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Incentive effects of bonus taxes in a principal-agent model☆

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A B S T R A C T

Several countries have implemented bonus taxes for corporate executives in response to the current financial crisis. Using a principal-agent model, this paper investigates the incentive effects of bonus taxes by analyzing the agent's and principal's behavior. Specifically, we show how bonus taxes affect the agent's incentives to exert effort and the principal's decision regarding the composition of the compensation package (fixed salary and bonus rate). We find that, surprisingly, a bonus tax can increase the bonus rate and decrease the fixed salary if the agent is highly risk averse. Additionally, a bonus tax can induce the principal to pay higher bonuses even though the agent's effort unambiguously decreases. Nevertheless, a bonus tax reduces the overall salary of the agent. Further results are derived with respect to the existence and uniqueness of the equilibrium for a general effort cost function.

1. Introduction

In response to the current financial crisis, several countries have implemented bonus taxes for corporate executives in firms that received large amounts of federal bailout funds. For example, the US House of Representatives approved a 90% tax on bonuses in such firms. Similarly, Ireland introduced in January 2011 a 90% tax on executives' bonuses in banks that received government support. Moreover, in the UK, a bonus tax of 50% was imposed on bankers' bonuses for a period of several months in 2010. In Switzerland, the Council of States discussed proposals to introduce a tax on executive bonuses above CHF 3 million.

Despite their political relevance, the economic effects of bonus taxes have received little attention in academic research. This paper tries to fill part of this gap by developing basic insights into the functioning and consequences of bonus taxes on executive pay based on the principal-agent model of Holmstrom and Milgrom (1987). We introduce a tax that is levied on the agent's bonus to analyze how it affects the agent's incentive to exert effort, the composition of executives' compensation packages (fixed salary and bonus rate) as well as the agent's bonus payment and overall salary. The objective of our paper,

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however, is not to provide a normative analysis about the desirability of bonus taxes but rather, given their existence in the real world, to analyze the incentive effects of such taxes.

In our model, the principal chooses the fixed salary and the bonus rate by satisfying the agent's participation constraint and anticipating the agent's optimal effort level. For a general effort cost function, the agent unambiguously reacts to a higher bonus tax with lower effort, while the behavior of the principal depends on the agent's degree of risk aversion and the variance in the firm value. Basic intuition might suggest that by taxing the agent's bonus, the compensation package is shifted to the fixed salary. However, the opposite can occur if the agent is highly risk averse and/or the variance in the firm value is large. Moreover, a bonus tax can lead to the counterintuitive result that both the fixed salary and the bonus rate increase. Surprisingly, a higher bonus tax can induce the principal to pay higher bonuses even though the agent exerts less effort. However, the overall salary of the agent unambiguously decreases through a bonus tax. Further results are derived with respect to the existence and uniqueness of the equilibrium for a general effort cost function.

The remainder of the paper is structured as follows. Section 2 briefly reviews the related literature. Section 3 introduces our principal-agent model with its main assumptions and notations in Section 3.1. In Section 3.2, we solve the model and present the optimality conditions and equilibria. In Section 3.3, we compute the effects of bonus taxes on the equilibrium outcomes. Finally, Section 4 discusses the main insights and presents our conclusions.

2. Related literature

Despite the large body of literature and numerous theoretical and empirical studies on executive compensation, only a few papers have addressed the consequences of executive compensation regulation in general and the effects of bonus taxes in particular. For example, Dew-Becker (2009) reviews the history of government rules and regulations in the US that affects executive compensation. By discussing disclosure rules, advancements in corporate governance, and say-on-pay, Dew-Becker analyzes the evolution of pay regulation and concludes that mandatory say-on-pay could be the most effective and least harmful measure of controlling executive compensation. Knutt (2005) examines diverse regulatory issues from a legal point of view. He claims that the various attempts to regulate executive compensation, such as the disclosure and tax regulations, have not yet been effective.

Hall and Liebman (2000) analyze the extent to which tax policy influences the composition of executive compensation and discuss the consequences of rising stock-based pay.[1] Their empirical study shows that the dramatic explosion in executive stock-option pay since 1980 cannot be attributed to tax rate changes. Moreover, the so-called million dollar rule induced a substitution from fixed salary toward performance-related pay. Unlike Hall and Liebman (2000), who concentrate on a tax on stock-based pay, we study a tax that is levied on the agent's bonus.

Radulescu (2010) analyzes the effects of bonus taxes in a two-country, principal-agent model with relocation possibilities for the managers. The paper focuses on tax incidence and analyzes the effects of bonus taxes on firm profits, dividends and welfare in the case of a quadratic effort cost function. The paper shows that a bonus tax induces lower profits and dividends so that the incidence is borne by the shareholders. The welfare implications of bonus taxes depend on the relocation possibilities for the managers. In contrast to our model, in which we focus on the incentive effects of bonus taxes for a general cost function and derive an ambiguous effect of a bonus tax on the fixed and variable salary, Radulescu (2010) finds that the effort-based compensation component (bonus) unambiguously increases with a higher bonus tax.[2]

Finally, there is now a growing literature on regulating incentive pay in the financial sector.[3] For example, Hakenes and Schnabel (2012) show that the presence of bailout guarantees induce bankers to increase their risk-taking behavior and lead to a steeper compensation scheme. An upper limit on the bonus could alleviate these problems. Bolton et al. (2010) develop a theoretical model to show that the credit default swap reduces risk taking of executives at highly levered financial firms. Based on a model of workers in the financial sector, Besley and Ghatak (2011) show that bailouts induce lower effort and higher risk taking.

3. Model

3.1. Notations and assumptions

Our model is based on the principal-agent model of Holmstrom and Milgrom (1987) and introduces a tax denoted by $\tau \in (0, 1)$ that is levied on the agent's variable salary (bonus). We consider a single-period employment relationship in a firm between a risk-neutral principal (e.g., a firm's owner) and a risk-averse agent (e.g., CEO). The agent chooses the unobservable

[1] Based on a large sample of US firms during 1994–2004, Tzioumis (2008) empirically analyzes how the adaptation of CEO stock option plans is influenced by CEO and firm characteristics. Palmon et al. (2008) determine the optimal strike prices of stock options for executives in a simulation model.

[2] Cunat and Guadalupe (2009) utilize a panel of US executives and find that an increase in the financial sector through deregulations in the 1990s induced an increase in the variable and a decrease in the fixed components of executive pay. Using data from Germany, Kraft and Niederprüm (1999) show that a higher variance in firm profits decreases the variable salary component. Finally, Graziano and Parigi (1998) show in a principal agent model that more competition represented by a higher number of firms induces the agent to decrease efforts in the case of a low product differentiation.

