 2: Existence of equilibria for different configurations. Left: $\theta_H = 1$, $\theta_L = 0.5$, $\rho = 1$, $\sigma = 0.2$; right: like left, but $\theta_L = 0.2$. No equilibrium in dark grey area; equilibrium in Region 2 exists in light grey area; equilibrium exists, but none in Region 2, in white area.

low type's productivity is higher ($\theta_L = 0.5$) than in the right graph ($\theta_L = 0.2$), so that the productivity difference between the two types is higher in the right picture.

The graphs show when equilibria exist and when the equilibria are second-best efficient: In the white area, pure-strategy equilibria exist, but not in Region 2 of Proposition 1. In the light grey area, equilibria exist in Region 2, i.e., some equilibria are second-best efficient. In the dark grey area, in contrast, no equilibrium exists.

Figure 2 allows to relate our results readily to screening with perfect competition, to monopolistic screening, and to the results in Bénabou and Tirole (2013) with horizontally differentiated firms. In this respect, recall first that under perfect competition, the unique Rothschild-Stiglitz equilibrium requires that each agent type is offered exactly her expected output.[15]

However, if α is large, so that the proportion of low types is small, then no equilibrium exists, as the LCA is not interim efficient: The principal benefits from reducing the inefficiency in the contract for the high type via a cross-subsidy from the high type to the low type. Figure 2 shows that a similar non-existence result emerges in our model since, when both α and β are high, no equilibrium exists (dark grey areas in the two graphs). Recall, however, that the interim efficiency of the LCA is no requirement for the existence of an equilibrium when firms are vertically differentiated. Rather, if β is sufficiently small, the good firm may still have an incentive to outbid the bad firm. Thus, there may be parameter constellations in our model where equilibria exist even

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[15]In Rothschild and Stiglitz (1976), each firm offers just one contract, but the result carries over to models where both firms offer two contracts.

for high α.

Second, it is well-known from monopolistic screening and from screening with perfect competition that equilibria are inefficient: In the monopolistic case ($\beta = 0$), the high type has an imitation incentive if second-best contracts are offered, and vice versa for the case of perfect competition ($\beta = 1$). This shows also in Figure 2: For both small and large values of β we find only inefficient equilibria (white areas in the two graphs). The equilibria in the white area to the left of the light grey zone are equilibria in Region 1 of Proposition 1. In these equilibria, the contract for the low type is inefficient. The equilibria in the white area to the right of the light grey zone, in contrast, are equilibria in Region 3 of Proposition 1 with inefficient contracts for the high type. The impact of β on the (in)efficiency of these equilibria will be discussed in greater detail in Section 5. Comparing the left and right graphs in Figure 2, it can also be seen that a higher productivity difference between the types (right graph) leads to a smaller zone of equilibria solely in Region 1. This is because a higher productivity difference reduces the high type's imitation incentive. As a consequence, a lower distortion in the low type's piece rate is required for establishing a separating equilibrium, thus broadening the light grey area of second-best efficient equilibria.

Finally, to relate our results on existence and efficiency of equilibria to Bénabou and Tirole (2013), recall that equilibrium existence is no concern in their model as they assume interim efficiency of LCA. While efficient equilibrium contracts arise only for exactly one level of competition in their model, Figure 2 shows a whole region for which private information causes no welfare loss in our model. As has already been laid out in Section 3, the existence of a whole region of intermediate degrees of competition where equilibrium contracts are second-best efficient is caused by our assumption of risk-averse agents.

5   Competition for agents and social welfare

Figure 2 illustrates how existence and efficiency of equilibria depend on the degree of competition for agents, β. In Proposition 1 on the good firm's best response function, we saw how the different regions depend on $\Delta \widehat{U}^B$, the difference in the two types' utility offered by the bad firm. Thus, it remains to show how β translates into $\Delta \widehat{U}^B$, and thereby into the regions of Proposition 1.

Recall first that there are multiple equilibria whenever $\overline{U}_L^B > \underline{U}_L^B$. The properties of these equilibria depend on the utility the bad firm offers to the low type beyond the minimum utility $\underline{U}_L^B$ required for an equilibrium (competitive pressure). Any $\widehat{U}_L^B$ chosen by the bad firm leads to a different equilibrium configuration. Therefore, we need to be consistent in our choice of $\widehat{U}_L^B$ (equilibrium selection) when doing comparative statics with respect to β. We introduce the following assumption:

Assumption 2. *For any β, either the equilibrium with $\widehat{U}_L^B = \underline{U}_L^B$ or the equilibrium with $U_L^B = \overline{U}_L^B$ is played.*

The assumption covers the two extreme cases where $\Delta \widehat{U}^B$ is smallest and where it is greatest (see Equation (19) in the appendix and the analysis following Equation (19)). Since, according to Proposition 1, the contract inefficiencies arise for small and large $\Delta \widehat{U}^B$, these are the two most interesting cases to study further. The impact of β on $\Delta \widehat{U}^B$ is now expressed in the following Lemma:

Lemma 2. *Assume that $\underline{U}_L^B$, resp. $\overline{U}_L^B$, exists in a neighborhood of β, and assume that (PCH) is binding. (i) The difference in the expected utilities the two agent types are offered by the bad firm, $\Delta \widehat{U}^B$, is (weakly) increasing in the degree of competition for agents, $\dfrac{\partial \Delta \widehat{U}^B}{\partial \beta} \geq 0$. (ii) The piece rates offered by the good firm are (weakly) increasing in β, $\dfrac{\partial w_i^*(\beta)}{\partial \beta} \geq 0$.*

Note first that if *(PCH)* is not binding, which corresponds to Region 1(a) in Proposition 1, then the best response of the bad firm is not uniquely determined and therefore a general statement on $\Delta \widehat{U}^B$ is not possible.

The basic reason for part (i) is that the two types' productivity difference in the bad firm, $\beta(\theta_L - \theta_H)$, is increasing in β. For low β, both types are unproductive in the bad firm, so that the difference in their utilities offered by the bad firm is small as well. The higher β, the higher is the two types' productivity difference, which is reflected in their utility difference. The formal proof of part (i) is more involved as the high type's optimal piece rate in the bad firm, w_H^B, also depends on β. So, aside from the change in the productivity difference, determining the impact of β on $\Delta \widehat{U}^B$ requires taking into account the change in the distortion of the high type's contract. For part (ii) of the Lemma, recall that Proposition 1 on the good firm's best response already expresses the connection between $\Delta \widehat{U}^B$ and the piece rates offered by the good firm. Thus, the impact on the piece rates follows immediately from part (i). From Lemma 2, we can now easily derive our main result on the impact of β on regions and social welfare:

Proposition 6. (i) *Let $\beta_0 < \beta$ and suppose that equilibria exist for $\underline{U}_L^B$, resp. $\overline{U}_L^B$, at β_0 and β. Then, the equilibrium at β is in the same or a higher region than at β_0. (ii) Social welfare is increasing in β if the good firm's best response lies in Region 1 of Proposition 1, and it is decreasing in β if the good firm's best response lies in Region 3.*

Proposition 6 summarizes our main insights on the impact of competition for agents on the piece rates and social welfare in case an equilibrium exists (see Figure 2 above): For low β, we are in Region 1, and the downwards distortion in the low type's piece rate decreases in β. Thus, higher labor market competition is beneficial. In Region 2, neither private information nor labor market competition influence social welfare as two second-best piece rates are feasible. In Region 3, higher β increases the upwards distortion in the high type's piece rate and hence reduces social welfare.

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6   Conclusion

We develop a tractable model where two firms with different productivity (vertical differentiation) compete for risk-averse agents by offering contracts with fixed and variable payments. Agents exert unobservable effort and their abilities are private information.

We show that the equilibrium configuration depends crucially on the productivity difference between the two firms, and that three regions need to be distinguished: If the productivity difference between the firms is large (Region 1), then the more productive firm offers a piece rate below the second best to the low type. Thus, effort incentives for the low-ability type are inefficiently small and social efficiency increases in the degree of competition. For intermediate levels of productivity differences (Region 2), two second-best piece rates are offered, and incomplete information has no impact on equilibrium contracts. Moderate degrees of competition hence deliver a maximum of social efficiency despite the fact that ability types of agents are private information. Finally, if the productivity difference between the two firms is sufficiently small (Region 3), the more productive firm offers a piece rate above the second-best level to the high type. Effort incentives are then too high-powered, at the expense of insufficient risk-sharing for the high-ability agent.

Our results support current findings that fierce labor market competition induces inefficiently high-powered incentive contracts (Region 3). Due to severe competition for managerial talent, firms have incentives to offer variable payments to high-ability agents that are above the second-best levels. This result is obtained in our model even without introducing limited liability or externalities, that is, even without the factors that are usually blamed for excessive performance pay, for instance in the financial industry. However, our paper also suggests that labor contracts induce effort incentives that are insufficient in markets where firms have significant oligopsonistic market power. In this case, it is the segment of agents with lowest ability that contribute to the inefficiency.

