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FEMM Working Paper No. 26, December 2007

FEMM

Faculty of Economics and Management Magdeburg

Working Paper Series

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December 3, 2007

Abstract

In this paper we analyze a dynamic agency problem where contracting parties learn about the agent's future productivity over time. We consider a two period model where both the agent and the principal observe the agent's second period performance productivity at the end of the first period. This observation is assumed to be non verifiable information. We compare long-term contracts to short-term contracts with respect to their suitability to motivate effort in both periods. On the one hand short-term agreements allow for a better fine-tuning of second period incentives as they can be aligned to the observation of the agent's second period performance productivity. On the other hand in short-term agreements the effect of early effort on future performance is ignored as contracts have to be sequentially optimal. Hence, the difference between long-term and short-term agreements is characterized by a trade-off between inducing effort in the first and in the second period. We analyze the determinants of this trade-off and demonstrate its implications for performance measurement and information system design (e.g. we compare accrual to cash-accounting).

*I acknowledge helpful comments from Christian Riegler, Barbara Schöndube-Pirchegger, and from participants of the EAA annual conference 2007 in Lisbon.

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1 Introduction

In previous literature the scientific community has spent enormous effort to analyze long-term incentive problems (see for example Lambert (1983), Fudenberg/Holmström/Milgrom (1990), Chiappori et al. (1994) or Christensen/Feltham/Şabac (2005)). Two aspects are of particular relevance: The ability of parties to commit to a sequence of actions and the distinction between observability and verifiability of information.[1] When contracting is complete in the sense that all jointly observable variables are verifiable, long-term commitment has proven to be valuable and the possibility of ex post contract modification (via renegotiation or short-term contracting) turned out to be inefficient: Given the complete contracting assumption each anticipated future contract decision can be included in the initial contract such that there is no value to modify the contract subsequently. Rather, limited commitment may worsen the outcome as contracting parties are forced to act sequentially optimal, while under full commitment they can commit to strategies that are not sequentially optimal. Roughly stated, short-term contracting or renegotiation is ex ante efficient only if there is no difference between ex ante optimality and ex post optimality.[2]

For real incentive problems, however, it is reasonable to assume that contracting parties are better informed than e.g. a court, that would enforce the contract in case of a dispute.[3] Most transactions and relationships are very specific such that the court is not able to interpret data in the manner an insider would do. In such a setting the complete contract assumption is violated and the notion of a characteristic of the relationship being "observable but not verifiable" has been introduced into the literature.[4] If contracting parties jointly observe variables that are not verifiable the possibility of renegotiation or short-term contracting might improve the outcome of the relationship, as it allows to implicitly incorporate non verifiable information into the contract. A very prominent analysis of this kind is Hermalin/Katz (1991) where the agent's effort is observable but not verifiable.

A general lesson from analyzing long-term incentive problems is that slight changes in the information structure may have substantial consequences on the outcome of the agency[5] and therefore may lead to different implications for optimal performance management and information system design. In this sense e.g. Lambert (2001) emphasizes the need to investigate long-term incentive problems especially related to commitment issues to attain a deeper understanding of the impact of performance measurement in dynamic agencies.

[1] See Bolton (1990) for an overview.

[2] Fudenberg/Holmström/Milgrom (1990) and Chiappori et al. (1994) developed criteria that ensure identity of ex post optimality and ex ante optimality in complete contracts.

[3] See Hermalin/Katz (1991).

[4] See Tirole (1999) for an interpretation of the "observable but non verifiable" asumption in terms of the incomplete contracting approach.

[5] Compare e.g. Fudenberg/Tirole (1990) to Hermalin/Katz (1991).

In this paper we model a long-term agency-relationship that brings two of the points mentioned before together. On the one hand contracting parties observe non verifiable information during the relationship which facilitates spot commitment as future effort incentives can be improved. On the other hand the possibility of ex post contract adjustment may weaken early effort incentives. Hence, the answer to the question whether a long-term agreement or spot contracting is preferred depends on the importance of early effort relative to late effort.

Specifically, we consider a two-period agency-relationship in which the contracting parties privately learn the agent's future performance productivity at the end of the first period. It is natural to assume that the manager's future contribution to both firm value and performance measures is uncertain ex ante and becomes more transparent by observing the production process over time. This uncertainty might be due to either limited knowledge about the agent's ability (talent) for the job or some characteristics of the job being unknown ex ante. By repeating the production process over time some characteristics of the job show and Bayesian inferences on the agent's ability might be drawn. Meyer (1995), Jeon (1996), and Meyer/Vickers (1997) model a manager's ability as an (additive separable) time invariant random variable in the production process. By observing the outcome of the current period, parties update their beliefs about the agent's ability. From the ex ante perspective this updating process creates implicit incentives and the main emphasis of this literature is to analyze the determinants of this implicit effect. In contrast to this literature in this paper observed productivity is non verifiable information and it is modeled as the agent's marginal productivity such that it is getting directly incentive relevant.

We analyze the trade-off between early and late effort motivation by comparing short-term agreements and long-term agreements. This trade-off is shown to be critically influenced by strategic effort and potential multi-tasking problems. Furthermore, in addition to the congruity of firm value and performance measures the variance of the a priori unknown second period performance productivity of the agent is an important influencing factor; not due to risk sharing considerations but by virtue of a costly effort allocation across different states of nature. In the short-term contracting setting we further distinguish if the agent's effort is unobservable or observable but not verifiable.[6] We do so for two reasons: First, combining these elements with learning about productivity allows us to clearly confine how the specific determinants of first and second period effort motivation vary with (small) changes in the informational structure. Second, the analysis of observable but not verifiable actions is applicable to a couple of real world situations[7] and itself generates interesting results, in particular a full separation of periods.