[3] Bebchuk and Spamann (2010) identify the underlying mechanisms regarding the compensation structures for bankers that have produced incentives for excessive risk-taking.

action (effort) $a \in \mathbb{R}_0^+$ to produce a firm value given by $x = a + \varepsilon$, where ε is a normally distributed error term with $\varepsilon \sim N(0, \sigma_\varepsilon^2)$ representing potential effects on the firm value beyond the agent's control.[4] A high variance in the error term σ_ε^2 can be interpreted as a more uncertain economic environment that creates a high variance in the firm value or a situation in which the agent's performance cannot be measured precisely.

Because the principal can only observe the firm value x, the agent's effort a cannot be specified in a legally enforceable contract. The agent's effort generates costs according to a strictly convex cost function $c(a) \in C^3$ that satisfies

Assumption 1. $c'(a) > 0$, $c''(a) > 0$ for $a > 0$, $c'(0) = c''(0) = 0$. Moreover, $c'''(a) \geq 0$ for $a \geq 0$ and $\lim_{a \to \infty} c'(a) = \infty$.

In line with the agency literature, we assume that the principal offers the agent a linear employment contract that generates a payoff to the agent according to[5]

$$w(x) \equiv s + (1-\tau)bx = s + (1-\tau)b(a+\varepsilon),$$

where $s \in \mathbb{R}_0^+$ is the fixed salary component and bx is the variable salary or bonus payment given by the principal. We follow Gibbons (1998, p. 116) and refer to the incentive-based component $b \in (0, 1)$ as the bonus rate.[6] It should be noted that the gross salary paid by the principal is given by $W(x) \equiv s + bx$, and that $w(x) \equiv s + (1-\tau)bx$ is the net-of-tax salary received by the agent. The state receives the difference between gross and net salary as tax revenue τbx. We further assume that the agent has an exogenously given outside option, represented by his reservation utility $\widehat{u} \in \mathbb{R}_0^+$. The reservation utility can be interpreted as the utility the agent would receive in another firm or in a country without a bonus tax and therefore is assumed to be exogenous.

From the properties of the normal distribution, we derive that the agent's (net-of-tax) salary $w(x)$ is also normally distributed with

$$w(x) \sim N(s + (1-\tau)ba; (1-\tau)^2 b^2 \sigma_\varepsilon^2).$$

Thus, the expected salary of the agent is given by $E[w] = s + (1-\tau)ba \equiv \overline{w}$, and the variance of the salary is $V[w] = (1-\tau)^2 b^2 \sigma_\varepsilon^2 \equiv \sigma_w^2$.

We assume that the agent is risk-averse with a constant absolute risk-averse (CARA) utility function that is given by the negative exponential function $U(w, a) = -e^{-r(w-c(a))}$, where $r \in \mathbb{R}^+$ is the Arrow–Pratt measure of the agent's degree of absolute risk aversion. The expected value of this utility yields $E[U] \equiv \int U(w, a) f(w) dw$, where $f(w)$ is the probability density function of w. Because the salary is normally distributed with $w \sim N(\overline{w}, \sigma_w^2)$, the expected value of the agent's utility is given by $E[U] = -e^{-r(\overline{w}-c(a)-r\sigma_w^2/2)}$. Using a monotonic transformation, which preserves the ordering, we conclude that the agent's expected net utility $E[U_A]$ yields

$$E[U_A] \equiv s + (1-\tau)ba - \frac{r\sigma_\varepsilon^2}{2}(1-\tau)^2 b^2 - c(a).$$

The net utility is the certainty equivalent minus costs, where $(1/2) r\sigma_\varepsilon^2 (1-\tau)^2 b^2$ characterizes the agent's risk premium required to compensate him for the uncertainty in his expected salary.

The principal is assumed to be risk neutral because she is well diversified. Her profit π_P is the difference between the firm value and the agent's gross salary: $\pi_P \equiv x - W(x) = (1-b)x - s$. Hence, the principal's expected profit is given by

$$E[\pi_P] \equiv (1-b)a - s.$$

The timing is as follows. In $t = 0$, the state sets a certain level for the bonus tax $\tau \in (0, 1)$ that is levied on the agent's bonus payment. In $t = 1$, the principal offers the agent an employment contract with a fixed salary s and a bonus rate b. The agent accepts this contract if it guarantees him at least his reservation utility, which is given by $\widehat{u}$. In $t = 2$, after accepting the contract, the agent exerts effort a. In $t = 3$, the firm value x is realized, and all the payments are made in $t = 4$.

[4] Because we want to focus on the incentive effects of bonus taxes in a microeconomic environment of a firm and its employee, we neglect possible negative externalities of the agent's behavior on the economy as a whole. Hence, in our model, we do not analyze how a bonus tax might correct potential inefficiencies of the employment contract between the principal and the agent. Moreover, we do not aim to investigate how a bonus tax influences the risk-taking behavior of corporate executives.

[5] Linear contracts are widely used in the literature because of their analytical convenience (see, e.g., Baker, 2002; Feltham and Xie, 1994; Hughes et al., 2005). Holmstrom and Milgrom (1987) found the optimal dynamic compensation scheme to be linear for certain intertemporal contracting problems where the agent controls a stationary technology. Hellwig and Schmidt (2002) show that the result of Holmstrom and Milgrom does not only apply to continuous-time but also to discrete-time settings.

[6] Note that in the literature on executive compensation b is also referred to as the pay-performance sensitivity (PPS) or piece rate (see, e.g., Conyon and Sadler, 2001; Faulkender et al., 2010; Jensen and Murphy, 1990; Murphy, 1999).

3.2. Optimality conditions and equilibria

The agent maximizes his expected net utility $E[U_A]$ with respect to the effort level a so that the maximization problem is given by

$$\max_{a\geq 0}\left\{E[U_A]=s+(1-\tau)ba-\frac{r\sigma_\varepsilon^2}{2}(1-\tau)^2b^2-c(a)\right\}.$$

The corresponding first-order condition is

$$\frac{\partial E[U_A]}{\partial a}=(1-\tau)b-c'(a)=0 \tag{1}$$

and has a familiar interpretation. It states that the marginal benefit of effort must be equal to the marginal costs of effort in equilibrium. For a cost function that satisfies Assumption 1, the second-order condition for a maximum is fulfilled.