A crucial issue in the literature on screening with competition is the existence of equilibria. In the paper most closely related to ours by Bénabou and Tirole (2013) with horizontally differentiated firms, existence of equilibria is ensured by restricting attention to cases where the least-cost separating allocation is interim efficient, so that there are no subsidies to the low type. In our setting with vertically integrated firms, we do not need to impose this assumption, and this enables us to derive interesting results on equilibrium characterization and existence. While with perfect competition equilibria fail to exist when there are incentives to subsidize low types, subsidies offered by the bad firm may indeed be necessary for equilibria with vertically differentiated firms. One of the driving forces behind this result is that existence of equilibria requires that the low type is offered the same utility by both firms as the bad firm could otherwise profitably attract the high type.

The fact that we do not assume the least-cost separating allocation to be interim efficient has several implications. First, there are cases without equilibrium and with multiple equilibria, and second, social welfare in the latter depends on equilibrium se-

lection. For any given degree of competition β, the set of equilibria can be characterized by the minimum and the maximum utility the bad firm can offer to the low type. If the equilibrium associated with the minimum offer is in Region 1, then any equilibrium with a higher offer leads to an increase in the low type's piece rate in the good firm, and therefore also to higher social efficiency. In fact, the bad firm's maximum offer to the low type may even induce an equilibrium in Region 2 where social welfare is maximized. Hence, whenever the equilibrium with the lowest offer is in Region 1, increasing the competitive pressure on the good firm by offering the low type more than her expected output gives rise to equilibria with a higher degree of social welfare. If, for some β, equilibria are in Region 3, the opposite holds.

Due to this equilibrium multiplicity, we need to be consistent in equilibrium selection, when analyzing the impact of β on equilibrium characteristics. Assuming that the bad firm either offers the minimum or the maximum utility to the low type that establishes an equilibrium, we show that higher competition in fact weakly increases the piece rates for both types, which is welfare enhancing in Region 1 and detrimental in Region 3. In this respect, competition for agents indeed plays a double-edged role.

A Formal statements and proofs

A.1 The good firm's best response

Proof of Lemma 1.

1. We first show that $w_H^* \geq w_H^{sb}$. Consider a set of contracts satisfying all constraints with $w_H^* < w_H^{sb}$. We show that there exists a contract with piece rate w_H^{sb} that yields higher profit. From the conditions for *(PCH)* and *(ICCH)* we take $U_H(F_H^*, w_H^*) = \max(\widehat{U}_H^B, U_H(F_L^*, w_L^*))$, as any greater utility offered to the high type cannot be optimal. Offering w_H^{sb} and $F_H^{sb} := U_H(F_H^*, w_H^*) - U_H(0, w_H^{sb})$ ensures that *(PCH)* and *(ICCH)* still hold. *(PCL)* does not depend on (F_H^*, w_H^*), so it remains fulfilled. To see that *(ICCL)* still holds, observe that $U_L(F_H^{sb}, w_H^{sb}) = U_H(F_H^*, w_H^*) - \dfrac{w_H^{sb2}}{4}(\theta_H^2 - \theta_L^2) < U_H(F_H^*, w_H^*) - \dfrac{w_H^{*\,2}}{4}(\theta_H^2 - \theta_L^2) = U_L(F_H^*, w_H^*)$. The principal's profit is increasing in w_H for $w_H < w_H^{sb}$, (see the case with complete information case in Section 2). Since the contract for the low type is unchanged, expected profits are higher than for $w_H^* < w_H^{sb}$.

For $w_L^* \leq w_L^{sb}$, the proof is similar.

2. The proof is is similar to the proof of part 3 which follows.

3. For *(i)*, we show that a set of contracts including $w_L^* = w_L^{sb}$ is optimal. Setting $w_L^* = w_L^{sb}$, choose $F_L^* := \max(\widehat{U}_L^B, U_L(F_H^*, w_H^*)) - \dfrac{(w_L^*)^2}{4}\left(\theta_L^2 - 2\rho\sigma^2\right)$, which implies $U_L(F_L^*, w_L^*) = \max(\widehat{U}_L^B, U_L(F_H^*, w_H^*))$. Hence, *(PCL)* and *(ICCL)* are fulfilled. Suppose that (F_H^*, w_H^*) are such that *(PCH)* is fulfilled. It remains to show that *(ICCH)* is fulfilled, that is $U_H(F_H^*, w_H^*) \geq U_H(F_L^*, w_L^*)$. Suppose first that *(ICCL)* is binding, $U_L(F_L^*, w_L^*) = U_L(F_H^*, w_H^*)$. Then, using $F_L^* = U_L(F_H^*, w_H^*) - U_L(0, w_L^*)$,

$$
\begin{aligned}
U_H(F_H^*, &w_H^*) - U_H(F_L^*, w_L^*) \\
&= F_H^* + U_H(0, w_H^*) - F_H^* - U_L(0, w_H^*) + U_L(0, w_L^*) - U_H(0, w_L^*) \\
&= U_H(0, w_H^*) - U_L(0, w_H^*) - (U_H(0, w_L^*) - U_L(0, w_L^*)) \\
&= \frac{(w_H^{*2} - w_L^{*2})(\theta_H^2 - \theta_L^2)}{4},
\end{aligned}
$$

and *(ICCH)* holds since $w_H^* \geq w_H^{sb} \geq w_L^{sb} \geq w_L^*$, as the second-best piece rate increases in θ_i. Now suppose that *(PCL)* is binding instead of *(ICCL)*, that is, $U_L(F_L^*, w_L^*) = \widehat{U}_L^B$, so that $F_L^* = \widehat{U}_L^B - U_L(0, w_L^*)$. Then, together with $U_H(F_H^*, w_H^*) \geq \widehat{U}_H^B$, we have

$$
\begin{aligned}
U_H(F_H^*, w_H^*) - U_H(F_L^*, w_L^*) &\geq \widehat{U}_H^B - \widehat{U}_L^B + U_L(0, w_L^*) - U_H(0, w_L^*) \\
&= \widehat{U}_H^B - \widehat{U}_L^B - \frac{w_L^{*2}}{4}(\theta_H^2 - \theta_L^2),
\end{aligned}
$$

which is strictly positive if and only if $\Delta \widehat{U}_B \geq \dfrac{w_L^{*2}}{4}(\theta_H^2 - \theta_L^2)$. By definition of the case considered, we have $w_H^* > w_H^{sb}$, since *(ICCLB)* is violated if the high type is offered

w_H^{sb} and F_H^{sb} such that $U_H(F_H^{sb}, w_H^{sb}) = \max(\widehat{U}_H^B, U_H(F_L^*, w_L^*))$. The violated *(ICCL)* -condition can be re-written as $\Delta \widehat{U}_B > \frac{w_H^{sb2}}{4}(\theta_H^2 - \theta_L^2)$, and the claim then follows since $w_H^{sb} \geq w_L^*$. Finally, recall from the complete information case that this choice of (F_L^*, w_L^*) maximizes the principal's profit from the low type.

For *(ii)*, we show first that *(PCH)* is binding. Assume a contract $(F_H, w_H), (F_L, w_L)$ where *(PCH)* is non-binding and for which *(ICCH)* and *(PCH)* are fulfilled. We show that this contract is not optimal. Choose $\overline{w}_H = w_H$ and $\overline{w}_L = w_L$ and set

$$\overline{F}_H = \widehat{U}_H^B - \frac{\overline{w}_H^2}{4}(\theta_H^2 - 2\rho\sigma^2), \tag{9}$$

$$\overline{F}_L = \max(U_L(\overline{F}_H, \overline{w}_H), \widehat{U}_L^B) - \frac{\overline{w}_L^2}{4}(\theta_L^2 - 2\rho\sigma^2). \tag{10}$$

By construction, $(\overline{F}_H, \overline{w}_H), (\overline{F}_L, \overline{w}_L)$ fulfills *(PCH)*, *(PCL)* and *(ICCL)*. For *(ICCH)* observe first that if *(PCL)* is binding, then

$$U_H(\overline{F}_H, \overline{w}_H) - U_H(\overline{F}_L, \overline{w}_L) = \widehat{U}_H^B - \widehat{U}_L^B - \frac{\overline{w}_L^2}{4}(\theta_H^2 - \theta_L^2),$$

which is strictly positive if and only if $\Delta \widehat{U}_B \geq \frac{w_L^2}{4}(\theta_H^2 - \theta_L^2)$. This holds as we consider the case where $w_H^* > w_H^{sb}$; see the proof of (i). Now suppose that *(ICCL)* is binding. Then,

$$U_H(\overline{F}_H, \overline{w}_H) - U_H(\overline{F}_L, \overline{w}_L) = \frac{w_H^2 - w_L^2}{4}(\theta_H^2 - \theta_L^2) \geq 0.$$

The so-constructed contracts yield higher profits, since the only change is that both fixed wages $\overline{F}_H$ and $\overline{F}_L$ are smaller than F_H and F_L, respectively, cf. Equations (9) and (10).

