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The impact of corporate taxes and flexibility on entrepreneurial decisions with moral hazard and simultaneous firm and personal level taxation

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Abstract

In this paper we investigate the incentive effects of corporate taxes in an agency setting with a principal facing an investment opportunity including an abandonment option. We are particularly interested in the interplay of taxation and the real option on the principal's incentives to motivate the agent to work hard. First, we extend the well-known studies on tax effects on decision making under uncertainty to moral hazard settings. In a benchmark case we find that, as confirmed in current literature, the corporate income tax has no incentive effect. If the principal accounts for the real option we show that paradoxical tax effects may occur. Also, with respect to the effect of the real option on the incentive problem we show that the option makes it less attractive for the principal to induce the agent to exert a high effort.

Keywords: Tax Effects; Real Options; Moral Hazard; Investment Decisions

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1 Introduction

It is widely recognized that the presence of agency conflicts typically influences investment decisions.[1] Many companies use performance-based remuneration to counteract these incentive problems. Furthermore, it is well-known that taxes affect entrepreneurial decisions and should be considered when assessing investment opportunities. Analyzing tax effects in an agency setting will allow us to improve our knowledge about how investors respond to tax reforms. A principal who accounts for tax effects in decision making processes has to figure out how taxes affect the impact of remuneration paid to the agent as an incentive on the agent's effort level and the resulting likelihood that he will receive high post-tax cash flows from the investment. Thus, besides tax effects, the investor simultaneously has to be aware of the possibility of agency conflicts and also their implications for the applied optimization routine.

So far there have been few attempts at studying the interaction between taxation and agency conflicts and its influence on investment decisions. However, in this paper we do not try to develop a general theory of the interaction between taxation and agency conflicts. Instead we address a very specific question. We investigate whether taxation influences the principal's willingness to provide the agent with incentives. First, we generalize the well-known concepts of normal and paradoxical tax effects to adverse selection settings. Thus, a so-called paradoxical tax effect occurs if an increase in tax rates increases the principal's willingness to induce the agent to work hard. Conversely, if a higher tax rate leads the principal to induce the agent to exert a lower effort level in equilibrium, we have a normal tax effect. More precisely, we study whether increasing corporate income tax rates can lead to normal or paradoxical effects in the presence of an exit option. We are particularly interested in the option's effect on the investment incentives.

[1] For basic agency models see Ross 1973 or Jensen and Meckling 1976. On the influence of agency conflicts on investment decisions see, e.g., Reichelstein 1997, 2000 or Dutta and Reichelstein 2003.

This paper is essentially related to two streams of literature.[2] The first combines principal-agent models and issues of taxation. Fellingham and Wolfson (1985) model an agency conflict to show that optimal risk-sharing contracts do not generally result in expected tax maximization. Banerjee and Besley (1990) prove that an increase in profits' taxation, used to finance a transfer to creditors, yields a welfare improvement under limited liability. Niemann and Simons (2003) examine the impact of different tax regimes on the implementation decision and the design of stock option plans. Niemann (2011) analyzes the effects of symmetric and asymmetric taxation on performance-based versus fixed remuneration contracts in a binary principal-agent model. He shows that wage tax increases remuneration costs and makes the agent's employment less attractive, whereas corporate tax turns out to be irrelevant for the optimal remuneration contract. In contrast to the present literature and especially to Niemann 2011, we investigate the effect of the presence of an abandonment option on the principal's decisions and find that it can lead to paradoxical tax effects.

The second stream of literature contributes to a broad research agenda that investigates the impact of taxation on investment decisions.[3] Mackie-Mason (1990) studies the effects of tax system nonlinearities in the presence of uncertainty. He demonstrates that policy may subsidize or discourage individual investment depending on the tax system. Bloom, Bond and Van Reenen (2007) point out that the responsiveness of firms to any given fiscal policy stimulus may be much weaker in periods of high uncertainty. De Waegenaere and Sansing (2008) develop a model of a firm's foreign investment decisions and characterize optimal investment and repatriation strategies. Among other findings they show that the arrival of a tax holiday increases firm value if a subsidiary accumulates financial assets and

[2] Our paper also references a number of studies that investigate the incentive effects of compensation contracts in accounting theory, such as Bushman and Indjejikian 1993, Feltham and Xie 1994, Dutta and Reichelstein 2005, Drymiotes 2007 or Schöndube-Pirchegger and Schöndube 2010.

[3] Concerning so-called neutral tax systems that do not affect investment decisions and which have been proven under certainty see Brown 1948, Samuelson 1964, Johansson 1969, Boadway and Bruce 1984 or Bond and Devereux 1995.

repatriates them at a tax holiday. Robinson and Sansing (2008) analytically investigate how tax advantages and financial reporting disadvantages of immediate expensing affect investment decisions and find countervailing effects on the decision to investment in internally developed intangible assets. Alpert (2010) analyzes the impact of personal income taxation on call options and shows that tax can explain a large portion of early exercise events that have been classified as "irrational" in previous studies. To summarize, while the mentioned literature analyzes investment incentive effects of taxes in particular settings, our major contribution that extends the existing work is that we study the interplay of taxes and real options in an agency setting.

More precisely, our work is related to the literature that studies the interaction of real options and tax effects.[4] Agliardi (2001) examines the impact of the tax system on the firm's incentives to invest and disinvest in an uncertain environment and finds ambiguous effects on investment timing under this specific tax setting following the real options approach. Gries, Prior and Sureth (2007 and 2012) use a real option model and find distorting tax treatment of risk-free and risky investment. They analytically identify general paradoxical settings as well as a whole set of neutral tax regimes in case of tax rate changes. Alvarez and Koskela (2008) focus on the impact of progressive taxation on irreversible investment under uncertainty and among other findings show that for sufficiently high volatilities, the investment threshold depends positively on volatility but negatively on the tax rate. Wong (2009) shows that firms with an option to liquidate are encouraged to liquidate their operation earlier under progressive taxation as the corporate income tax rate rises. Thus, in the presence of tax progression and corporate income taxes holding decisions are distorted in a real option setting. Niemann and Sureth (2009 and 2012) examine whether capital gains or differential capital income taxation affect immediate and delayed investment asymmet-

[4] For real option-based models under uncertainty and irreversibility see Dixit and Pindyck 1994 or Trigeorgis 1996. Real option models have been extended with respect to taxation, e. g. by Pennings 2000, Panteghini 2004, 2005, or Niemann and Sureth 2004, 2005, 2011. Furthermore, for studies integrating real options into agency models see Arya, Glover and Routledge 2002 or Mittendorf 2004.

rically under a combined exit-and-entry option for risky investment projects and uncertain cash flows, and find parameter-dependent ambiguous effects. Schneider and Sureth (2010) investigate the interdependencies between effects from profit taxation and real options. They identify scenarios with paradoxical tax effects and show that these observed effects are due to the presence of the real option itself. In contrast to the following analysis these papers focus on first-best settings.