The principal maximizes her expected profit $E[\pi_P]$ and solves

$$\max_{(s,b)\geq 0}\left\{E[\pi_P]=(1-b)a-s\right\}$$

subject to[7]

$$E[U_A(a^*)]=s+(1-\tau)ba^*-\frac{r\sigma_\varepsilon^2}{2}(1-\tau)^2b^2-c(a^*)\geqslant\widehat{u}, \tag{2}$$

$$a^*\in arg\max_{a\geq 0}\ E[U_A]. \tag{3}$$

The first constraint is the participation constraint (PC) which reflects that the agent's expected utility must not be below his reservation utility $\widehat{u}$. The second constraint represents the incentive compatibility constraint (IC) derived from the agent's maximization problem. The principal is able to control the agent's effort a by choosing an appropriate bonus rate b. Therefore, instead of replacing a, we use the IC and replace b with $c'(a)/(1-\tau)$ to set up the associated Lagrangian $\mathcal{L}_P$. Then, the Lagrangian with multiplier λ is given by

$$\mathcal{L}_P(a,s,\lambda)\equiv a-\frac{ac'(a)}{1-\tau}-s+\lambda\left(s+c'(a)a-\frac{r\sigma_\varepsilon^2}{2}c'(a)^2-c(a)-\widehat{u}\right).$$

The corresponding first-order conditions are

$$\frac{\partial\mathcal{L}_P}{\partial a}=1-\frac{c'(a^*)}{1-\tau}-\frac{c''(a^*)}{1-\tau}a^*+\lambda[c''(a^*)a^*-c'(a^*)c''(a^*)r\sigma_\varepsilon^2]=0,$$
$$\frac{\partial\mathcal{L}_P}{\partial s}=-1+\lambda=0,\ \frac{\partial\mathcal{L}_P}{\partial\lambda}=s+c'(a^*)a^*-\frac{r\sigma_\varepsilon^2}{2}c'(a^*)^2-c(a^*)-\widehat{u}=0.$$

Note that the principal has an incentive to provide a compensation package so that the PC is binding, i.e., the agent's expected utility is equal to his reservation utility $\widehat{u}$. Therefore, the derivative of $\mathcal{L}_P$ with respect to λ equals zero. With the above system, the agent's optimality condition $c'(a^*)=(1-\tau)b^*$ and $\lambda=1$, we can rearrange the first-order condition of the principal and obtain[8]

$$1=\underbrace{\left(b^*+\frac{\tau}{1-\tau}c''(a^*)a^*\right)}_{\text{leakage effect}}+\underbrace{r\sigma_\varepsilon^2\cdot(1-\tau)b^*c''(a^*)}_{\text{risk effect}}. \tag{4}$$

Eq. (4) has an intuitive interpretation. A one-unit increase in the agent's effort (induced by a higher bonus rate) produces one-to-one higher expected revenue yielding a marginal revenue of one (lhs). The marginal revenue must be equal to the sum of the *leakage effect* (first term on rhs) and the *risk effect* (second term on rhs).[9] The former effect reflects the leakage in the contracting environment created through the bonus tax: the principal incurs the full cost of the bonus payment, while the agent receives only fraction $1-\tau$ of it. Recall that the state keeps fraction τ of the bonus payment. The leakage effect makes the use of bonuses more costly for the principal and is composed of two parts: (i) on the one hand, higher effort generates higher costs for the principal, given by $b^*+c''(a^*)a^*/(1-\tau)$, as she must pay the agent a higher bonus and incurs the full cost of the bonus payment.[10] (ii) On the other hand, higher effort induces an income effect $-c''(a^*)a^*$ for the agent so

[7] We implicitly assume that, e.g., the outside option $\hat{u}$ and the bonus tax τ are sufficiently small so that the principal obtains non-negative equilibrium profits.

[8] As shown in Appendix A.1, the second-order condition for a maximum is satisfied if $c'''(a^*)\geq 0$.

[9] We are grateful to an anonymous referee who pointed out the leakage effect.

[10] The first term represents the higher bonus paid by the principal, induced by a one-unit increase in the agent's effort and the second term reflects the effort-induced effect on the bonus rate.

that the PC is relaxed. This income effect takes into account that the agent receives only fraction $1 - \tau$ of the bonus payment. Combining (i) and (ii) yields the leakage effect.

The risk effect indicates that higher effort implies higher uncertainty for the agent regarding his expected salary because the salary variance increases so that the PC is tightened. It follows that the principal has to compensate the agent with a larger risk premium to accept the higher risk. It is important to mention that a higher degree of risk aversion of the agent and/or a larger variance in the firm value strengthen the risk effect because the risk premium increases. As we will see below, the risk effect plays a crucial role and may lead to counter-intuitive results regarding the effect of a bonus tax.

The next proposition establishes the existence and uniqueness of the equilibrium and presents the optimality conditions deduced from the first-order conditions of the agent and the principal.

Proposition 1.

(i) The equilibrium (b^*, s^*, a^*) exists and is unique.
(ii) The principal sets the optimal compensation package (b^*, s^*) as

$$b^* = \frac{(1-\tau) - a^*c''(a^*)\tau}{(1-\tau)[1+(1-\tau)c''(a^*)r\sigma_\varepsilon^2]} \quad \text{and} \quad s^* = \widehat{u} - c'(a^*)a^* + \frac{c'(a^*)^2}{2}r\sigma_\varepsilon^2 + c(a^*). \tag{5}$$

(iiii) The agent exerts optimal effort a^* according to

$$c'(a^*) = (1-\tau)b^*. \tag{6}$$

Proof. See Appendix A.1. □

According to Proposition 1, a unique equilibrium exists for a general cost function that satisfies Assumption 1. The optimal bonus rate b^*, the optimal fixed salary s^*, and the optimal effort level a^* in equilibrium are defined implicitly by Eqs. (5) and (6). The proposition further shows that the bonus rate b^* in equilibrium depends on the agent's degree of risk aversion r, the variance in the firm value σ_ε^2, the curvature of the agent's effort cost $c''(a^*)$, the bonus tax τ and the agent's equilibrium effort a^*.