To show that *(ICCL)* is binding, we use that *(PCH)* is binding, and re-write *(ICCL)* as

$$U_H(F_H, w_H) - U_L(F_H, w_H) \geq \widehat{U}_H^B - U_L(F_L, w_L). \tag{11}$$

For the principal it is optimal to choose $w_H \geq w_H^{sb}$ as small as possible. Furthermore, by the single-crossing property, Equation (3), the left-hand side of Equation (11) is increasing in w_H. Hence, it is optimal to choose w_H such that *(ICCL)* is binding.

For *(iii)*, that is *(ICCH)* non-binding, observe that if *(ICCH)* is binding, then together with the binding *(ICCL)* we have

$$U_H(F_H, w_H) - U_H(F_L, w_L) = F_H - F_L + \frac{w_H^2 - w_L^2}{4}(\theta_H^2 - 2\rho\sigma^2) = 0$$

$$U_L(F_H, w_H) - U_L(F_L, w_L) = F_H - F_L + \frac{w_H^2 - w_L^2}{4}(\theta_L^2 - 2\rho\sigma^2) = 0.$$

This implies $\frac{w_H^2 - w_L^2}{4}(\theta_H^2 - \theta_L^2) = 0$ which requires $w_H = w_L$, i.e., a pooling contract. But this cannot be, as w_L is the second-best piece rate and $w_H \geq w_H^{sb} > w_L$, since the second-best optimal piece rate is increasing in θ_i (cf. Section 2). $\qquad\square$

Proof of Proposition 1. We consider Region 3, in which the low type has an imitation incentive (see Part 3 of Lemma 1). The proof for Region 1 is similar. Region 2 is the case where two second-best contracts are feasible (see the discussion after Lemma 1).

We can express the good firm's maximization problem as a function of just one variable, w_H. Since the piece rate for the low type is second best, and together with the binding *(PCH)* and *(ICCL)* conditions, we obtain

$$F_H(w_H) = \widehat{U}_H^B - U_H(0, w_H)$$
$$F_L(w_H) = U_L(F_H(w_H), w_H) - U_L(0, w_L^{sb})$$
$$= \widehat{U}_H^B - U_H(0, w_H) + U_L(0, w_H) - U_L(0, w_L^{sb}).$$

The good firm hence solves

$$\max_{w_H} \Pi(w_H) = \alpha \left(\frac{1}{2}(1 - w_H)w_H \theta_H^2 \right)$$
$$+ (1 - \alpha) \left(\frac{1}{2}(1 - w_L^{sb})w_L^{sb}\theta_L^2 - U_L(0, w_H) + U_L(0, w_L^{sb}) \right) - (\widehat{U}_H^B - U_H(0, w_H)), \quad (12)$$

subject to *(PCL)*, which we write as $\widehat{U}_H^B - \widehat{U}_L^B \geq U_H(0, w_H) - U_L(0, w_H)$.

Observe first that $w^* := w_H^*$ is non-decreasing in $\Delta \widehat{U}_B$ as higher $\Delta \widehat{U}_B$ relaxes *(PCL)*, and as $\frac{\partial}{\partial w}[U_H(0, w) - U_L(0, w)] = \frac{w}{2}(\theta_H^2 - \theta_L^2) > 0$. This implies that w^* is strictly increasing in $\Delta \widehat{U}^B$ if *(PCL)* is binding (Region 3(b)).

The partial derivatives are

$$\frac{\partial}{\partial w}\Pi(w) = \frac{1}{2}\left(\alpha\theta_H^2 + w\left((1 - 2\alpha)\theta_H^2 - (1 - \alpha)\theta_L^2 - 2\alpha\rho\sigma^2\right) \right)$$
$$\frac{\partial^2}{\partial w^2}\Pi(w) = \frac{1}{2}\left((1 - 2\alpha)\theta_H^2 - (1 - \alpha)\theta_L^2 - 2\alpha\rho\sigma^2 \right).$$

Let w^* solve the FOC $\frac{\partial}{\partial w}\Pi(w^*) = 0$. If $\Delta\widehat{U}^B > U_H(0, w^*) - U_L(0, w^*)$ and $\frac{\partial^2}{\partial w^2}\Pi(w^*) < 0$ (which are the conditions for Region 3(a)), then, because of the binding *(PCH)*, *(PCL)* is fulfilled but non-binding, and $\Pi(w^*)$ is therefore the greatest profit the good firm can derive. Note that $w^* > 0$ if and only if $\frac{\partial^2}{\partial w^2}\Pi(w^*) < 0$. In this case the maximum is global and w^* is constant whenever

$\Delta \widehat{U}_B > \dfrac{\alpha^2 \theta_H^4 \left(\theta_H^2 - \theta_L^2\right)}{4\left((2\alpha - 1)\theta_H^2 + (1 - \alpha)\theta_L^2 + 2\alpha\rho\sigma^2\right)^2}$, where the right-hand side corresponds to the threshold where both w^* satisfies the FOC and *(PCL)* is binding.

On the other hand, *(PCL)* is binding whenever

$\Delta \widehat{U}_B \leq \dfrac{\alpha^2 \theta_H^4 \left(\theta_H^2 - \theta_L^2\right)}{4\left((2\alpha - 1)\theta_H^2 + (1 - \alpha)\theta_L^2 + 2\alpha\rho\sigma^2\right)^2}$. In this case w^* just solves the binding *(PCL)*.

If $\dfrac{\partial^2}{\partial w^2}\Pi(w^*) > 0$, then the piece rate that solves the FOC is negative, so that $\Pi(w)$ is strictly increasing on $[0, 1]$ and constrained only by the (then binding) *(PCL)* condition, so that this case corresponds to Region 3(b).

Finally, to prove that in Region 3 social welfare is decreasing in $\Delta \widehat{U}^B$, observe first that social welfare is given by

$$W(w_H) = \Pi(F_H, w_H, F_L, w_L) + \alpha\, U_H(F_H, w_H) + (1 - \alpha)U_L(F_L, w_L)$$
$$= \alpha \left(\frac{1}{2}w_H\theta_H^2 - \frac{1}{4}w_H^2\theta_H^2 - \frac{1}{2}w_H^2\rho\sigma^2\right) + (1 - \alpha)\left(\frac{1}{2}w_L\theta_L^2 - \frac{1}{4}w_L^2\theta_L^2 - \frac{1}{2}w_L^2\rho\sigma^2\right),$$

where $w_L = w_L^{sb}$ is constant in Region 3. We thus need to consider the first two derivaties with respect to w_H, which are given by

$$\frac{\partial}{\partial w_H}W(w_H) = \alpha\left(\frac{1}{2}\theta_H^2 - \frac{1}{2}w_H\theta_H^2 - w_H\rho\sigma^2\right)$$
$$\frac{\partial^2}{\partial w_H^2}W(w_H) = -\alpha\left(\frac{\theta_H^2}{2} + \rho\sigma^2\right)$$

and $W(w_H)$ is greatest if $w_H = \dfrac{\theta_H^2}{\theta_H^2 + 2\rho\sigma^2} = w_H^{sb}$. Since $w_H^* > w_H^{sb}$ in Region 3, social welfare is decreasing. $\qquad\square$

A.2 Equilibrium

Proof of Proposition 2. The proof is in the order *(iii)*, *(i)*, *(ii)*.

(iii). We first show that the bad firm offers the high type exactly her expected output. This consists of two parts: First, if she is offered less and *(PCH)* is binding, then the bad firm has a profitable deviation. Second, offering more is weakly dominated as the high type has no imitation incentive in the bad firm.