To our knowledge an analysis combining real options and tax effects with agency conflicts has not yet been performed. To fill the void we model a scenario in which a principal faces an investment project including an abandonment option, and investigate whether the presence of the option impacts on the occurrence and direction of tax effects. Abandoning the project's cash flows is associated with an additional investment outlay that has to be capitalized and is depreciated in the following periods.[5] Further, we assume that the relationship between the principal and his agent involves moral hazard and thus the principal faces a trade-off whether or not to provide the agent with incentives to exert a high effort.[6] Taking into account that taxes significantly affect investment decisions, we analyze the influence of corporate income tax on the principal's behavior. As mentioned before we have to formally define the notion of normal and paradoxical tax effects in the agency setting. In the moral hazard model a tax effect is normal/paradoxical if higher tax rates decrease/increase the principal's willingness to induce the agent to exert an effort. In

[5]In practice, there are two typical groups of (depreciable) exit investments. The first group concerns investments in safeguards or safety devices necessary for environmental reasons. For example, when a nuclear power plant is shut down the nuclear fuel rods have to be kept in special facilities for many years (to cool down). These facilities represent property, plant and equipment and are therefore capitalized and depreciated over their useful life. Another example is a gas station which must undergo extensive reconstruction and investments in professional hazardous waste disposal before being put to a new use, i.e. before being sold. In the second group, bad planning during product development or a deteriorating market situation makes (depreciable) exit investments necessary in order to improve the product and thereby ensure that a product line that has lost its competitiveness can be sold off. For example, due to bad planning in product development, a renowned shipbuilding company had to buy a bigger lifting unit in order to complete the project and minimize losses. The inherent assumption is that the company will not be liquidated, but rather abandon a specific investment and continue to work on other projects.

[6]For seminal papers concerning moral hazard see Holmström 1979, 1982. On moral hazard problems in accounting theory see, e.g., Liang 2000.

the absence of the option we find that corporate income tax does not change the decisions. That is, it does not influence the principal's efforts to induce the agent to work harder.[7] However, if no option is present we show as a minor result that normal tax effects can occur if the agent's bonus is not tax-deductible.

We first investigate the effects of the real option in the presence of the abandonment option. We show that the presence of the real option reduces the principal's incentives to induce a high effort level. This notwithstanding, our main finding is that paradoxical tax effects with respect to corporate income tax can occur. Therefore, given the benchmark result in the absence of the option where we do not have tax effects, we can conclude that the option to abandon can lead to paradoxical tax effects. Also, we find that in the absence of an agency problem no such effect arises. Therefore our research contributes to the literature that characterizes conditions that lead to paradoxical tax effects. In contrast to the present results we show that real options can cause paradoxical tax effects in second best settings. To summarize, our main finding is that we identify a situation in which the interplay between a real option and agency conflicts causes paradoxical tax effects.

The remainder of the paper is organized as follows. In Section 2 we introduce the basic features of the model and give a formal definition of normal, no and paradoxical tax effects in the presence of moral hazard. In Section 3 we investigate the absence of the abandonment option as a benchmark case. In Section 4 we expand the model to include an abandonment option. We find that the presence of the abandonment option can lead to paradoxical tax effects. Section 5 summarizes the results.

[7] This result is consistent with Niemann 2011.

2 Model

We consider a firm consisting of a principal and an agent. This firm realizes a taxable profit from current operating activities which is used to make further investments. The principal contracts with the agent to run an additional project on his behalf. This project generates stochastic cash flows $\widetilde{CF}$ that take a value of either CF_H or CF_L with $CF_H > 0 > CF_L$. The agent's task is to supply some (operating) effort a. For simplicity, we assume that the agent's effort choice is a binary decision. Specifically, the agent can either provide a high effort level a_H or a low effort level a_L. The agent's effort choice influences the probability distribution of the firm's cash flows. We denote the probability of a high cash flow CF_H by p_H if the agent has provided the low effort level a_L. In other words, p_H denotes the conditional probability of a high cash flow given a low effort level ($p_H = P(CF_H|a_L)$). By analogy, p_L denotes the probability of a low cash flow CF_L given the low effort level $p_L = P(CF_L|a_L) = 1 - p_H$. Furthermore, $\overline{p}_H$ denotes the conditional probability of CF_H given a_H and $\overline{p}_L$ the conditional probability of CF_L given a_H ($\overline{p}_H = P(CF_H|a_H)$ and $\overline{p}_L = P(CF_L|a_H)$). Note that if the agent provides a high effort level the probability p_H for CF_H increases to $\overline{p}_H$ ($\overline{p}_H > p_H$). In particular, the distribution of $\widetilde{CF}$ given a_H stochastically dominates the distribution of $\widetilde{CF}$ given a_L.

The relationship between the principal and the agent involves moral hazard, as the agent's choice of effort is unobservable by the principal and therefore cannot be used for contracting purposes. Hence, the payment to the agent only depends on the realization of the cash flow (CF_H or CF_L) but not on the agent's choice of effort. A contract consists of a tuple (s_H, s_L). Let s_H be the agent's remuneration if CF_H occurs. Similarly, s_L denotes the agent's remuneration if the cash flow equals CF_L. We assume the agent to be risk-neutral and effort-averse. His utility function $U(\cdot)$ satisfies

$$U(s_i, a_j) = s_i - K(a_j) \text{ with } i, j = \{H, L\}, \tag{1}$$

where $K(a_j)$ denotes the disutility associated with a_j. Without loss of generality we set $K(a_H) = K$ and $K(a_L) = 0$. The agent has a reservation utility of $\underline{U}$. Therefore, he will only accept contracts that provide him with an expected utility of at least $\underline{U}$. For reasons of analytical simplicity, we set the reservation utility $\underline{U}$ equal to 0. Also, we assume limited liability. That is, all payments to the agent have to be positive ($s_H, s_L \geq 0$).[8]

After the contract has been signed and before the cash flows are generated, the principal (and the agent) obtain perfect information about the future realization of the cash flows.[9] At this point in time, the principal can still abandon the project and avoid the payment of the (negative) cash flows. Abandonment is associated with an additional investment, i.e. exit cost E. The additional investment has to be capitalized and is depreciated over the course of the following N years. We denote the principal's abandonment decision by L. The decision L is a binary variable and takes the value 0 when the project is abandoned. Otherwise L equals 1. Since the abandonment option depends on the potential realization of the cash flow the abandonment strategy is given by L_H and L_L, where L_H is the decision in case of CF_H. Similarly, L_L denotes the abandonment decision in case of CF_L.