3.3. Effects of a bonus tax

In this section, we analyze how a bonus tax τ affects the agent's effort level a^*, the bonus rate b^*, and the fixed salary s^* in equilibrium. For notational simplicity, henceforth the parameter ρ stands for the product of the agent's level of risk aversion r and the variance in the firm value σ_ε^2, i.e., $\rho \equiv r\sigma_\varepsilon^2$. We refer to ρ as the "risk parameter" and establish the following proposition[11]:

Proposition 2. *A higher bonus tax τ has the following effects in equilibrium:*

(i) The agent unambiguously reduces his effort, i.e., $\frac{da^*}{d\tau} < 0$.
(ii) The principal increases (decreases) the bonus rate b^* if the risk parameter is larger (lower) than ρ_b, i.e.,

$$\frac{db^*}{d\tau} \gtreqless 0 \Leftrightarrow \rho \gtreqless \rho_b \equiv \frac{c''(a^*)[1-(1+\tau)b^* + c''(a^*)a^*] - \tau b^* c'''(a^*)a^*}{c'(a^*)[2c''(a^*)^2 + c'(a^*)c'''(a^*)]}.$$

(iii) The principal decreases (increases) the fixed salary s^* if the risk parameter is larger (lower) than ρ_s, i.e.,

$$\frac{ds^*}{d\tau} \lesseqgtr 0 \Leftrightarrow \rho \gtreqless \rho_s \equiv \frac{a^*}{c'(a^*)}.$$

Proof. See Appendix A.2. □

To highlight the results from Proposition 2, we provide Example 1 and illustrate the results in Fig. 1.

Example 1. Suppose that $c(a) = (\phi/2)a^2$. We set $\phi = 1$, $\widehat{u} = 0.1$ and restrict the range of bonus taxes to the interval $\tau \in [0, 0.5]$ for which the principal's profits are non-negative. Note that the thresholds for the risk parameter in Proposition 2 are given by $\rho_b = \rho_s = 1$. Fig. 1 depicts the bonus rate in Panel (a), the fixed salary in Panel (b) and the agent's effort in Panel (c) on

[11] Note that in the case of an endogenously determined outside option $\hat{u}(\tau)$, which negatively depends on τ, the results of Proposition 2 remain unchanged except for the effect of a bonus tax on the fixed salary s^*. In this case, only the condition in part (iii) changes to $\frac{ds^*}{d\tau} = \frac{d\hat{u}(\tau)}{d\tau} + \frac{da^*}{d\tau}c''(a^*)[\rho c'(a^*) - a^*] \gtreqless 0$.

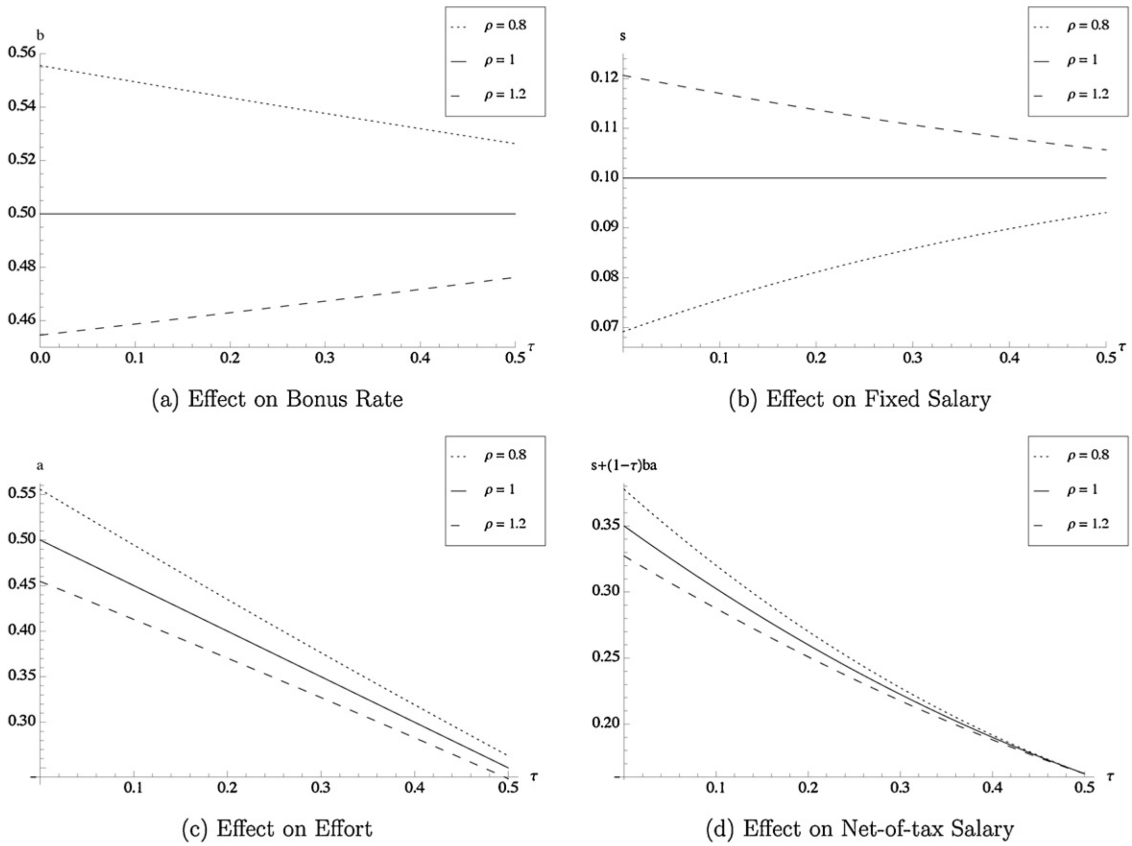

Fig. 1. Bonus tax effects for quadratic cost functions.

the *y*-axis as functions of the bonus tax on the *x*-axis for different risk parameters ρ. We choose $\rho \in \{0.8, 1, 1.2\}$ to highlight the different cases in Proposition 2. Panel (a) shows that a higher bonus tax increases (decreases) the bonus rate if the risk parameter is larger (lower) than 1. The opposite is true with respect to the fixed salary (Panel b). If the risk parameter is equal to 1, then a bonus tax has neither an effect on the fixed salary nor on the bonus rate. Panel (c) shows that the agent's effort unambiguously decreases with a higher bonus tax.