Suppose the bad firm offers contracts $(F_H^{B,*}, w_H^{B,*}), (F_L^{B,*}, w_L^{B,*})$ where the high type is offered less than her output. Then, since *(PCH)* is binding by definition of the case considered, the bad firm has the following profitable deviation: It can increase its offer to the high type and profitably attract her. Of course, the low type must not

be attracted, and therefore the profitable deviation entails a greater distortion in the contract designed for the high type. Formally, choose $(\overline{F}_H^B, \overline{w}_H^B)$ with $\overline{w}_H^B > w_H^{B,*}$ and

$$\overline{F}_H^B(\overline{w}_H^B) = U_L^B(F_H^{B,*}, w_H^{B,*}) - U_L^B(0, \overline{w}_H^B) = F_H^{B,*} + \frac{w_H^{B,*2} - \overline{w}_H^{B\,2}}{4}(\beta^2\theta_L^2 - 2\rho\sigma^2).$$

By construction, $U_L^B(\overline{F}_H^B, \overline{w}_H^B) = U_L^B(F_H^{B,*}, w_H^{B,*})$, so *(ICCLB)* is satisfied. Furthermore,

$$U_H^B(\overline{F}_H^B, \overline{w}_H^B) - U_H^B(F_H^{B,*}, w_H^{B,*})$$
$$= U_L^B(F_H^{B,*}, w_H^{B,*}) - U_L^B(0, \overline{w}_H^B) + U_H^B(0, \overline{w}_H^B) - U_H^B(F_H^{B,*}, w_H^{B,*})$$
$$= \frac{\overline{w}_H^{B\,2} - w_H^{B,*2}}{4}(\beta^2\theta_H^2 - \beta^2\theta_L^2) > 0,$$

which implies that *(ICCHB)* is satisfied, and that the bad firm attracts the high type because *(PCH)* was binding.

It remains to show that there exists $\overline{w}_H^B$ such that the expected profit from the high type, $\Pi_H^B(\overline{F}_H^B, \overline{w}_H^B)$, is positive. But this follows directly by observing that

$$\Pi_H^B(\overline{F}_H^B(\overline{w}_H^B), \overline{w}_H^B) = \alpha\left\{\frac{1}{2}(1 - \overline{w}_H^B)\overline{w}_H^B\beta^2\theta_H^2 - F_H^{B,*} - \frac{w_H^{B,*2} - \overline{w}_H^{B\,2}}{4}(\beta^2\theta_L^2 - 2\rho\sigma^2)\right\}$$

is continuous in $\overline{w}_H^B$, and that $\Pi_H^B(F_H^{B,*}, w_H^{B,*}) > 0$ as the high type is offered less than her output. Thus, a profitable deviation exists when the bad firm offers the high type less than her expected output.

Next, the only reason to offer the high type more than her expected output would be to reduce her imitation incentive. Otherwise, this is weakly dominated. It is hence sufficient to show that the high type has no imitation incentive when the bad firm offers two second-best contracts. Suppose first that both piece rates are second-best and that each type receives her expected output, that is, $F_i^B(w) = (1 - w)\frac{1}{2}w\beta^2\theta_i^2$. We must investigate

$$U_H^B(w_H^{B,sb}) = \frac{1}{2}(1 - w_H^{B,sb})w_H^{B,sb}\beta^2\theta_H^2 + \frac{w_H^{B,sb2}}{4}(\beta^2\theta_H^2 - 2\rho\sigma^2)$$
$$U_H^B(w_L^{B,sb}) = \frac{1}{2}(1 - w_L^{B,sb})w_L^{B,sb}\beta^2\theta_L^2 + \frac{w_L^{B,sb2}}{4}(\beta^2\theta_H^2 - 2\rho\sigma^2).$$

We have

$$U_H^B(w_L^{B,sb}) \le \frac{1}{2}(1 - w_L^{B,sb})w_L^{B,sb}\beta^2\theta_H^2 + \frac{w_L^{B,sb2}}{4}(\beta^2\theta_H^2 - 2\rho\sigma^2) \le U_H^B(w_H^{B,sb}),$$

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which implies that the high type has no incentive to imitate. Let us now loosen the assumption that the low type is offered exactly her expected output. The only reason to offer the low type more than her output is to reduce her imitation incentive, and to profitably attract the high type with a more attractive contract. Of course, such a contract does not exist when the high type's piece rate is second-best, and then, offering the low type more than her output is weakly dominated.

Since offering the high type her expected output is sufficient to keep her from imitating if second-best contracts were offered, offering more is weakly dominated.

That the low type is offered at least her expected output by the bad firm, is a straightforward consequence of the analysis so far. It suffices to observe that, whenever *(PCL)* is binding, offering the low type less than her output and less than the second-best piece rate allows the bad firm to profitably attract the low type.

(i). In the proof of *(iii)* it was shown that the high type does not have an incentive to imitate if she is offered exactly her output. Hence, it follows from standard results that the piece rate for the low type is second-best and that the piece rate for the high type is distorted upwards.

(ii). That *(ICCLB)* is binding and *(ICCHB)* is non-binding follows again as a standard results from the fact that the low type has an incentive to imitate when two second-best contracts are offered.

If *(PCH)* is not binding, then the bad firm need not keep the high type from imitating as she will not be attracted anyway. Hence, the offer to the high type is not uniquely determined. However, any offer to the high type is bounded by the high type's expected output, as higher offers are weakly dominated. Since *(PCH)* is slack, *(PCL)* is binding. Offering the low type less than a second-best piece rate and her expected output yields – together with the binding *(PCL)* – a profitable deviation, where the bad firm may attract the low type. $\qquad \square$

Proof of Proposition 3. **(i).** Suppose that *(PCL)* is non-binding. We show that there exists a profitable deviation that allows the bad firm to attract the high type. When *(PCL)* is non-binding, the bad firm can increase its offer to the low type without attracting her, which allows to reduce the inefficiency in the piece rate for the high type. Suppose contracts (F_H^*, w_H^*), (F_L^*, w_L^*), $(F_H^{B,*}, w_H^{B,*})$, $(F_L^{B,*}, w_L^{B,*})$ with a non-binding *(PCL)*, $U_L(F_L^*, w_L^*) > U_L^B(F_L^{B,*}, w_L^{B,*})$. Choose $(\overline{F}_L^B, \overline{w}_L^B), (\overline{F}_H^B, \overline{w}_H^B)$ such that

$$\overline{w}_L^B = 0, \tag{13}$$

$$\overline{F}_L^B = U_L(F_L^*, w_L^*) =: \widehat{U}_L^G, \tag{14}$$

$$\overline{F}_H^B = \widehat{U}_L^G - U_L^B(0, \overline{w}_H^B), \tag{15}$$

$$U_H^B(\overline{F}_H^B, \overline{w}_H^B) = U_H(F_H^*, w_H^*). \tag{16}$$

Equations (13) and (14) imply that *(PCL)* is binding. Because of Equation (16), the contract $(\overline{F}_H^B, \overline{w}_H^B)$ does not attract the high type. We proceed as follows: We verify that the contract pair fulfills all constraints, and that the high type receives less than her expected output. Then, the existence of a profitable deviation follows from Proposition 2, part *(iii)*.

By construction, *(PCL)* and *(ICCLB)* are binding. *(ICCHB)* is fulfilled since

$$U_H^B(\overline{F}_H^B, \overline{w}_H^B) = \widehat{U}_H > \widehat{U}_L = \overline{F}_L^B,$$

where the first equality follows from the binding *(PCH)*, which follows from the initially non-binding *(PCL)*.

To see that the high type receives less than her expected output, we first show that $w_H^{B,*} > \overline{w}_H^B$: From *(ICCLB)* in the initial contract, we have

$$U_H^B(F_H^{B,*}, w_H^{B,*}) \leq U_L^B(F_L^{B,*}, w_L^{B,*}) + \frac{\beta^2 w_H^{B,*\,2}}{4}(\theta_H^2 - \theta_L^2).$$

Furthermore,

$$U_H^B(F_H^{B,*}, w_H^{B,*}) = U_H^B(\overline{F}_H^B, \overline{w}_H^B) = \widehat{U}_L + \frac{\beta^2 \overline{w}_H^{B\,2}}{4}(\theta_H^2 - \theta_L^2),$$

so that

$$\frac{\beta^2}{4}(w_H^{B,*\,2} - \overline{w}_H^{B\,2})(\theta_H^2 - \theta_L^2) \geq \widehat{U}_L - U_L^B(F_L^{B,*}, w_L^{B,*}) > 0,$$

which implies that $w_H^{B,*} > \overline{w}_H^B$.

Next, recall from the proof of Proposition 2, part *(iii)*, that $\overline{w}_H^B > w_H^{B,sb}$. Together with $w_H^{B,*} > \overline{w}_H^B$, it follows that the high type receives less than her expected output: Since $w_H^{B,*} > \overline{w}_H^B > w_H^{B,sb}$, her utility is higher with $\overline{w}_H^B$ compared to $w_H^{B,*}$ if offered her expected output in both cases. And as her certainty equivalent is unchanged by construction via the choice of $\overline{F}_H^B$, the claim follows.