To summarize, the sequence of events is as follows.

$t = 0:$ The principal faces the investment and offers a contract to the agent. The agent accepts the contract, if it provides him with his reservation utility. Finally, the agent makes his effort choice.

$t = 1:$ The principal and the agent obtain information about $\widetilde{CF}$. Based on this information the principal decides whether or not to abandon the project. If the project is not abandoned the cash flow is realized. If the project is abandoned the principal has to undertake the abandonment investment. The agent is paid in any case.

[8] Limited liability is a standard assumption in agency theory. See for example Laffont and Martimort 2002, p. 118.

[9] This assumption is consistent with Schneider and Sureth 2010.

$t = 2, ..., N$: If the abandonment investment has been made, it is written off and leads to tax refunds.

We assume a tax system with a corporate income tax at the principal's firm level. We denote the corresponding tax rate by τ. Losses are tax deductible and incur a tax refund in the same fiscal period.[10] We assume a classic tax system with a definitive corporate income tax on the firm level and personal income taxation of dividends, interest earned, capital gains and wages on the individual level.[11] Hence, both the agent's and the principal's individual incomes are subject to a personal income tax. The agent's and manager's income is equal to their renumeration and is tax liable at rate τ_m. The principal has to pay taxes at tax rate τ_p on his return from the investment. Interest earned from an alternative capital market investment are subject to the final tax rate τ_f.[12] Let r denote principal's rate of return. Consequently, we define $r_{\tau_f} := (1 - \tau_f)r$ as the after-tax rate of return. According to these assumptions the present value of the "abandonment investment" is[13]

$$(1 - \tau_p)\frac{-E}{1 + r_{\tau_f}} + \tau(1 - \tau_p)\left(\sum_{i=2}^{N+1} \frac{E}{N}\frac{1}{(1 + r_{\tau_f})^i}\right). \tag{2}$$

Note that the above value is subject to two separate levels of taxation: to corporate taxation at firm's level, and individual income taxation on personal income from investment, i.e. interest and dividends.[14]

[10] This assumption can be motivated by modeling only one of the principal's projects and simultaneously assuming that there are sufficient profits from other (independent) projects. Therefore a loss reduces the total tax base. For a similar assumption see Schneider and Sureth 2010.

[11] Tax systems with shareholder relief are a special case of this stylized tax system with a personal tax rate levied on dividends as a fraction of the income tax rate on other income.

[12] Several countries levy a final tax on income from capital market investment, like interest, capital gains and dividends, e.g., Austria, Spain, Switzerland and Germany. In Germany, all interest, dividends and capital gains from investments in bonds and shares which were generated since the beginning of 2009 are subject to a final flat tax rate of 25 percent. This implies $\tau_p = \tau_f$ as a special case of our model.

[13] Here, we do not include the effect on the original cash flow $\widetilde{CF}$ but focus on the effects from the exit only. According to the solvency test, which is applied in most countries to determine the maximum dividend payout, the exit cost reduces the distributable profit in $t = 1$ and thus the principals' income tax base – as illustrated in eqn. (2).

[14] As reflected in the second term in the above equation, depreciation allowances lead to a tax refund at the corporate level, which increases the taxable dividend payout to the principal.

Finally, we have to define normal, no and paradoxical tax effects in a moral hazard setting. In a classic investment setting with only one decision maker we have normal tax effects if the decision maker's willingness to invest decreases with an increase in the tax rate. Conversely, if the investor's willingness to invest increases with an increasing tax rate we have paradoxical tax effects. Finally, if the tax rate does not affect the investor's behavior there are no tax effects.[15]

In our moral hazard model with two decision makers the principal does not directly perform an investment. Instead, he provides the agent with incentives to exert some effort. Therefore, we expect that the "willingness to invest" will decrease whenever the principal refrains from providing the agent with incentives to exert the high effort level. This interpretation leads to the following definition.

Definition 1 *In a moral hazard problem, we define that*

1. *normal tax effects occur if an increase in a tax rate decreases the principal's willingness to induce the agent to exert effort;*
2. *no tax effects occur if an increase in a tax rate does not affect the principal's willingness to induce the agent to exert effort;*
3. *paradoxical tax effects occur if an increase in a tax rate increases the principal's willingness to induce the agent to exert effort;*

In the following section we abstract from an option to abandon as a benchmark case and investigate the impact of taxes on the principal's willingness to induce high effort. We will see that taxation does not affect the principal's choice. Furthermore, we show that in the

[15] See for example Schneider and Sureth 2010, who apply a similar definition has been applied to a real-option setting.

absence of an abandonment option no or only normal, rather than paradoxical, tax effects occur.

3 No abandonment option

Abstracting from an abandonment option we investigate under what conditions paradoxical or normal tax effects occur. There are two possible cases.

(i) The principal offers incentives such that the agent exerts the high effort.

(ii) The principal refrains from offering incentives and the agent exerts the low effort.

Therefore our analysis contains two steps. In a first step we separately derive the optimal contract for both of the above cases. In a second step we compare the principal's expected profits in both cases and determine whether the principal should or should not induce the high effort level (a_H).

We start with case (i), where the principal induces the high effort level a_H. In this case, the principal's optimization problem can be written as[16]

$$\max_{s_H, s_L} \frac{\overline{p}_H}{1+r_{\tau_f}}(1-\tau_p)(1-\tau)(CF_H - s_H) + \frac{\overline{p}_L}{1+r_{\tau_f}}(1-\tau_p)(1-\tau)(CF_L - s_L) \tag{3}$$

[16] We assume that there are sufficient profits from other activities in the firm such that a loss from the underlying projects reduces the overall dividend payout as described in eqn. (3).

subject to

$$\tfrac{\bar{p}_H}{1+r_{\tau_f}}(1-\tau_m)s_H + \tfrac{\bar{p}_L}{1+r_{\tau_f}}(1-\tau_m)s_L - K$$

$$\geq \tfrac{p_H}{1+r_{\tau_f}}(1-\tau_m)s_H + \tfrac{p_L}{1+r_{\tau_f}}(1-\tau_m)s_L \quad (IC)$$

$$\tfrac{\bar{p}_H}{1+r_{\tau_f}}(1-\tau_m)s_H + \tfrac{\bar{p}_L}{1+r_{\tau_f}}(1-\tau_m)s_L - K \geq 0 \quad (PC)$$

$$s_H, s_L \geq 0 \quad (NN).$$

The principal optimizes the remuneration paid to the agent such that the agent exerts high effort. The payments s_H, s_L are tax deductible and hence reduce the corporate tax base. The incentive constraint (IC) provides the agent with incentives to exert the high effort level a_H. The participation constraint (PC) ensures that the agent accepts the contracts, as the expected present value of the after-tax renumeration minus the disutility from exerting an effort has to be at least equal to zero. Finally, the limited liability constraint (NN) guarantees that all payments to the agent are positive. The limited liability constraints (NN) together with the incentive constraint (IC) imply the participation constraint. Therefore, we can neglect the participation constraint (PC) in the further investigation.