Now, we return to the case of a general cost function and provide the intuition for the results of Proposition 2. According to part (i), the agent unambiguously reduces effort as a reaction to a higher bonus tax. Recall from the optimality condition that the agent chooses effort so that the marginal effort costs equal the marginal benefit of effort in equilibrium, i.e., $c'(a^*) = (1-\tau)b^*$. The direct tax effect $(1-\tau)$ has a negative effect on the marginal benefit of effort (rhs). Based on part (ii) of Proposition 2, we know that b^* decreases in τ if $\rho < \rho_b$, which further reduces the marginal benefit. It follows that the marginal benefit unambiguously decreases if the bonus tax increases. In this case, it is clear that the agent reduces his effort in equilibrium. If $\rho > \rho_b$, then the bonus rate b^* increases through a higher bonus tax, which results in a positive effect on the marginal benefit of effort. However, the direct tax effect always overcompensates for a higher b^* so that the marginal benefit still decreases. Also in this case, the agent will reduce his effort in equilibrium.[12]

Parts (ii) and (iii) show that, contrary to its intention, a bonus tax can induce the principal to set a higher bonus rate and a lower fixed salary. Particularly, the reaction of the principal to a higher bonus tax crucially depends on the variance in the firm value and how risk averse the agent is. If the corresponding risk parameter is sufficiently large (i.e., $\rho > \rho_b$), then a higher bonus tax leads to a higher bonus rate and thus increases the incentive power of the contract. Yet, if ρ is larger than another threshold (i.e., $\rho > \rho_s$), then a higher bonus tax leads to a lower fixed salary.[13]

The intuition for the effect on the bonus rate is as follows. From the principal's first-order condition (4), we deduce that a higher bonus tax does not influence the principal's marginal revenue; the marginal revenue of effort is constant and equals one (lhs). However, a bonus tax influences the leakage and risk effects (rhs). On the one hand, a higher bonus tax strengthens

[12] To trigger an increase in the agent's effort, the principal would have to increase the bonus rate sufficiently strongly to compensate for the decrease in $1-\tau$. However, the principal has no incentives to increase b^* in such a way because this would violate her first-order condition.

[13] It should be noted that the bonus rate b^* and the fixed salary s^* depend on the risk parameter so that the threshold values ρ_b and ρ_s themselves depend on ρ.

the leakage effect because the agent receives a lower fraction of the bonus paid by the principal. As a consequence, the principal has incentives to reduce the bonus rate. On the other hand, a higher bonus tax decreases the risk premium required to compensate the agent for the uncertainty in his expected salary due to a lower salary variance. It follows that the principal has incentives to increase the bonus rate. Hence, the leakage effect induces the principal to decrease the bonus rate, while the risk effect provides incentives to increase the bonus rate. Whether the bonus rate increases or decreases through the introduction of a bonus tax depends on the relative size of these two effects. Because a higher risk parameter ρ has no direct influence on the leakage effect but it increases the risk premium and therefore strengthens the risk effect, the risk effect will dominate the leakage effect if ρ is sufficiently large (i.e., $\rho > \rho_b$). In this case a higher bonus tax induces the principal to increase the bonus rate b^*. If, however, $\rho < \rho_b$, then the principal decreases the bonus rate b^* through a higher bonus tax because the leakage effect dominates the risk effect. If $\rho = \rho_b$, then the leakage and risk effects balance each other out so that b^* is not affected by a change in the bonus tax.

In a next step, we provide the intuition for the principal's behavior with respect to the fixed salary s^*. The partial derivative of s^* with respect to τ is given by

$$\frac{ds^*}{d\tau} = [\underbrace{c''(a^*)a^*}_{\text{income effect}} - \underbrace{\rho(1-\tau)b^*c''(a^*)}_{\text{risk effect}}]\underbrace{\left(-\frac{da^*}{d\tau}\right)}_{>0}.$$

From the discussion regarding Eq. (4), we know that the income effect relaxes and the risk effect tightens the PC. We derive the following effects of a higher bonus tax. On the one hand, a higher tax diminishes the income effect because the agent receives a lower fraction of the bonus payment, and hence, the principal must increase the fixed salary to satisfy the PC. On the other hand, a higher tax lowers the salary variance in the agent's salary yielding a lower risk premium. In this case, the principal can decrease the fixed salary to satisfy the PC. Similar to above, the risk parameter influences the magnitude of the risk effect and therefore determines how bonus taxes affect the fixed salary. If $\rho > \rho_s$, then the risk effect dominates the income effect so that the principal has an incentive to decrease the fixed salary in equilibrium: that is, $\frac{ds^*}{d\tau} < 0$. The opposite holds true if $\rho < \rho_s$. In this case, the income effect dominates the risk effect and the principal increases the fixed salary: that is, $\frac{ds^*}{d\tau} > 0$. Note that if $\rho = \rho_s$, then both effects are equally strong and s^* is not affected by a change in τ.

Based on parts (ii) and (iii) of Proposition 2, we can derive the following corollary:

Corollary 1. *The introduction of a bonus tax does not necessarily imply a substitution effect between the fixed salary s^* and the bonus rate b^*.*

Basic intuition might suggest that a bonus tax induces a substitution between the fixed salary and the bonus rate. However, such a substitution effect is not guaranteed because the threshold values ρ_s and ρ_b are not necessarily equal for a general cost function. For example, a higher bonus tax can induce a simultaneous increase in the fixed salary and the bonus rate. Such a pattern can occur, e.g., in the case of a cubic cost function.[14] However, for a quadratic cost function, the threshold values ρ_s and ρ_b are equal. In this case, a substitution effect is present between s^* and b^*, i.e., whenever a tax change induces the principal to increase the bonus rate, she will lower the fixed salary and vice versa.

In the next proposition, we analyze how a bonus tax affects the expected bonus payment and the expected salary in the case of a quadratic effort cost function $c(a) = (\phi/2)a^2$.

Proposition 3. *For a quadratic cost function, a higher bonus tax τ has the following effects in equilibrium:*

(i) The expected bonus payment b^*a^* given by the principal increases until the maximum is reached for a bonus tax given by $\tau' \equiv \frac{\rho\phi-3}{\rho\phi-1}$ if $\rho \in (\frac{3}{\phi}, \frac{5-\tau}{\phi(1-\tau)})$. However, the agent unambiguously receives a lower expected bonus payment $(1-\tau)b^*a^*$.
(ii) The expected gross salary $s^* + b^*a^*$ paid by the principal and the expected net-of-tax salary $s^* + (1-\tau)b^*a^*$ received by the agent unambiguously decrease.