(ii). Note first that, with exogenous reservation levels of utility $\widehat{U}_i$ and without further restrictions, it could of course be profit-maximizing to employ just one agent type. For instance, if the high type's reservation level of utility, $\widehat{U}_H$, were greater than her output with a second-best piece rate, then it would be optimal to employ only the low type. In our model, however, the reservation levels of utility are endogenously derived from the bad firm's offers, and hence bounded from above. We show that, given these upper bounds, the good firm can never increase its profit by hiring just one agent type. Regarding the upper bounds, recall from Proposition 2 (iii) that the bad firm will never offer the high type more than her expected output. Furthermore, offering the low type more than her expected output requires either that the bad firm makes an overall profit by attracting both types or that the good firm attracts the low type. This given, we can distinguish two cases:

Case 1. (PCL) and (PCH) are both binding.

Suppose first that the good firm hires both types, as assumed in the best response function Equation (6) and that *(PCL)* and *(PCH)* are binding in its best response. Recall that this is the case in Regions 1(b), 2 and 3(a). We show that there is no profitable deviation for the good firm.

Note first that, due to the good firm's productivity advantage, the bad firm can only derive profit from attracting a single type or both types if this is also the case for the good firm. Therefore, the bad firm will not bid more for a type than is profitable for the good firm. When the good firm offers two contracts, then at most one contract is distorted to prevent the other type from imitating. Offering no contract instead of a distorted contract for the respective type foregoes any positive expected profit from this type. All other contracts are second-best, and profits cannot be increased by not offering contracts due to the binding *(PC)s*. Therefore, not placing an offer for any one type cannot be a profitable deviation.

There are two potential profitable deviations for the good firm:

Contract offer only to the low type: As the bad firm never offers the high type more than her expected output, the good firm's profit from the high type is positive. Furthermore, offering no contract to the high type would not allow to increase the profit from the low type as her contract is second-best anyway, and since *(PCL)* is binding. Thus, offering a contract only to the low type can never be a profitable deviation.

Contract offer only to the high type: If the bad firm offers the low type not more than her expected output, then the good firm gains positive profit from the low type, again due to its productivity advantage. Now suppose the bad firm's offer to the low type is so high that even the good firm would face losses from the low type, and hence has a profitable deviation by offering only a contract to the high type. But then, the bad firm would attract only the low type and face losses, so that the contract pair assumed for the bad firm cannot be an equilibrium offer.

The argument is similar for Regions 2 and 1(b), where both *(PCL)* and *(PCH)* are binding as well. Thus, there is no profitable deviation by offering just one contract *if (PCL)* and *(PCH)* are both binding in the good firm's best response when employing both types.

So far, we have shown that the good firm has no profitable deviation when it employs both types as the profit from both types is positive. Note that this implies that the good firm *does* have a profitable deviation when it employs just one type as hiring the bad type, for instance, does not change the profit from the good type. Thus, the fact that the profit from both types is positive excludes the existence of equilibria where the good firm hires just one type.

Case 2. (PCH) is non-binding.

The non-trivial case arises in Region 1(a), where *(PCH)* is non-binding, so that the high type receives an information rent if attracted. For this case, we know from textbook models that, whenever the probability of meeting a low type, $1 - \alpha$, is sufficiently small,

it may be profitable to hire only the high type in order to save the information rent. We show that this is not the case in our model. The reason is that the high type's information rent depends on α and, in particular, as $1 - \alpha$ tends to 0, so does the high type's information rent. As a consequence it turns out that the profits from offering two contracts versus offering only one contract converge as $1 - \alpha \to 0$, with offering two contracts being strictly more profitable than offering only one for arbitrary $1 - \alpha > 0$.

Formally, in Region 1(a), when offering two contracts we have

$$F_L(w_L) = \widehat{U}_L^B - U_L(0, w_L) \qquad \text{(binding \textit{(PCL)})}$$

$$F_H(w_L) = U_H(F_L, w_L) - U_H(0, w_H) \qquad \text{(binding \textit{(ICCH)})}$$

$$w_H = w_H^{sb}$$

Furthermore, w_L solves the FOC of the good firm's profit function, and is given by

$$w_L = \frac{\theta_L^2}{\theta_L^2 + 2\rho\sigma^2 + \alpha/(1 - \alpha)(\theta_H^2 - \theta_L^2)}.$$

Let us analyse the difference in offering two contracts with non-binding *(PCH)* versus offering one contract with binding *(PCH)*, which is given by (assuming that $\Delta \widehat{U}^B$ is small enough so that we are in Region 1(a))

$$\Delta = \Pi(F_H(w_L), w_H, F_L(w_L), w_L) - \alpha \left(\frac{1}{2}(1 - w_H)w_H\theta_H^2 - (\widehat{U}_H^B - U_H(0, w_H)) \right).$$

Simplifying yields

$$\Delta = \frac{(1 - \alpha)^2\theta_L^4}{4(\alpha(\theta_H^2 - \theta_L^2) + (1 - \alpha)(\theta_L^2 + 2\rho\sigma^2))} + \alpha\widehat{U}_H^B - \widehat{U}_L^B. \tag{17}$$

When $\beta = 0$, then both $\widehat{U}_H^B = 0$ and $\widehat{U}_L^B = 0$, and only the first term (a positive constant) remains. On the other hand, on the boundary between Regions 1(a) and 1(b), where *(PCH)* becomes binding, Δ is just the profit derived from the low type. In an equilibrium where the bad firm hires the low type, this would be strictly positive, as (i) $\beta < 1$ (when $\beta = 1$ we are in Region 3, as the low type has an imitation incentive) and (ii) the bad firm would pay the low type at most her output (otherwise the bad firm would not want to hire the low type).

It remains to analyse whether $\Delta > 0$ for $\beta > 0$ in Region 1(a). Since the explicit expression for $\widehat{U}_H^B$ is too involved, we find a lower bound for Δ. First, observe that the constant term in Δ (the first term on the RHS of Equation (17)) can be re-written as

$$\frac{(1 - \alpha)^2\theta_L^4}{4(\alpha(\theta_H^2 - \theta_L^2) + (1 - \alpha)(\theta_L^2 + 2\rho\sigma^2))} = \frac{w_L^2}{4}(\alpha(\theta_H^2 - \theta_L^2) + (1 - \alpha)(\theta_L^2 + 2\rho\sigma^2))$$

$$\geq \frac{w_H^{B\,2}}{4}\beta^2(\alpha(\theta_H^2 - \theta_L^2) + (1 - \alpha)(\theta_L^2 + 2\rho\sigma^2)), \tag{18}$$

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where the inequality follows since $w_L = \beta w_H^B$ when *(PCH)* is binding and $w_L > \beta w_H^B$ when *(PCH)* is non-binding. [16] Inserting the lower bound for the constant term from Equation (18), we obtain after simplifying

$$\Delta \geq \frac{1}{2}(1-\alpha)w_H^B \left(\beta^2(\theta_H^2(w_H^B - 1) - w_H^B(\theta_L^2 + \rho\sigma^2)) + \rho\sigma^2 w_H^B \right) =: \Delta'.$$

At $\beta = 0$, we have $\Delta' = \frac{1}{2}(1-\alpha)\rho\sigma^2 w_H^{B\,2} > 0$, whereas on the boundary between Regions 1(a) and Region 1(b), we have $\Delta' = \Delta \geq 0$. Furthermore, Δ' as a function of β has at most one zero on $[0, 1]$, so that we can conclude that $\Delta' \geq 0$ in Region 1(a). $\square$

Proof of Proposition 4. We show that, if $\widehat{U}_L^B \in [\underline{U}_L^B, \overline{U}_L^B]$, then the mutual best responses of both firms are given by Equation (6) for the good firm, resp. (7a)–(7c) by the bad firm, and that a profitable deviation exists for at least one firm if $\widehat{U}_L^B \notin [\underline{U}_L^B, \overline{U}_L^B]$.

Consider first the bad firm whose best response is given by (7a)–(7c): For any $\widehat{U}_L^G \geq \widehat{U}_{L,LCA}^B$, that is, where the low type is offered at least her expected output, there is no profitable deviation to attract solely the low type. Thus, the only profitable deviation aims at attracting (also) the high type. We need to distinguish two cases, depending on whether the bad firm's best response leads to a binding, respectively non-binding, *(PCH)* in the good firm.

Case 1. (PCH) *is binding.*

In this case, the minimum utility to be offered to the high type so that she cannot be profitably attracted regardless of the actions of the good firm is given by $\widehat{U}_{L,CS}^B$. For $\widehat{U}_{L,CS}^B > \widehat{U}_{L,LCA}^B$, the bad firm would respond to $U_L^G \in [\widehat{U}_{L,CS}^B, \widehat{U}_{L,LCA}^B)$ by offering the low type more than her output, which reduces the inefficiency in the piece rate for the high type. The increase in the high type's expected output does not only compensate for the loss from the low type, but also allows to profitably attract the high type. This is shown in Appendix B.