As explained in detail in the mathematical appendix the incentive constraint can be rewritten as

$$(\overline{p}_H - p_H)s_H - (\overline{p}_H - p_H)s_L = \frac{1+r_{\tau_f}}{1-\tau_m}K. \tag{4}$$

Since $\overline{p}_H - p_H > 0$ the left hand side of equation (4) is increasing in s_H and decreasing in s_L and the principal's objective function is decreasing in both s_H and s_L, it is optimal to choose $s_L = 0$. Therefore, the agent's payment in case of a high cash flow CF_H equals

$$s_H = \frac{K \cdot (1+r_{\tau_f})}{(1-\tau_m)(\overline{p}_H - p_H)}. \tag{5}$$

Using the results for s_H and s_L the principal's expected NPV in case (i) can be calculated as

$$\begin{aligned} EE(a_H) &= (1-\tau_p)\frac{1-\tau}{1+r_{\tau_f}}\left(\overline{p}_H CF_H + \overline{p}_L CF_L - \overline{p}_H \frac{K\cdot(1+r_{\tau_f})}{(1-\tau_m)(\overline{p}_H - p_H)}\right) \\ &= (1-\tau_p)\frac{1-\tau}{1+r_{\tau_f}}\left(\overline{p}_H CF_H + \overline{p}_L CF_L - \frac{K\cdot(1+r_{\tau_f})}{(1-\tau_m)(1-\frac{p_H}{\overline{p}_H})}\right). \end{aligned} \tag{6}$$

If the principal refrains from inducing the high effort level (case (ii)) his optimization problem equals

$$\max_{s_H,s_L} \frac{p_H}{1+r_{\tau_f}}(1-\tau_p)(1-\tau)(CF_H - s_H) + \frac{p_L}{1+r_{\tau_f}}(1-\tau_p)(1-\tau)(CF_L - s_L) \tag{7}$$

subject to

$$\begin{aligned} &\tfrac{\overline{p}_H}{1+r_{\tau_f}}(1-\tau_m)s_H + \tfrac{\overline{p}_L}{1+r_{\tau_f}}(1-\tau_m)s_L - K \\ &\qquad \le \tfrac{p_H}{1+r_{\tau_f}}(1-\tau_m)s_H + \tfrac{p_L}{1+r_{\tau_f}}(1-\tau_m)s_L \qquad (IC) \\ &\tfrac{p_H}{1+r_{\tau_f}}(1-\tau_m)s_H + \tfrac{p_L}{1+r_{\tau_f}}(1-\tau_m)s_L \ge 0 \qquad (PC) \\ &s_H, s_L \ge 0 \qquad (NN). \end{aligned}$$

The above problem can be interpreted in the same way as in case (i). As proven in the mathematical appendix the optimal payments equal $s_H = s_L = 0$. Consequently, the principal's expected NPV in case (ii) is

$$EE(a_L) = (1-\tau_p)\frac{1-\tau}{1+r_{\tau_f}}(p_H CF_H + p_L CF_L). \tag{8}$$

The following proposition summarizes this result.

Proposition 1 *In the absence of the option to abandon, we obtain the following result:*

1. *If the principal wants to induce the high effort level the optimal payments to the agent equal*

$$s_L = 0 \qquad \text{and} \qquad s_H = \frac{K \cdot (1 + r_{\tau_f})}{(1 - \tau_m)(\overline{p}_H - p_H)}. \tag{9}$$

His expected NPV is

$$EE(a_H) = (1 - \tau_p)\frac{1 - \tau}{1 + r_{\tau_f}} \left(\overline{p}_H CF_H + \overline{p}_L CF_L - \frac{K \cdot (1 + r_{\tau_f})}{(1 - \tau_m)(1 - \frac{p_H}{\overline{p}_H})} \right). \tag{10}$$

2. *If the principal refrains from inducing the high effort level the optimal payments to the agent equal*

$$s_L = 0 \qquad \text{and} \qquad s_H = 0. \tag{11}$$

His expected NPV is

$$EE(a_L) = (1 - \tau_p)\frac{1 - \tau}{1 + r_{\tau_f}}(p_H CF_H + p_L CF_L). \tag{12}$$

The above proposition shows that the principal faces a trade-off. If he provides the agent with incentives to exert the high effort level a_H, he obtains an expected cash flow of $\overline{p}_H CF_H + \overline{p}_L CF_L$. In case of a_L the expected cash flow equals $p_H CF_H + p_L CF_L$. Since the distribution of $\widetilde{CF}$ given a_H stochastically dominates that under a_L, we have

$$\overline{p}_H CF_H + \overline{p}_L CF_L \geq p_H CF_H + p_L CF_L. \tag{13}$$

Therefore, the principal obtains higher expected cash flows if the agent supplies the high effort level (a_H). However – as shown in proposition 1 – the agent's payment is higher if the principal induces a_H. The difference in the expected payments equals

$$\frac{K \cdot (1 + r_{\tau_f})}{(1 - \tau_m)(1 - \frac{p_H}{\overline{p}_H})}. \tag{14}$$

It equals the agent's expected payment and is increasing in the agent's personal income rate (τ_m). This finding can be explained as follows. The principal can only generate incentives for the agent by differences of the net payment between the different states. If the agent's tax rate rises, the spread of the gross payments has to increase in order to generate the same difference in net payments. The principal induces the high effort level if and only if

$$EE(a_H) \geq EE(a_L). \tag{15}$$

According to proposition 1 this condition is equivalent to

$$(1 - \tau_p)\frac{1 - \tau}{1 + r_{\tau_f}}\left(\overline{p}_H CF_H + \overline{p}_L CF_L - \frac{K \cdot (1 + r_{\tau_f})}{(1 - \tau_m)(1 - \frac{p_H}{\overline{p}_H})}\right) \geq (1 - \tau_p)\frac{1 - \tau}{1 + r_{\tau_f}}(p_H CF_H + p_L CF_L). \tag{16}$$

Let $\Delta_H := \overline{p}_H - p_H$. Using this definition the above inequality can be rewritten as

$$\Delta_H CF_H - \Delta_H CF_L - \frac{K \cdot (1 + r_{\tau_f})}{(1 - \tau_m)(1 - \frac{p_H}{\overline{p}_H})} \geq 0. \tag{17}$$