Proof. See Appendix A.3. □

Part (i) of the proposition posits that the bonus paid by the principal can increase if these payments are taxed. This surprising result emerges if the risk parameter is sufficiently large (i.e., $\rho > 3/\phi$). Recall that the agent always reduces effort a^* with a higher bonus tax and that the principal's reaction depends on ρ.[15] It is clear that the bonus payment cannot increase if $\rho < 1/\phi$, because then, the principal also decreases the bonus rate b^*. Hence, a necessary condition to obtain an increase in the bonus payment with a higher tax rate is $\rho > 1/\phi$. According to Proposition 3, the threshold value of the risk parameter above which the bonus payment increases with the introduction of a bonus tax is given by $\rho = 3/\phi$. That is, only if $\rho > 3/\phi$ will the increase in the bonus rate compensate for the decrease in the agent's effort level. In this case, the bonus payment increases with a higher tax until the maximum is reached for $\tau = \tau'$. Raising the bonus tax above τ' decreases the bonus payment so that it can be even lower than in the benchmark case without a tax. As the state keeps τb^*a^*, the agent only receives $(1-\tau)b^*a^*$,

[14] Detailed simulation results for different cost functions are available from the corresponding author upon request.
[15] Note that the thresholds ρ_s and ρ_b are given by $\rho_s = \rho_b = 1/\phi$ for $c(a) = (\phi/2)a^2$.

which is always lower than without a tax. That is, the tax-induced decrease in $(1-\tau)$ always compensates for a potential increase in the bonus payment.

Part (ii) examines how a bonus tax affects the agent's salary.[16] We find that a bonus tax unambiguously induces a decrease in the gross salary, and consequently, also in the net-of-tax salary. Hence, a bonus tax is an effective policy instrument in reducing the agent's (gross and net-of-tax) salary. The intuition regarding the effect on the gross salary is as follows. If $\rho < 1/\phi$, then the increase in the fixed salary s^* cannot compensate for the decrease in the bonus payment b^*a^*. If $\rho \in (1/\phi, 3/\phi)$ both the fixed salary and the bonus payment decrease and if $\rho > 3/\phi$, then the decrease in the fixed salary outweighs the increase in the bonus payment so that the agent's gross salary unambiguously decreases independent of the risk parameter. It immediately follows that also the net-of-tax salary decreases. See Panel (d) of Fig. 1, which depicts the agent's net-of-tax salary (y-axis) as a function of the bonus tax (x-axis) for different risk parameters.

It should be noted that the risk parameter influences how strong the salary decreases with a higher bonus tax. For example, a lower degree of risk aversion on the part of the agent and/or a lower variance in the firm value engender a stronger decrease in the agent's gross salary.

4. Conclusion

This paper has investigated the consequences of taxing the agent's bonus in a principal-agent model. A bonus tax has different effects on the fixed salary and the bonus rate because the principal sets an optimal compensation package on the conditions that the agent is expected to reach at least his reservation utility and the package is incentive compatible. To determine the composition of the package, the principal anticipates that a higher bonus tax will increase the leakage in the contracting environment because she incurs the full cost of the bonus payment, while the agent receives only a fraction of it. This leakage effect makes the use of bonuses more costly for the principal. However, a higher bonus tax decreases the risk premium required to compensate the agent for the uncertainty in his expected salary due to a lower salary variance. This risk effect provides the principal with incentives to increase the bonus rate. Whether the bonus rate increases or decreases through the introduction of bonus taxes depends on the relative size of these two effects. Our model further shows that a bonus tax does not necessarily induce the principal to substitute variable salary with fixed salary for a general effort cost function. In particular, it is possible that a higher bonus tax simultaneously increases the fixed salary component and the bonus rate.

Moreover, we derive that the agent unambiguously reacts to a higher bonus tax with lower effort. For quadratic effort costs, despite a tax-induced effort reduction, a higher bonus tax induces the principal to pay higher bonuses if the agent is sufficiently risk averse and/or the variance in the firm value is sufficiently large. In this case, the increase in the bonus rate overcompensates for the decrease in the agent's effort. Therefore, it is not guaranteed that firms will have to pay lower bonuses after implementing a bonus tax. Nevertheless, a bonus tax reduces the overall salary of the agent so that a bonus tax proves to be an effective policy instrument in reducing the agent's salary. Hereby, the reduction of the agent's salary is more pronounced the lower the risk parameter.

To sum up, a bonus tax influences both the overall size and the structure of the agent's salary. For example, if the agent is highly risk averse, then the reduction in the agent's gross salary induced by a bonus tax is relatively small and, in addition, the principal shifts the compensation package from the fixed salary to the variable salary. However, if the agent is not too risk averse, then a bonus tax induces a relatively large reduction in the gross salary and also shifts the compensation package towards the fixed salary.

Our model yields potentially testable comparative-static results. In particular, our model might help to predict the sectors and firms in which bonuses would decrease or increase. In uncertain economic environments and/or in firms, in which the monitoring and evaluation of the manager's performance is comparatively hard, we expect that bonus taxes will induce a firm to pay higher bonuses. Additionally, we do not expect bonus taxes to have the effect of shifting the bonus rate towards a fixed salary. That is, we anticipate low fixed salaries and high bonus rates. Moreover, our model predicts that the overall salary will only experience a relatively small reduction. We can derive the following examples of firms for these predictions: (i) new-economy firms: These firms tend to operate in more uncertain economic environments than old-economy firms. In addition, it might be more difficult to observe the manager's marginal contribution in new-economy firms because these firms grow faster, are more R&D intensive and have larger market-to-book ratios than old-economy firms (see Ittner et al., 2003). (ii) Large firms: according to Schaefer (1998), large firms have more noisy measures of individual performance than small firms. Moreover, in large firms, one manager's action has less influence on the firm value than it might have in small firms. (iii) Privately held firms: Marino and Zabojnik (2008) suggest that it is harder for privately held firms to evaluate their managers because a public firm's stock price provides an informative measure of performance which is less available in privately held firms.

Our simple model may serve as a basic framework to further analyze bonus taxes in a principal-agent model. There is a broad range of further applications and model extensions. For instance, an interesting avenue for further research could be the extension of our model to more than one period. An agent's effort decisions are often connected over time, and working contracts extend over several time periods. The implementation of these dynamics in the model could shed more light on

[16] We are grateful to an anonymous referee who suggested to analyze the overall salary.

the impact of bonus taxes on executive pay. Furthermore, interesting extensions would be to analyze the effects of bonus taxes on executives' risk-taking behavior or to study the welfare implications of bonus taxes.

Appendix A.

A.1. Proof of Proposition 1

First, we compute the condition under which the principal's second-order condition is satisfied. The first-order condition of the principal can be written as

$$1-\gamma^*-\frac{c''(a^*)}{1-\tau}a^*+c''(a^*)a^*-(1-\tau)\gamma^*c''(a^*)r\sigma_\varepsilon^2=0.$$

To ensure that the second-order condition for a maximum is satisfied, a lower bound of the third order derivative of the cost function is required at a^*, i.e.,

$$c'''(a^*)\geq\Psi^*\equiv -c''(a^*)\frac{1+\tau+(1-\tau)c''(a^*)r\sigma_\varepsilon^2}{a^*\tau+(1-\tau)c'(a^*)r\sigma_\varepsilon^2}. \tag{A.1}$$

This inequality is satisfied because we assumed that $c'''(a)\geq 0$ for $a\geq 0$.