Recall next from Propositon 3, that a non-binding *(PCL)* entails a profitable deviation for the bad firm. If *(PCL)* is binding for certainty equivalent $\widehat{U}_L^G$, then it is also binding for all greater certainty equivalents. To see this, observe that it follows directly from Equations Equation (7a)–Equation (7c) that $w_L^{B,*} = w_L^{B,sb}$ and

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[16]When *(PCH)* is binding we have in Region 1, because of the binding *(ICCH)*,

$$\Delta\widehat{U}^B = U_H(F_L, w_L) - U_L(F_L, w_L) = \frac{w_L^2}{4}(\theta_H^2 - \theta_L^2).$$

In the bad firm, we have because of the binding *(ICCLB)*,

$$\Delta\widehat{U}^B = U_H^B(F_H^B, w_H^B) - U_L^B(F_H^B, w_H^B) = \frac{w_H^{B\,2}}{4}\beta^2(\theta_H^2 - \theta_L^2),$$

so that in Region 1(b) we have $w_L = w_H^B\beta$. For Equation (18), we have equality on the boundary between Regions 1(a) and 1(b) and strict inequality in Region 1(a).

$F_L^{B,*} = \widehat{U}_L^G - U_L^B(0, w_L^{B,sb})$. The explicit solution for the high type's piece rate in the bad firm's best response is then given by[17]

$$w_H^{B,*} = \frac{\beta^2\theta_H^2 + \sqrt{\beta^4\theta_H^4 - 4\widehat{U}_L^G(2\beta^2\theta_H^2 - \beta^2\theta_L^2 + 2\rho\sigma^2)}}{2\beta^2\theta_H^2 - \beta^2\theta_L^2 + 2\rho\sigma^2}. \tag{19}$$

Hence, Equation (19) implies $\frac{\partial w_H^B}{\partial \widehat{U}_L^G} \leq 0$, which implies that $\Delta\widehat{U}^B = \frac{w_H^{B\,2}}{4}\beta^2(\theta_H^2 - \theta_L^2)$ decreases in $\widehat{U}_L^G$. Furthermore, we know from Proposition 1 that *(PCL)* remains binding as U_L^G increases. Hence, the bad firm's best response to $\widehat{U}_L^G > \max(\widehat{U}_{L,LCA}^B, \widehat{U}_{L,CS}^B, \widehat{U}_{L,PCL}^B)$ does not allow her to profitably attract any type.

The explicit expression for $\widehat{U}_{L,PCL}^B$ is determined by the threshold that separates Regions 3(a) and 3(b) in Proposition 1, that is, where

$$\Delta\widehat{U}^B = \frac{\alpha^2\theta_H^4 \left(\theta_H^2 - \theta_L^2\right)}{4\left((2\alpha - 1)\theta_H^2 + (1-\alpha)\theta_L^2 + 2\alpha\rho\sigma^2\right)^2}.$$

By the binding *(ICCLB)* constraint we have that

$$\Delta\widehat{U}^B = U_H^B(F_H^B, w_H^B) - U_L^B(F_H^B, w_H^B) = \frac{w_H^{B\,2}}{4}\beta^2(\theta_H^2 - \theta_L^2),$$

so that

$$w_H^B = \frac{\alpha\theta_H^2}{\beta((2\alpha - 1)\theta_H^2 + (1-\alpha)\theta_L^2 + 2\alpha\rho\sigma^2)}. \tag{20}$$

The resulting low type's certainty equivalent is

$$\widehat{U}_{L,PCL}^B = \frac{1}{2}(1 - w_H^B)w_H^B\beta^2\theta_H^2 + \frac{w_H^{B\,2}}{4}(\beta^2\theta_L^2 - 2\rho\sigma^2), \tag{21}$$

with w_H^B given by Equation (20).

Case 2. (PCH) *is non-binding.*

In this case, $\max(\widehat{U}_{L,LCA}^B, \widehat{U}_{L,CS}^B, \widehat{U}_{L,PCL}^B) \neq \widehat{U}_{L,PCL}^B$, since at least one of the participation contraints is binding in the good firm's best response. If the maximum is $\widehat{U}_{L,CS}^B$, then $\widehat{U}_L^G < \widehat{U}_{L,CS}^B$ may hold in equilibrium as it may not give rise to a profitable deviation which attracts the high type: $\widehat{U}_L^G$ can be lowered to the point where either the low type receives her expected output, or where the high type can be profitably attracted, which then requires that *(PCH)* is binding.

Summing up so far, any $\widehat{U}_L^G \geq \underline{U}_L^B$ rules out that the bad firm can profitably attract any type, whereas any $\widehat{U}_L^G < \underline{U}_L^B$ entails that the bad firm can profitably attract at

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[17]Existence of a solution in $\mathbb{R}$ follows from $w_H^{B,*} \geq w_H^{B,sb}$, and since the right-hand side of Equation (19) is decreasing in $\widehat{U}_L^G$ and smaller than $w_H^{B,sb}$ when the expression in the square root is 0.

least one type. Since the good firm attracts both types in equilibrium, the latter case does not constitute an equilibrium, while the former case can constitute an equilibrium provided the good firm is willing to bid and provided that best responses are not weakly dominated in the sense of Assumption 1.

Therefore, consider now the good firm's best response as given by Equation (6).[18] The good firm's best response to $\widehat{U}_L^B > \widehat{U}_{L,\max}^B$, where the bad firm offers the low type even more than her expected output in the *good* firm, is to not bid for the low type. Thus, $\widehat{U}_L^B > \widehat{U}_{L,\max}^B$ cannot hold in equilibrium. For $\widehat{U}_L^B \leq \widehat{U}_{L,\max}^B$ and given the binding *(PCL)*, the good firm attracts the low type, for it will otherwise just forego the profit derived from her.

Similarly, the good firm will not offer the high type more than her expected output. Given that the contract for the high type in the bad firm is inefficient and offers exactly her output, this case is subsumed by $\widehat{U}_{L,\max}^B$. This proves that the good firm's best response to any offer below $\widehat{U}_{L,\max}^B$ is to attract both types.

The greatest certainty equivalent offered to the low type such that the high type receives her output is determined by the case when both $w_H^B = w_H^{B,sb}$ and *(ICCLB)* is binding, which is given by

$$\widehat{U}_{L,\text{no imi.}}^B := U_L^B(F_H^{B,sb}, w_H^{B,sb}) = \frac{\beta^4 \theta_H^4 (\beta^2 \theta_L^2 + 2\rho\sigma^2)}{4(\beta^2 \theta_H^2 + 2\rho\sigma^2)^2}. \tag{22}$$

As Assumption 1 excludes weakly dominated strategies, the bad firm will not offer the low type more than $\widehat{U}_{L,\text{no imi.}}^B$ if $\widehat{U}_{L,\text{no imi.}}^B > \widehat{U}_{L,LCA}^B$, as the only reason to offer the low type more than her expected output is to keep her from imitating. And as a non-binding *(ICCLB)* implies that this is not necessary, this is weakly dominated.

Finally, the offers by the bad firm must be such that the high type is offered her expected output by the bad firm, cf. Proposition 2. The highest certainty equivalent offered to the *low* type such that the high type receives her expected output fulfills the first-order condition

$$\frac{\partial}{\partial w_H^B} \left[\frac{1}{2}(1 - w_H^B)w_H^B \beta^2 \theta_H^2 + \frac{w_H^{B^2}}{2}\left(\frac{\beta^2 \theta_L^2}{2} - 2\rho\sigma^2\right)\right] = 0,$$

cf. Equations (7b) and (7c), which in turn yields $U_L^B(F_H^B, w_H^B) = \dfrac{\beta^4 \theta_H^4}{4(\beta^2(2\theta_H^2 - \theta_L^2) + 2\rho\sigma^2)}$. It is easily shown that this expression is greater than $\widehat{U}_{L,\text{no imi.}}^B$, so that this case can be ignored.