It is obvious that the above condition is independent of τ and τ_p. Therefore, the corporate tax rate (and the principal's personal income tax rate τ_p) does not influence whether the principal should induce the high effort level, i.e. we find no corporate tax effects. The result can be interpreted as follows. Both the cash flows and the payments to the agent are affected in the same way by the tax. This effect is also independent of whether the principal induces the high effort level or not. Therefore, the optimal choice of the effort level is independent of the corporate income tax rate, resulting in no tax effects. The following proposition summarizes this result.[17]

Proposition 2 *In the absence of the option to abandon the principal induces the high effort level whenever*

$$\Delta_H CF_H - \Delta_H CF_L - \frac{K \cdot (1 + r_{\tau_f})}{(1 - \tau_m)(1 - \frac{p_H}{\bar{p}_H})} \geq 0. \tag{18}$$

He refrains from providing the agent with incentives if

$$\Delta_H CF_H - \Delta_H CF_L - \frac{K \cdot (1 + r_{\tau_f})}{(1 - \tau_m)(1 - \frac{p_H}{\bar{p}_H})} < 0 \tag{19}$$

Therefore, in the absence of the option we do not have tax effects on the principal's decision arising from the corporate income tax.

To summarize, the above result is a consequence of both the cash flows and the agent's payment being affected symmetrically by corporate income tax.

There follows a brief illustration of how the results would change if the agent's bonus was not tax-deductible. The analogy to equation (17) then is

$$(1 - \tau_p)(1 - \tau)(\Delta_H CF_H - \Delta_H CF_L) - \frac{K \cdot (1 + r_{\tau_f})}{(1 - \tau_m)(1 - \frac{p_H}{\bar{p}_H})} \geq 0. \tag{20}$$

Since the left side of the above inequality is decreasing in the tax rate, this yields normal tax effects.

Although this result is not surprising we can use proposition 2 in the following analysis as a benchmark result. We show in the following that integrating a real option into our model can lead to paradoxical tax effects. Comparing the expanded model to the benchmark case

[17] This result is consistent with the findings of Niemann 2011.

in section 4, we find that the real option directly causes a paradoxical effect.

4 Abandonment option

First, we have to determine the principal's optimal abandonment decision. As mentioned before the principal can make an additional investment (E) to avoid (abandon) the cash flow ($\widetilde{CF}$). The investment has to be capitalized and is depreciated in the subsequent N years. Therefore, the present value of the investment and future tax savings equals[18]

$$\frac{1}{1+r_{\tau_f}}\left(-E(1-\tau_p)+\tau(1-\tau_p)\left(\sum_{i=1}^{N}\frac{E}{N}\frac{1}{(1+r_{\tau_f})^i}\right)\right). \tag{21}$$

This value can be rewritten as

$$\frac{1}{1+r_{\tau_f}}\Big(-(1-\tau_p)(1-\tau)(1-\gamma)E-(1-\tau_p)\gamma E\Big), \tag{22}$$

where

$$\gamma = 1-\sum_{i=1}^{N}\frac{1}{N}\frac{1}{(1+r_{\tau_f})^i}. \tag{23}$$

We have $0<\gamma<1$ and γ is increasing in r_{τ_f}. Integrating an option to abandon, we prove that there are situations where higher tax rates lead to a higher effort on the part of the agent in equilibrium. Since such a paradoxical effect does not occur in the benchmark case we will be able to show that the real option causes this effect.

The principal uses the abandonment option ($L_H=0$) in the good state if and only if

$$\frac{1}{1+r_{\tau_f}}(1-\tau_p)(1-\tau)CF_H \le -\frac{1}{1+r_{\tau_f}}(1-\tau_p)(1-\tau)(1-\gamma)E-\frac{1}{1+r_{\tau_f}}(1-\tau_p)\gamma E \tag{24}$$

[18] See eqn. (2).

or

$$(1-\tau)(CF_H + (1-\gamma)E) \leq -\gamma E. \tag{25}$$

Similarly, the principal uses the abandonment option in the bad state if

$$(1-\tau)(CF_L + (1-\gamma)E) \leq -\gamma E. \tag{26}$$

Especially, we have

$$L_i \in \arg\max_{L_i \in \{0,1\}} (1-\tau)CF_i \cdot L_i - [(1-\tau)(1-\gamma)+\gamma]E(1-L_i), \tag{27}$$

where $i \in \{L, H\}$.

In general there exists a critical corporate tax rate τ^* with $0 \leq \tau^* \leq 1$ such that

1. the principal uses the abandonment option in the bad state for $\tau < \tau^*$,
2. the principal never uses the abandonment option for $\tau \geq \tau^*$.

Since the interesting case is the one in which the principal abandons in the bad state (L) but not in the good state (H), we assume $\tau < \tau^*$ in the following. We first assume that the principal induces the high effort level a_H. In this case, his optimization problem can be written as

$$\begin{aligned}\max_{s_H, s_L} (1-\tau_p)\Bigg(&\overline{p}_H \frac{1-\tau}{1+r_{\tau_f}}(CF_H \cdot L_H - (1-\gamma)E(1-L_H) - s_H) - \frac{1-L_H}{1+r_{\tau_f}}\overline{p}_H \gamma E \\ &+ \overline{p}_L \frac{1-\tau}{1+r_{\tau_f}}(CF_L \cdot L_L - (1-\gamma)E(1-L_L) - s_L) - \frac{1-L_L}{1+r_{\tau_f}}\overline{p}_L \gamma E\Bigg)\end{aligned} \tag{28}$$

subject to

$$\tfrac{\bar{p}_H}{1+r_{\tau_f}}(1-\tau_m)s_H + \tfrac{\bar{p}_L}{1+r_{\tau_f}}(1-\tau_m)s_L - K$$
$$\geq \tfrac{p_H}{1+r_{\tau_f}}(1-\tau_m)s_H + \tfrac{p_L}{1+r_{\tau_f}}(1-\tau_m)s_L \qquad (IC)$$

$$\tfrac{\bar{p}_H}{1+r_{\tau_f}}(1-\tau_m)s_H + \tfrac{\bar{p}_L}{1+r_{\tau_f}}(1-\tau_m)s_L - K \geq 0 \qquad (PC)$$

$$s_H, s_L \geq 0 \qquad (NN)$$

$$L_i \in \arg\max_{L_i \in \{0,1\}} (1-\tau)CF_i \cdot L_i - [(1-\tau)(1-\gamma)+\gamma]E(1-L_i) \quad (OO).$$

The above optimization problem can be interpreted as an analogy to the benchmark scenario. Note that both the incentive constraint (IC) and the participation constraint (PC) remain unchanged. The same is true for the limited liability constraint (NN) that requires all payments to be positive. Nevertheless, there are two main differences between the two optimization problems. First, we have to consider the additional constraint (OO). This constraint ensures that the principal executes the abandonment option optimally. Second, the form of the objective function changes. The new structure reflects the principal's opportunity to avoid the cash flow $\widetilde{CF}$ by executing the abandonment option.