Second, we derive the optimality conditions. By solving Eq. (4), we obtain the optimal bonus rate b^* as

$$b^*=\frac{(1-\tau)-a^*c''(a^*)\tau}{(1-\tau)[1+(1-\tau)c''(a^*)r\sigma_\varepsilon^2]}. \tag{A.2}$$

With the binding PC, we calculate the optimal fixed salary s^* as

$$s^*=\widehat{u}-c'(a^*)a^*+\frac{c'(a^*)^2}{2}r\sigma_\varepsilon^2+c(a^*). \tag{A.3}$$

From Eq. (1), it is straightforward to derive the agent's optimality condition $c'(a^*)=(1-\tau)b^*$.

Third, we show that the equilibrium (b^*, s^*, a^*) exists and is unique. By combining the two optimality conditions

$$c'(a)=(1-\tau)b \quad\text{and}\quad b=\frac{(1-\tau)-ac''(a)\tau}{(1-\tau)[1+(1-\tau)c''(a)r\sigma_\varepsilon^2]},$$

we obtain

$$\underbrace{1-\tau}_{\equiv\kappa_{lhs}} = \underbrace{c'(a)+c''(a)(a\tau+(1-\tau)r\sigma_\varepsilon^2c'(a))}_{\equiv\kappa_{rhs}(a)}. \tag{A.4}$$

The left-hand side κ_{lhs} of Eq. (A.4) is independent of a and the right-hand side $\kappa_{rhs}(a)$ is a continuous function in a because the cost function satisfies Assumption 1. (i) For $a=0$, we obtain $\kappa_{lhs}=1-\tau>0=\kappa_{rhs}(0)$. (ii) For $a>0$, we derive

$$\frac{\partial\kappa_{rhs}(a)}{\partial a}>0\Leftrightarrow c'''(a)>\Psi(a)=-c''(a)\frac{1+\tau+(1-\tau)c''(a)r\sigma_\varepsilon^2}{a\tau+(1-\tau)c'(a)r\sigma_\varepsilon^2}. \tag{A.5}$$

Because $\Psi(a)<0$ for $a>0$ and according to Assumption 1, $c'''(a)\geq 0$, we conclude that $\frac{\partial\kappa_{rhs}(a)}{\partial a}>0$. Thus, $\kappa_{rhs}(a)$ is a monotonically increasing function in a. Combining (i) and (ii) and using the assumption $\lim_{a\to\infty} c'(a)=\infty$, it is guaranteed that $\kappa_{rhs}(a)$ passes the constant κ_{lhs} for a certain effort $a=a^*>0$. Hence, there exist exactly one intersection, which defines the unique equilibrium a^*. Plugging a^* into Eqs. (A.2) and (A.3) yields the other equilibrium values (b^*, s^*).

A.2. Proof of Proposition 2

To prove parts (i) and (ii), we use the optimality conditions

$$c'(a^*)=(1-\tau)b^* \text{ and } b^*=\frac{(1-\tau)-a^*c''(a^*)\tau}{(1-\tau)[1+(1-\tau)c''(a^*)\rho]},$$

rearrange them and obtain

$$g_1(a^*,b^*,\tau):=c'(a^*)-(1-\tau)b^*=0,$$
$$g_2(a^*,b^*,\tau):=(1-\tau)-a^*c''(a^*)\tau-(1-\tau)b^*[1+(1-\tau)c''(a^*)\rho]=0.$$

Next, we derive the total differential of $g_1(a^*, b^*, \tau) = 0$ and $g_2(a^*, b^*, \tau) = 0$:

$$\frac{\partial g_1}{\partial a^*}da^* + \frac{\partial g_1}{\partial b^*}db^* + \frac{\partial g_1}{\partial \tau}d\tau = 0,$$
$$\frac{\partial g_2}{\partial a^*}da^* + \frac{\partial g_2}{\partial b^*}db^* + \frac{\partial g_2}{\partial \tau}d\tau = 0.$$

The total differential can also be written as

$$\begin{bmatrix} g_{1a} & g_{1b} \\ g_{2a} & g_{2b} \end{bmatrix} \begin{bmatrix} da^* \\ db^* \end{bmatrix} = \begin{bmatrix} -g_{1\tau} \\ -g_{2\tau} \end{bmatrix} d\tau, \tag{A.6}$$

where

$$\begin{aligned} g_{1a} &= \frac{\partial g_1}{\partial a^*} = c''(a^*), g_{1b} = \frac{\partial g_1}{\partial b^*} = -(1-\tau), g_{1\tau} = \frac{\partial g_1}{\partial \tau} = b^*, \\ g_{2a} &= \frac{\partial g_2}{\partial a^*} = -[\tau c''(a^*) + c'''(a^*)(a^*\tau + (1-\tau)^2 b^* \rho)], \\ g_{2b} &= \frac{\partial g_2}{\partial b^*} = -(1-\tau)[1 + \rho(1-\tau)c''(a^*)], \\ g_{2\tau} &= \frac{\partial g_2}{\partial \tau} = b^* - 1 - c''(a^*)[a^* - 2b^*\rho(1-\tau)]. \end{aligned} \tag{A.7}$$

Applying Cramer's rule to (A.6), we derive

$$\frac{da^*}{d\tau} = \frac{g_{1b}g_{2\tau} - g_{2b}g_{1\tau}}{g_{1a}g_{2b} - g_{1b}g_{2a}} \text{ and } \frac{db^*}{d\tau} = \frac{g_{2a}g_{1\tau} - g_{1a}g_{2\tau}}{g_{1a}g_{2b} - g_{1b}g_{2a}}. \tag{A.8}$$

Plugging (A.7) into (A.8), we obtain

$$\frac{da^*}{d\tau} = \frac{c''(a^*)[(1-\tau)b^*\rho - a^*] - 1}{\zeta},$$
$$\frac{db^*}{d\tau} = \frac{b^*(a^*\tau + \rho(1-\tau)^2 b^*)c'''(a^*) - c''(a^*)[1 - (1+\tau)b^* + (a^* - 2\rho(1-\tau)b^*)c''(a^*)]}{(1-\tau)\zeta},$$

with $\zeta \equiv c''(a^*)[1 + \tau + (1-\tau)c''(a^*)\rho] + c'''(a^*)[a^*\tau + (1-\tau)^2 b^* \rho]$. It follows that

$$\frac{db^*}{d\tau} = 0 \Leftrightarrow \rho = \rho_b \equiv \frac{c''(a^*)(1 - (1+\tau)b^* + c''(a^*)a^*) - \tau b^* c'''(a^*)a^*}{c'(a^*)[2c''(a^*)^2 + c'(a^*)c'''(a^*)]}.$$

It is straightforward to show that $\frac{d[db^*/d\tau]}{d\rho} > 0$, i.e., $\frac{db^*}{d\tau}$ is a monotonically increasing function in ρ. It follows that $\frac{db^*}{d\tau} \gtreqless 0 \Leftrightarrow \rho \gtreqless \rho_b$, which proves part (ii) of the proposition.