Summing up, $\widehat{U}_L^G < \underline{U}_L^B$ implies that the bad firm has a profitable deviation, whereas $\widehat{U}_L^B > \overline{U}_L^B$ implies that either the good firm does not attract both types or that the bad firm's best response is weakly dominated. Any $\widehat{U}_L^B \in [\underline{U}_L^B, \overline{U}_L^B]$ fulfills the necessary

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[18]Recall from Proposition 3 that, in equilibrium, the good firm employs both types.

conditions of Propositions 2 and 3, and is also sufficient as the offered contracts are mutual best responses. □

Proof of Proposition 5. **(i).** The proof is based on expressing the good firm's contract offers, i.e., $F_H^*, w_H^*, F_L^*, w_L^*$, as functions of $\widehat{U}_L^B$. Differentiating the good firm's profit with respect to U_L^B then yields the claim. We consider each region of the good firm's best response in turn and start with Region 3. Using the binding *(ICCLB)*, we have

$$\Delta\widehat{U}^B = U_H^B(F_H^{B,*}, w_H^{B,*}) - U_L^B(F_H^{B,*}, w_H^{B,*}) = \frac{w_H^{B,*\,2}\beta^2}{4}(\theta_H^2 - \theta_L^2).$$

Using in addition the properties from Lemma 1 and Proposition 1, and that *(PCL)* is binding in equilibrium, we get

$$w_H^*(\widehat{U}_L^B) = 2\sqrt{\frac{\Delta\widehat{U}^B}{\theta_H^2 - \theta_L^2}} = \beta w_H^{B,*}(\widehat{U}_L^B)$$

$$w_L^*(\widehat{U}_L^B) = w_L^{sb}$$

$$F_H^*(\widehat{U}_L^B) = \widehat{U}_H^B - U_H(0, w_H^*)$$

$$= \widehat{U}_L^B + \frac{w_H^{B*\,2}}{4}\beta^2(\theta_H^2 - \theta_L^2) - \frac{(\beta w_H^{B*})^2}{4}(\theta_H^2 - 2\rho\sigma^2)$$

$$= \widehat{U}_L^B - \frac{\beta^2(w_H^{B*}(\widehat{U}_L^B))^2}{4}(\theta_L^2 - 2\rho\sigma^2)$$

$$F_L^*(\widehat{U}_L^B) = \widehat{U}_L^B - U_L(0, w_L^{sb}).$$

Then,

$$\frac{\partial}{\partial U_L^B}\Pi = \frac{\partial}{\partial U_L^B}\left\{\alpha\left(\frac{1}{2}(1 - \beta w_H^{B*}(\widehat{U}_L^B))\beta w_H^{B*}(\widehat{U}_L^B)\theta_H^2 + \frac{\beta^2 w_H^{B*}(\widehat{U}_L^B)^2}{4}(\theta_L^2 - 2\rho\sigma^2)\right)\right\} - 1 < 0$$

since $\dfrac{\partial}{\partial U_L^B}w_H^{B*}(U_L^B) \le 0$.

For Region 2, the piece rates do not change, but since $\widehat{U}_L^B$ and $\widehat{U}_H^B$ increase, both fixed wages increase as well, which trivially decreases the good firm's profit.

The proof for Region 1(b) is similar to Region 3, and proceeds by showing that the profit decreases in $\widehat{U}_H^B$, taking into account that $w_L^* = \beta w_H^{B*}$.

Region 1(a) is similar to Region 2: As the piece rates are constant in Region 1(a), only the fixed wages change, which again decreases the good firm's profit.

(ii). Since $\widehat{U}_L^G = \widehat{U}_L^B$ due to the binding *(PCL)*, Equation (19) illustrates that the distortion in the piece rate for the high type decreases as $\widehat{U}_L^B$ increases. As the high type is offered her expected output, her utility increases as well. At the same time,

because of the binding *(ICCLB)* and the single-crossing property (3), $\Delta\widehat{U}^B$ decreases as $\widehat{U}^B_L$ increases:

$$\frac{\partial}{\partial U^B_L}\Delta\widehat{U}^B = \frac{\partial}{\partial U^B_L}(U^B_H(F^{B,*}_H, w^{B,*}_H) - U^B_L(F^{B,*}_H, w^{B,*}_H))$$

$$= \frac{\partial}{\partial w^B_H}(U^B_H(F^{B,*}_H, w^{B,*}_H) - U^B_L(F^{B,*}_H, w^{B,*}_H)) \cdot \frac{\partial w^B_H}{\partial U^B_L} \leq 0. \quad (23)$$

The claim follows directly from Equation (23) and Proposition 1, which states that social welfare is greatest in Region 2. $\qquad\square$

A.3 The impact of competition for agents

Proof of Lemma 2. **(i).** By Equations (7a)-(7c) we have

$$\Delta\widehat{U}^B(\beta) = U^B_H(0, w^{B,*}_H(\beta)) - U^B_L(0, w^{B,*}_H(\beta)) = \frac{w^{B,*}_H(\beta)^2}{4}\beta^2(\theta^2_H - \theta^2_L),$$

with $w^{B,*}_H(\beta)$ given according to Equation (19) (observe that $\widehat{U}^G_L$ depends on β). Hence,

$$\frac{\partial}{\partial\beta}\Delta\widehat{U}^B = \frac{w^{B,*}_H(\beta)}{2}\left\{\beta w^{B,*\,\prime}_H(\beta) + w^{B,*}_H(\beta)\right\}\beta(\theta^2_H - \theta^2_L),$$

and it is sufficient to show that $w^{B,*\,\prime}_H(\beta) \geq 0$.

We need to prove the claim both for the case where $U^B_L = \underline{U}^B_L$ (Case 1) and where $U^B_L = \overline{U}^B_L$ (Case 2).

Case 1: $U^B_L = \underline{U}^B_L$.

Since *(PCH)* is binding, $\underline{U}^B_L = \max(\widehat{U}^B_{L,LCA}, \widehat{U}^B_{L,CS}, \widehat{U}^B_{L,PCL})$, cf. Equation (8). Suppose first that cases do not change at β, and consider each case in turn.

Assume first that $\underline{U}^B_L = \widehat{U}^B_{L,LCA} = \frac{\beta^4\theta^4_L}{4(\beta^2\theta^2_L + 2\rho\sigma^2)}$. Inserting this expression into Equation (19) and taking the derivative, we obtain

$$w^{B,*\,\prime}_H(\beta) = \frac{4\beta\rho\sigma^2\left(\beta^6(\theta^2_H\theta^6_L - \theta^4_H\theta^4_L) + \beta^2(\theta^2_H\theta^2_L\sqrt{\beta^8\theta^4_L(\theta^2_H - \theta^2_L)^2 + 2\rho\sigma^2(\text{pos. terms})})\right)}{\text{positive terms}}$$

$$+ \text{positive terms}$$

$$\geq 0.$$

If $\underline{U}^B_L = \widehat{U}^B_{L,PCL}$, by definition $\frac{\partial}{\partial\beta}\Delta\widehat{U}^B = 0$.

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Last, consider the case where $\underline{U}_L^B = \widehat{U}_{L,CS}^B$, assuming that $\widehat{U}_{L,CS}^B > \widehat{U}_{L,LCA}^B$. Let $\widehat{U}_{H,CS}^B$ be the minimum utility to be offered to the high type by the bad firm from the cross-subsidy strategy where the low type receives some of the high type's expected output, see Appendix B, in particular, Equation (27). By definition, we have $U_H^B(F_H^B(w_H^{B,*}), w_H^{B,*}) = \widehat{U}_{H,CS}^B$, and get

$$\frac{\partial}{\partial\beta}U_H^B = \frac{\partial}{\partial\beta}\widehat{U}_{H,CS}^B. \tag{24}$$

To deduce that $w_H^{B,*} \geq 0$ requires making each side of Equation (24) explicit. In the cross-subsidy contract from Equation (27), $w_L^{B,*} = w_L^{B,sb}$ and *(ICCLB)* is binding. Then, the problem that solves the cross-subsidy contract reduces to one variable, the optimal piece rate for the high type, denoted by w^*. As w^* solves the first-order condition $\frac{\partial}{\partial w}\widehat{U}_{H,CS}^B(w^*, \beta) = 0$, we get

$$\widehat{U}_{H,CS}^{B}{}'(w^*(\beta), \beta) = \frac{\partial}{\partial\beta}\widehat{U}_{H,CS}^B(w^*, \beta) + w^{*\prime}(\beta)\underbrace{\frac{\partial}{\partial w}\widehat{U}_{H,CS}^B(w^*, \beta)}_{=0},$$

and

$$\frac{\partial}{\partial\beta}\widehat{U}_{H,CS}^B(w^*, \beta) = \alpha(1 - w^*)w^*\beta\theta_H^2$$

$$+ (1 - \alpha)\left\{(1 - w_L^{B,sb})w_L^{B,sb}\beta\theta_L^2 - \frac{w^{*2} - w_L^{B,sb2}}{2}\beta\theta_L^2\right\} + \frac{w^{*2}}{2}\beta\theta_H^2$$

$$= \frac{2}{\beta}\left\{\widehat{U}_{H,CS}^B - (1 - \alpha)\frac{w^{*2} - w_L^{B,sb2}}{2}\rho\sigma^2 + \frac{w^{*2}}{2}\rho\sigma^2\right\} \tag{25}$$

$$= \frac{2}{\beta}\left\{\widehat{U}_{H,CS}^B + (1 - \alpha)\frac{w_L^{B,sb2}}{2}\rho\sigma^2 + \alpha\frac{w^{*2}}{2}\rho\sigma^2\right\}$$