As already explained, the structure of the incentive problem (the incentive (IC) and participation constraints (PC)) remains unchanged. Therefore, as in the benchmark case, we obtain for the agent's payments

$$s_L = 0 \qquad \text{and} \qquad s_H = \frac{K \cdot (1+r_{\tau_f})}{(1-\tau_m)(\overline{p}_H - p_H)}. \tag{29}$$

However, the principal's expected profits change, because he has the opportunity to abandon the investment. His expected NPV equals

$$
\begin{aligned}
&EE^O(a_H) \qquad (30)\\
=&(1-\tau_p)\Bigg(\frac{1-\tau}{1+r_{\tau_f}}\left(\overline{p}_H(CF_H\cdot L_H-(1-\gamma)E(1-L_H))-\frac{K\cdot(1+r_{\tau_f})}{(1-\tau_m)(1-\frac{p_H}{\overline{p}_H})}\right)-\frac{1-L_H}{1+r_{\tau_f}}\overline{p}_H\gamma E\\
&+\frac{1-\tau}{1+r_{\tau_f}}\left(\overline{p}_L(CF_L\cdot L_L-(1-\gamma)E(1-L_L))\right)-\frac{1-L_L}{1+r_{\tau_f}}\overline{p}_L\gamma E\Bigg).
\end{aligned}
$$

Since the principal only abandons in the bad state ($L_H=1$ and $L_L=0$)), we obtain

$$
\begin{aligned}
&EE^O(a_H) \qquad (31)\\
=&(1-\tau_p)\Bigg(\frac{1-\tau}{1+r_{\tau_f}}\left(\overline{p}_H CF_H-\frac{K\cdot(1+r_{\tau_f})}{(1-\tau_m)(1-\frac{p_H}{\overline{p}_H})}\right)-\frac{1-\tau}{1+r_{\tau_f}}\overline{p}_L(1-\gamma)E-\frac{1}{1+r_{\tau_f}}\overline{p}_L\gamma E\Bigg).
\end{aligned}
$$

Next, we consider the case in which the principal wants to induce a_L. Similarly, as above we obtain for the agent's payments

$$s_L=0 \qquad \text{and} \qquad s_H=0. \qquad (32)$$

Consequently, we obtain

$$
\begin{aligned}
&EE^O(a_L) \qquad (33)\\
=&(1-\tau_p)\Bigg(\frac{1-\tau}{1+r_{\tau_f}}\left(p_H(CF_H\cdot L_H-(1-\gamma)E(1-L_H))\right)-\frac{1-L_H}{1+r_{\tau_f}}p_H\gamma E\\
&+\frac{1-\tau}{1+r_{\tau_f}}\left(p_L(CF_L\cdot L_L-(1-\gamma)E(1-L_L))\right)-\frac{1-L_L}{1+r_{\tau_f}}p_L\gamma E\Bigg).
\end{aligned}
$$

Using the assumption $\tau<\tau^*$ which implies $L_H=1$ and $L_L=0$ the above equation can be rewritten as

$$
\begin{aligned}
&EE^O(a_L) \qquad (34)\\
=&(1-\tau_p)\bigg(\frac{1-\tau}{1+r_{\tau_f}}\left(p_H CF_H\right) - \frac{1-\tau}{1+r_{\tau_f}} p_L(1-\gamma)E - \frac{1}{1+r_{\tau_f}} p_L \gamma E\bigg).
\end{aligned}
$$

The following proposition summarizes this result.

Proposition 3 *In the presence of the option to abandon, we obtain the following result:*

1. *If the principal wants to induce the high effort level the optimal payments to the agent equal*

$$
s_L = 0 \qquad \textit{and} \qquad s_H = \frac{K \cdot (1+r_{\tau_f})}{(1-\tau_m)(\overline{p}_H - p_H)}. \qquad (35)
$$

   His expected NPV is

$$
\begin{aligned}
&EE^O(a_H) \qquad (36)\\
=&(1-\tau_p)\bigg(\frac{1-\tau}{1+r_{\tau_f}}\left(\overline{p}_H(CF_H \cdot L_H - (1-\gamma)E(1-L_H)) - \frac{K \cdot (1+r_{\tau_f})}{(1-\tau_m)(1-\frac{p_H}{\overline{p}_H})}\right) - \frac{1-L_H}{1+r_{\tau_f}}\overline{p}_H \gamma E\\
&+\frac{1-\tau}{1+r_{\tau_f}}\left(\overline{p}_L(CF_L \cdot L_L - (1-\gamma)E(1-L_L))\right) - \frac{1-L_L}{1+r_{\tau_f}}\overline{p}_L \gamma E\bigg).
\end{aligned}
$$

2. *If the principal refrains from inducing the high effort level the optimal payments to the agent equal*

$$
s_L = 0 \qquad \textit{and} \qquad s_H = 0. \qquad (37)
$$

   His expected NPV is

$$
\begin{aligned}
&EE^O(a_L) \qquad (38)\\
=&(1-\tau_p)\bigg(\frac{1-\tau}{1+r_{\tau_f}}\left(p_H(CF_H \cdot L_H - (1-\gamma)E(1-L_H))\right) - \frac{1-L_H}{1+r_{\tau_f}} p_H \gamma E\\
&+\frac{1-\tau}{1+r_{\tau_f}}\left(p_L(CF_L \cdot L_L - (1-\gamma)E(1-L_L))\right) - \frac{1-L_L}{1+r_{\tau_f}} p_L \gamma E\bigg).
\end{aligned}
$$

Next, we investigate the effect of the option on the principal's incentives to induce a_H. Generally, the following trade-off arises. The principal faces agency costs if he wants to induce a_H. However, high effort increases the probability of the high cash flow. As explained above the option does not affect the agency costs. In the absence of the option the difference in cash flows between the good and the bad state equals $(1-\tau_p)(1-\tau)(CF_H - CF_L)$. In the presence of the option the equivalent difference is (for $\tau < \tau^*$)

$$(1-\tau_p)((1-\tau)(CF_H - (1-\gamma)E) - \gamma E) < (1-\tau_p)(1-\tau)(CF_H - CF_L). \tag{39}$$

Therefore, the marginal gain of increasing the probability of CF_H is smaller in the presence of the option and hence the principal's incentives to induce a_H are smaller in the presence of the option. The following proposition summarizes this result.