Regarding the agent's optimal effort a^*, with $c'''(a^*) \geq 0$,

$$\frac{da^*}{d\tau} \gtreqless 0 \Leftrightarrow \rho \gtreqless \rho_a \equiv \frac{1 + c''(a^*)a^*}{c'(a^*)c''(a^*)}. \tag{A.9}$$

At first glance, given that the risk parameter is sufficiently large, i.e., $\rho > \rho_a$, it is possible that the agent exerts more effort in equilibrium if the bonus tax increases. However, we will provide a proof by contradiction to show that the agent always reduces his effort with a higher bonus tax. Suppose that $\frac{da^*}{d\tau} \geq 0$. This assumption directly implies that $\frac{db^*}{d\tau} > 0$ because $c'(a^*) = (1-\tau)b^*$.[17] Using the PC and the IC, we rearrange the principal's first-order condition and obtain

$$1 - b^* = \underbrace{c''(a^*)}_{\text{not dec. in}\,\tau} [\rho \underbrace{c'(a^*)}_{\text{not dec. in}\,\tau} + \underbrace{a^*}_{\text{not dec. in}\,\tau} \underbrace{\frac{\tau}{(1-\tau)}}_{\text{inc. in}\,\tau}]. \tag{A.10}$$

Under the assumption $\frac{da^*}{d\tau} \geq 0$, the rhs of Eq. (A.10) increases with a higher bonus tax τ. It follows that b^* on the lhs, which is by definition in the interval (0, 1), must decrease (i.e., $\frac{db^*}{d\tau} < 0$) to guarantee also an increase of the lhs. This result, however, contradicts the assumption $\frac{da^*}{d\tau} \geq 0$, which implies $\frac{db^*}{d\tau} > 0$. Hence, our assumption was wrong and it must be the case that $\frac{da^*}{d\tau} < 0$. This proves part (i) of the proposition.

[17] A higher bonus tax decreases the rhs of this equation and a necessary condition to guarantee an increase of the lhs is $\frac{db^*}{d\tau} > 0$.

Proof of part (iii). Based on the optimality condition regarding the fixed salary $s^* = \widehat{u} - c'(a^*)a^* + \frac{c'(a^*)^2}{2}\rho + c(a^*)$, we compute $\frac{ds^*}{d\tau} = \frac{da^*}{d\tau}c''(a^*)[\rho c'(a^*) - a^*]$. With $\frac{da^*}{d\tau} < 0$, we conclude $\frac{ds^*}{d\tau} \lesseqgtr 0 \Leftrightarrow \rho \gtreqless \rho_s \equiv \frac{a^*}{c'(a^*)}$. This proves part (iii) and completes the proof of the proposition.

A.3. Proof of Proposition 3

For a quadratic cost function $c(a) = (\phi/2)a^2$, we compute the optimal compensation package (b^*, s^*) and effort a^* as

$$(b^*, s^*) = \left(\frac{1}{1+\tau+\rho\phi(1-\tau)}, \widehat{u} - \frac{(1-\rho\phi)(1-\tau)^2}{2\phi[1+\tau+\rho\phi(1-\tau)]^2}\right), \quad a^* = \frac{1-\tau}{\phi[1+\tau+\rho\phi(1-\tau)]}.$$

Proof of part (i). The partial derivative of the expected bonus b^*a^* (paid by the principal) with respect to τ is given by

$$\frac{\partial(b^*a^*)}{\partial\tau} = \frac{\tau - 3 + \phi\rho(1-\tau)}{\phi[1+\tau+\phi\rho(1-\tau)]^3} = 0 \Leftrightarrow \tau = \tau' \equiv \frac{\rho\phi - 3}{\rho\phi - 1}.$$

If $\rho < 1/\phi$, then b^*a^* is a convex function in τ and has a minimum at $\tau = \tau'$. If $\rho \in \left(\frac{1}{\phi}, \frac{5-\tau}{\phi(1-\tau)}\right)$, then b^*a^* is a concave function in τ and has a maximum at $\tau = \tau'$. Moreover, we derive that for $\rho \in (1/\phi, 3/\phi)$, the threshold τ' is negative and for $\rho < 1/\phi$ or $\rho > 3/\phi$, τ' is positive. It follows that ρ has to be in the interval $\left(\frac{3}{\phi}, \frac{5-\tau}{\phi(1-\tau)}\right)$ to guarantee that the bonus paid by the principal increases with a higher bonus tax until the maximum is reached for $\tau = \tau'$. Moreover, the partial derivative of the expected bonus $(1-\tau)b^*a^*$ (received by the agent) with respect to τ is given by

$$\frac{\partial((1-\tau)b^*a^*)}{\partial\tau} = -\frac{4(1-\tau)}{\phi[1+\tau+\rho\phi(1-\tau)]^3} < 0.$$

Hence, the bonus received by the agent always decreases with a higher bonus tax.

Proof of part (ii). To show that the expected gross salary $s^* + b^*a^*$ and the net-of-tax salary $s^* + (1-\tau)b^*a^*$ decrease in τ, we compute

$$\frac{\partial(s^* + b^*a^*)}{\partial\tau} = -\frac{1}{\phi[1+\tau+\rho\phi(1-\tau)]^2} < 0,$$
$$\frac{\partial(s^* + (1-\tau)b^*a^*)}{\partial\tau} = -\frac{2(1+\rho\phi)(1-\tau)}{\phi[1+\tau+\rho\phi(1-\tau)]^3} < 0,$$

which proves the claim. Moreover, $\frac{\partial^2(s^*+b^*a^*)}{\partial\tau\partial\rho} = \frac{2(1-\tau)}{[1+\tau+\rho\phi(1-\tau)]^3} > 0$, which shows that the decrease in the gross salary is stronger the lower the risk parameter ρ.

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