On the other hand, with the piece rate offered in equilibrium,

$$\frac{\partial}{\partial\beta}U_H^B(w_H^{B,*}(\beta), \beta) = \frac{\partial}{\partial\beta}U_H^B(w_H^{B,*}, \beta) + w_H^{B,*\prime}(\beta)\frac{\partial}{\partial w}U_H^B(w_H^{B,*}, \beta)$$

$$= \frac{2}{\beta}\left\{U_H^B + \frac{w_H^{B,*2}}{2}\rho\sigma^2\right\} + w_H^{B,*\prime}(\beta)\left\{\frac{\beta^2\theta_H^2}{2} - \frac{w_H^{B,*}\beta^2\theta_H^2}{2} - w_H^{B,*}\rho\sigma^2\right\}. \tag{26}$$

To show that $w_H^{B,*\prime}(\beta) \geq 0$, recall first that because of Equation (24), the expressions Equation (25) and Equation (26) must be identical. Observe further that $\frac{\partial}{\partial w}U_H^B(w, \beta) \leq$

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0 for $w \geq w_H^{B,sb}$, the high type's optimal contract when she receives her output. This implies that the second term of Equation (26) is negative if $w_H^{B,*'}$ is positive and vice versa. If we show that $w_H^{B,*} > w^*$, which implies that the first term of Equation (26) is greater than Equation (25), then it follows directly by the equality of Equation (25) and Equation (26) that $w_H^{B,*'}$ is positive. But to see that $w_H^{B,*} > w^*$ observe that $U_H^B(F_H^B(w^*), w^*) > U_{H,CS}^B$ since the agent receives her full output in the first case, while she receives less in the cross-subsidy case.

It remains to observe that the above results also cover the cases where the case distinction of U_L^B switches due to the continuity of all variables involved.

Case 2: $U_L^B = \overline{U}_L^B$.

We now show that $w_H^{B,*'}(\beta) \geq 0$ for $U_L^B = \overline{U}_L^B$. Again, we need to consider the two candidates for $\overline{U}_L^B$ separately. For $\overline{U}_L^B = \widehat{U}_{L,\text{no imi.}}$, by definition $w_H^{B,*} = w_H^{B,sb} = \dfrac{\beta^2 \theta_H^2}{\beta^2 \theta_H^2 + 2\rho\sigma^2}$, which is increasing in β. For $\overline{U}_L^B = \widehat{U}_{L,\text{max}}$, we distinguish two cases: First, in Regions 2 and 3, the piece rate for the low type is second best, so that $\widehat{U}_{L,\text{max}} = \dfrac{\theta_L^4}{4(\theta_L^2 + 2\rho\sigma^2)}$. In this case, $w_H^{B,*}$ is given by Equation (19) with $\widehat{U}_L^G$ replaced by $\widehat{U}_{L,\text{max}}$, which is a constant that does not depend on β. One can then easily show that $w_H^{B,*}$ is increasing in β. Second, in Region 1(b), the piece rate for the low type is distorted and given by $w_L^* = \beta w_H^{B,*}$, which is easily derived from the expression for w_L^* in Region 1(b) given in Proposition 1 and the binding *(ICCLB)*. Hence, when the low type receives her full output from the good firm, then $\widehat{U}_L = (1 - \beta w_H^{B,*})\beta w_H^{B,*} \dfrac{\theta_L^2}{2} + \dfrac{(\beta w_H^{B,*})^2}{4}(\theta_L^2 - 2\rho\sigma^2)$, and plugging this into Equation (19) yields $w_H^{B,*} = \dfrac{\beta(\beta\theta_H^2 - \theta_L^2)}{\beta^2(\theta_H^2 - \theta_L^2) + (1 - \beta^2)\rho\sigma^2}$. This expression is non-negative if $\beta\theta_H^2 \geq \theta_L^2$, and, in particular, we have that $w_H^{B,*} \geq w_H^{B,sb} > 0$, because in the bad firm, the contract for the high type is distorted. Hence, it is sufficient to analyze $w_H^{B,*'}(\beta)$ under the condition that $\beta\theta_H^2 \geq \theta_L^2$. We have

$$
\begin{aligned}
w_H^{B,*'}(\beta) &= \frac{\beta^2\theta_L^2(\theta_H^2 - \theta_L^2) + \rho\sigma^2(2\beta\theta_H^2 - \theta_L^2 - \beta^2\theta_L^2)}{(\beta^2(\theta_H^2 - \theta_L^2 - \rho\sigma^2) + \rho\sigma^2)^2} \\
&\geq \frac{\beta^2\theta_L^2(\theta_H^2 - \theta_L^2) + \rho\sigma^2(1 - \beta^2)\theta_L^2}{(\beta^2(\theta_H^2 - \theta_L^2 - \rho\sigma^2) + \rho\sigma^2)^2} \geq 0,
\end{aligned}
$$

and the claim follows.

(ii). This is a straightforward consequence of part (i) and Proposition 1.

(iii). Follows directly from Proposition 1. $\square$

Proof of Proposition 6. Follows from Proposition 1 together with Lemma 2. $\square$

B Cross-subsidizing strategy

We formalize the minimum certainty equivalent $\widehat{U}^B_{L,CS}$ to be offered to the low type as result of a potential cross-subsidising strategy between the high and low types. This is used in the proofs of Proposition 4 and Lemma 2.

Of course, the bad firm never faces a loss when offering each type her expected output. However, taking into account that in the good firm's best response *(PCH)* is binding, the bad firm may have a profitable deviation by offering the high type less than her output, while offering more to the low type, since increasing the low type's information rent decreases the piece rate offered to the high type, thus reducing the inefficiency.[19]

The highest utility the bad firm can offer to the high type without incurring a loss (in expectation) when attracting her or both types is given by

$$\widehat{U}^B_{H,CS} := \max_{F^B_H, w^B_H, F^B_L, w^B_L} U^B_H(F^B_H, w^B_H) \tag{27}$$

subject to *(ICCLB), (ICCHB)* and

- $\alpha\left(\dfrac{1}{2}(1 - w^B_H)w^B_H\beta^2\theta^2_H - F^B_H\right)$

  $+ (1 - \alpha)\left(\dfrac{1}{2}(1 - w^B_L)w^B_L\beta^2\theta^2_L - F^B_L\right) = 0$ (break-even),

- $U_L(F^B_L, w^B_L) \geq \dfrac{\beta^4\theta^4_L}{4(\beta^2\theta^2_L + 2\rho\sigma^2)}$ (output L).

Any offer by the good firm to the high type with $\widehat{U}_H < \widehat{U}^B_{H,CS}$ will be outbid by the bad firm, so that $\widehat{U}^B_{H,CS}$ is the smallest certainty equivalent to be offered to the high type. The explicit expression for $\widehat{U}^B_{H,CS}$ given below is derived as follows: Using that *(ICCLB)* is binding, the break-even condition and $w^B_L = w^{B,sb}_L$, the high type's certainty equivalent is a function of her piece rate w^B_H only. Maximizing Equation (27) via the first-order condition yields

$$\widehat{U}^B_{H,CS} = \frac{\alpha^2\beta^4\theta^4_H}{4(\beta^2((2\alpha - 1)\theta^2_H + (1 - \alpha)\theta^2_L) + 2\alpha\rho\sigma^2)} + \frac{(1 - \alpha)\beta^4\theta^4_L}{4(\beta^2\theta^2_L + 2\rho\sigma^2)}. \tag{28}$$

This needs to be translated into the smallest certainty equivalent to be offered to the low type, which is given by

$$\widehat{U}^B_{L,CS} = U^B_L(F^B_H, w^B_H),$$

---

[19]This setup arises when α, the fraction of high types, is sufficiently large. The authors can provide details upon request.

with $U_H^B(F_H^B, w_H^B) = \widehat{U}_{H,CS}^B$ and $F_H^B = \frac{1}{2}(1 - w_H^B)w_H^B\beta^2\theta_H^2$. This offer ensures that the high type is offered $\widehat{U}_{H,CS}^B$ while fulfilling Equations (7a)–(7c). The explicit expression for $\widehat{U}_{L,CS}^B$ is then given by

$$\widehat{U}_{L,CS}^B = \widehat{U}_{H,CS}^B - \frac{\beta^2\left(\beta^2\theta_H^2 + \sqrt{\beta^4\theta_H^4 - 4\widehat{U}_{H,CS}^B(\beta^2\theta_H^2 + 2\rho\sigma^2)}\right)^2}{4(\beta^2\theta_H^2 + 2\rho\sigma^2)^2}(\theta_H^2 - \theta_L^2), \quad (29)$$

if condition (output L) of the optimisation problem (27) is fulfilled.

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