Proposition 4 *In the presence of the option to abandon the principal has c. p. fewer incentives to induce a_H.*

Next, we want to analyze in detail under which conditions the principal has incentives to induce a_H. Similarly as in the benchmark scenario the principal induces the high effort level if and only if

$$EE^O(a_H) \geq EE^O(a_L). \tag{40}$$

According to proposition 3 this condition is equivalent to

$$\begin{aligned}
&(1-\tau_p)\left[\frac{1-\tau}{1+r_{\tau_f}}\left(\overline{p}_H(CF_H \cdot L_H - (1-\gamma)E(1-L_H)) - \frac{K\cdot(1+r_{\tau_f})}{(1-\tau_m)(1-\frac{p_H}{\overline{p}_H})}\right) - \frac{1-L_H}{1+r_{\tau_f}}\overline{p}_H\gamma E\right. \\
&\quad \left. + \frac{1-\tau}{1+r_{\tau_f}}\left(\overline{p}_L(CF_L \cdot L_L - (1-\gamma)E(1-L_L))\right) - \frac{1-L_L}{1+r_{\tau_f}}\overline{p}_L\gamma E\right] \\
\geq &(1-\tau_p)\left[\frac{1-\tau}{1+r_{\tau_f}}\left(p_H(CF_H \cdot L_H - (1-\gamma)E(1-L_H))\right) - \frac{1-L_H}{1+r_{\tau_f}}p_H\gamma E\right. \\
&\quad \left. + \frac{1-\tau}{1+r_{\tau_f}}\left(p_L(CF_L \cdot L_L - (1-\gamma)E(1-L_L))\right) - \frac{1-L_L}{1+r_{\tau_f}}p_L\gamma E\right].
\end{aligned} \tag{41}$$

Using this definition $\Delta_H := \overline{p}_H - p_H$ and $L_H = 1$ and $L_L = 0$ the above inequality can be rewritten as

$$(1-\tau)\left(\Delta_H CF_H + \Delta_H(1-\gamma)E - \frac{K \cdot (1+r_{\tau_f})}{(1-\tau_m)(1-\frac{p_H}{\overline{p}_H})}\right) + \Delta_H \gamma E \geq 0. \tag{42}$$

At this point one should remember that the term

$$\frac{K \cdot (1+r_{\tau_f})}{(1-\tau_m)(1-\frac{p_H}{\overline{p}_H})} \tag{43}$$

is a measure of the severity of the agency conflict. It describes how costly it is for the principal to induce a high effort level. Especially, the severeness of the agency conflict increases with the agent's disutility of providing high effort (K) and if $\Delta_H = \overline{p}_H - p_H$ decreases. In the following we assume that the agency conflict is strong enough. Formally, this means that

$$\Delta_H CF_H + \Delta_H(1-\gamma)E - \frac{K \cdot (1+r_{\tau_f})}{(1-\tau_m)(1-\frac{p_H}{\overline{p}_H})} < 0. \tag{44}$$

If this condition is satisfied, the left side of equation (42) is increasing in the tax rate τ. Therefore, a rise in the corporate tax rate makes it more attractive for the principal to induce the high effort level. We observe a paradoxical tax effect. This result can be interpreted as follows. Both the cash flows and the payments to the agent are affected in the same way by the corporate tax. However, the abandonment investment is affected slightly differently. If the exit option is exercised, the abandonment investment is capitalized and only leads to tax refunds in future periods and not in the period of investment. This fact is also reflected in equation (22). Therefore, some part of the investment E is independent of the tax rate τ.

The abandonment investment only occurs in the bad state L. Also, the bad state occurs more often in case of low effort (a_L). These conditions explain the second term in equation

(42). It is positive because the abandonment investment, which in terms of cash flows represents an outflow, is less likely if the agent exerts high effort. The first term in equation (42) represents all components that are affected by the tax rate τ. Inducing the high effort level increases the probability of the high cash flow CF_H which means the investment needs not be abandoned as often. However, it causes agency costs. This agency conflict is explained by the first term (which consists of three separate elements) in equation (42). If the agency costs are high enough such that equation (42) is negative for $\tau = 0$ and if equation (42) is positive for $\tau = \tau^*$ there exists a cut-off value τ^{cut} such that the principal wants to induce the high effort level for $\tau \geq \tau^{cut}$ and refrains from incentives for $\tau < \tau^{cut}$. In particular, there are values $\tau^{'}$ and $\tau^{''}$ with $\tau^{'} < \tau^{''}$ such that the principal induces a_H in case of $\tau^{''}$ but not for $\tau^{'}$. This effect is clearly paradoxical.

Proposition 5 *Assume that the agency conflict is strong. In the presence of the option to abandon the principal induces the high effort level whenever*

$$(1-\tau)\left(\Delta_H CF_H + \Delta_H(1-\gamma)E - \frac{K \cdot (1+r_{\tau_f})}{(1-\tau_m)(1-\frac{p_H}{\bar{p}_H})}\right) + \Delta_H \gamma E \geq 0. \tag{45}$$

He refrains from providing the agent with incentives if

$$(1-\tau)\left(\Delta_H CF_H + \Delta_H(1-\gamma)E - \frac{K \cdot (1+r_{\tau_f})}{(1-\tau_m)(1-\frac{p_H}{\bar{p}_H})}\right) + \Delta_H \gamma E < 0. \tag{46}$$

Therefore, in the presence of the option paradoxical tax effects can occur with respect to the corporate income tax.

It is important to mention that in case of no agency conflict ($K = 0$) inequality (46) cannot be satisfied. Therefore, no paradoxical tax effect can occur. This result shows that the presence of an agency conflict causes paradoxical effects in our setting. To summarize, the presence of the real option leads to paradoxical effects. This happens in situations in which inducing the high effort level is not profitable if there is no taxation. Increasing the tax rate reduces the disadvantage of inducing the high effort while it only partly affects the abandonment decision. It is less likely the investment will be abandoned if the agent provides high effort. Therefore, higher values of E encourage the inducement of the high effort level. This effect is (partly) independent of the tax rate and therefore inducing a_H becomes more attractive for higher tax rates.

5 Conclusions

In this paper we analyze the impact of real options on tax effects in a moral hazard setting. What is new is our analysis of the specific interplay of corporate taxation and real options on an arising agency conflict. In contrast to the present literature which focuses either on the investment effects of taxes (in the presence of real options) or on the influence of taxation on agency conflicts, our analysis combines both streams and sheds light on the tax sensitivity of investment decisions under information asymmetry in the presence of an abandonment option. Furthermore, we extend the well-known concepts of tax effects with respect to adverse selection problems and provide evidence of the occurrence of paradoxical tax effects in second-best settings involving two decision makers.

To do so, we first generalize the concept of paradoxical tax effects to moral hazard settings. In the benchmark case where no option is present we find – consistent with the literature – that there are no tax effects with respect to corporate income tax. This result is a consequence of the cash flow and the agent's payment being equally affected by the tax rate. However, we show that for this scenario so-called normal tax effects can occur if the agent's bonus is not tax-deductible and consequently the cash flow and the agent's payment are asymmetrically affected by the tax rate.

This finding changes if an abandonment option is present. We assume that abandonment is associated with an additional investment which has to be capitalized and is depreciated in the subsequent years. The principal faces a trade-off in terms of whether or not to provide the agent with incentives to exert a high effort level and hence increase the probability of high cash flows. Therefore, we investigate the impact of an option to abandon on the principal's willingness to induce high effort.

If an option to abandon is integrated in the model the principal has fewer incentives to induce the high effort level because the marginal gain of increasing the probability of high cash flows is smaller in the presence of the option. Nevertheless, as our key finding we show that paradoxical tax effects with respect to the corporate income tax can occur if the agency conflict is strong enough. The paradoxical tax effect occurs because the investment to be abandoned that is capitalized and depreciated in future periods is taxed asymmetrically in comparison to the other cash flows. Our results highlight the tax sensitivity of investment decisions under information asymmetry. In particular, this is the first paper that shows how the presence of an abandonment option can lead to paradoxical tax effects if agency conflicts are present. In contrast to prior literature both the presence of the abandonment option and the presence of agency conflict are necessary for the occurrence of paradoxical effects.

Mathematical Appendix

Proof of proposition 1: We first consider case (i) and then case (ii).

As explained in the text the principal's optimization problem in case (i) equals

$$\max_{s_H, s_L} \frac{\overline{p}_H}{1 + r_{\tau_f}}(1 - \tau_p)(1 - \tau)(CF_H - s_H) + \frac{\overline{p}_L}{1 + r_{\tau_f}}(1 - \tau_p)(1 - \tau)(CF_L - s_L) \tag{47}$$

subject to

$$\begin{aligned}
&\tfrac{\bar{p}_H}{1+r_{\tau_f}}(1-\tau_m)s_H + \tfrac{\bar{p}_L}{1+r_{\tau_f}}(1-\tau_m)s_L - K \\
&\qquad \geq \tfrac{p_H}{1+r_{\tau_f}}(1-\tau_m)s_H + \tfrac{p_L}{1+r_{\tau_f}}(1-\tau_m)s_L \qquad (IC) \\
&\tfrac{\bar{p}_H}{1+r_{\tau_f}}(1-\tau_m)s_H + \tfrac{\bar{p}_L}{1+r_{\tau_f}}(1-\tau_m)s_L - K \geq 0 \qquad (PC) \\
&s_H, s_L \geq 0 \qquad (NN).
\end{aligned}$$

The incentive constraint is equivalent to

$$\Delta_H s_H - \Delta_H s_L \geq \frac{1 + r_{\tau_f}}{1 - \tau_m} K. \tag{48}$$

The left side of the above inequality is increasing in CF_H and decreasing in CF_L. Furthermore, it follows from the incentive constraint (IC) and the limited liability constraints (NN) that

$$\begin{aligned}
&\frac{\bar{p}_H}{1 + r_{\tau_f}}(1 - \tau_m)s_H + \frac{\bar{p}_L}{1 + r_{\tau_f}}(1 - \tau_m)s_L - K \\
&\qquad \geq \frac{p_H}{1 + r_{\tau_f}}(1 - \tau_m)s_H + \frac{p_L}{1 + r_{\tau_f}}(1 - \tau_m)s_L \geq 0.
\end{aligned} \tag{49}$$

This condition implies the participation constraint (PC). Therefore, the participation constraint can be neglected. Since both the principal's objective function and the left side of inequality (48) is decreasing in s_L it is optimal to set $s_L = 0$. Since the principal's objective function is decreasing in s_H it is optimal to set s_H equal to the smallest value that satisfies the constraints. Consequently, the incentive constraint (IC) must bind. Therefore, using $s_L = 0$, we have

$$\Delta_H s_H = \frac{1 + r_{\tau_f}}{1 - \tau_m} K. \tag{50}$$

This equation yields the optimal form of s_H. Inserting both the optimal form of s_H and $s_L = 0$ into the principal's objective function we obtain

$$EE(a_H) = (1 - \tau_p) \frac{1 - \tau}{1 + r_{\tau_f}} \left(\overline{p}_H CF_H + \overline{p}_L CF_L - \frac{K \cdot (1 + r_{\tau_f})}{(1 - \tau_m)(1 - \frac{p_H}{\overline{p}_H})} \right). \tag{51}$$

In case (ii) the optimization problem equals

$$\max_{s_H, s_L} \frac{p_H}{1 + r_{\tau_f}} (1 - \tau_p)(1 - \tau)(CF_H - s_H) + \frac{p_L}{1 + r_{\tau_f}} (1 - \tau_p)(1 - \tau)(CF_L - s_L) \tag{52}$$

subject to

$$\begin{aligned}
&\tfrac{\bar{p}_H}{1+r_{\tau_f}}(1-\tau_m)s_H + \tfrac{\bar{p}_L}{1+r_{\tau_f}}(1-\tau_m)s_L - K \\
&\qquad\qquad \le \tfrac{p_H}{1+r_{\tau_f}}(1-\tau_m)s_H + \tfrac{p_L}{1+r_{\tau_f}}(1-\tau_m)s_L \qquad (IC) \\
&\tfrac{p_H}{1+r_{\tau_f}}(1-\tau_m)s_H + \tfrac{p_L}{1+r_{\tau_f}}(1-\tau_m)s_L \ge 0 \qquad\qquad\qquad (PC) \\
&s_H, s_L \ge 0 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (NN).
\end{aligned}$$

The principal's objective function is decreasing in both s_H and s_L. Also, s_H and s_L have to be positive. Therefore, the smallest possible choice is $s_H = s_L = 0$. For this choice the incentive constraint (IC) reads as

$$-K \leq 0 \tag{53}$$

and the participation constraint (PC) is $0 \geq 0$. Consequently, both constraints are satisfied. Inserting $s_H = s_L = 0$ into the principal's objective function we obtain

$$EE(a_L) = (1 - \tau_p)\frac{1 - \tau}{1 + r_{\tau_f}}(p_H CF_H + p_L CF_L). \tag{54}$$

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