[6] As in long-term contracts the principal cannot react upon his observation of the agent's actions we need not to distinguish whether or not the agent's effort is observable.

[7] Consider relationships where both contracting parties work close together such that the principal can directly oberserve which actions the agent has taken without being able to formally prove it. Furthermore, there might be a subjective performance measure that allows the principal directly to infer the agent's action. The literature on implicit contracts often presumes that the agent's effort itself is the subjective measure that is implicitly contracted upon (see e.g. Bull (1987)).

Having analyzed the influencing variables of the trade-off between first and second period effort motivation we demonstrate implications for performance measurement and information system design. The accounting system of the firm can be interpreted as the information system providing the measures for the compensation contract with the manager.[8] We compare cash-accounting to accrual-accounting as different means to influence the effort allocation problem. In the accrual system all financial consequences of first period effort are reported in the first period (the period of transaction) whereas the cash system reports in the period of cash realization. In this aspect our analysis contributes to a bunch of literature comparing both accounting systems within dynamic agency models. Kwon (1989) compares cash-accounting to accrual-accounting in a two period setting with full commitment. The main emphasis of his paper is to analyze the trade-off between risk and incentives regarding the timing of information. Reichelstein (2000) analyzes performance measures based on cash-flows and on accruals (residual income). The objective is to implement incentive schemes that induce the agent to perform effort to find investment projects and then to realize only profitable projects. Wagenhofer (2003) considers a sequence of short-term contracts in a model where the agent's effort has long-term and short-term consequences. He analyzes optimal depreciation rules that induce the desired long-term incentives by transferring part of the contribution of the long-term activity in the period of choice. Cash-accounting is considered as a special case where the depreciation rate is 100% in the first period.
In the context of our model the timing of information is important as it influences the trade-off between early and late effort motivation. Assume the extreme case that all consequences of first period effort are measured in the second period. Then, in short-term contracts there is no possibility to directly control first period effort as the second period contract will be optimized only with regard to second period effort. This example emphasizes that the different timing of transactions' recognition under both systems crucially influences the trade-off between early and late effort.

Furthermore, we analyze whether it is indeed optimal to report the agent's productivity at the end of the first period or if contracting parties do better without this information. It is well known[9] that in strategic interactions (games) additional information may have negative value. It has been shown in Demski/Frimor (1999) and Indjejikian/Nanda (1999) amongst others that information rationing - for instance via aggregation of information - might be beneficial in dynamic incentive problems. The positive effect of information rationing stems from the principal's desire to discipline his ex post optimal behavior in order to avoid problems like the ratchet-effect. Most of the analyses showing this effect are dealing in a complete contracting world where the only information available is the verifiable performance measures. In the model employed here, however, we analyze whether or not the manager's unverifiable second period productivity should be internally reported. As the agent directly responds to the observed productivity information, not observing the agent's productivity may be beneficial as it may

[8] See Christensen/Demski (2003), ch. 11 ff.
[9] See for example Demski (1988).

prevent *both* contracting parties from taking second period sequentially optimal actions that distort the contracting parties first period actions/decisions. In addition, in long-term contracts not observing the agent's productivity may be optimal to avoid an uncontrollable random second period action taken by the manager.

Besides the ones cited above this paper is related to a couple of other papers. Baker (1992), Kopel (1998) and Bushman/Indjejikian/Penno (2000) also consider agency problems where the agent's productivity is unknown ex ante. These papers analyze a one shot full commitment problem with *private pre-decision information*: The agent privately observes his performance productivity after the contracting date. Baker and Kopel show that agency costs may occur even with risk neutral parties if the principal cannot optimally allocate the agent's effort across different states of nature (of performance productivity). Bushman/Indjejikian/Penno analyze the delegation of decision rights: In a centralized regime the agent's effort is contractible but performance productivity is not observable whereas in the decentralized system the agent privately observes his productivity but effort is non contractible. With regard to the comparison of long-term to short-term contracts (or renegotiation-proof contracts, respectively) with strategic (long-term) effort the paper is connected with Sliwka (2002) and Dutta/Reichelstein (2003).

The rest of the paper is organized as follows: In the next section we introduce the model. In section 3 we conduct the equilibrium analysis for the three contracting regimes considered in this paper. Section 4 analyzes the determinants of the trade-off between motivating early and late effort. In section 5 we demonstrate implications for performance measurement and information system design and section 6 summarizes.

2 The model

In this section we introduce the model. We use the most parsimonious model that allows to capture the relevant trade-offs between late and early effort motivation. Nonetheless, we are anxious to interpret the results in terms of a more general economic environment besides the specifics of the model. We consider a firm with a planning horizon of two periods. The firm is owned by the principal P and run by the agent (manager) A. Both parties are risk neutral. Performance measures for incentive contracting are given by

$$\begin{aligned} y_1 &= v_{11}e_{11} + v_{12}e_{12} + \eta_1 \\ y_2 &= v_{21}e_{11} + \theta e_2 + \eta_2. \end{aligned}$$

Here $\mathbf{e}_1' = (e_{11}, e_{12})$ are the manager's first-period actions and e_2 is his second period effort. The actions are non-verifiable, but they might be observable. We assume that the manager has to perform two tasks in the first period: a strategic (long-term) action e_{11} that influences the performance in both periods and an operational (short-term) action e_{12} that only influences first period performance. $\mathbf{v}_1 = (v_{11}, v_{12})'$ is the (marginal) productivity vector of first period effort in performance measure y_1 and $\mathbf{v}_2 = (v_{21}, 0)'$ is the productivity vector of $\mathbf{e}_1$ in performance measure y_2. We assume $\mathbf{v}_1 \geq \mathbf{0}$, i.e. $\mathbf{v}_1 \geqq \mathbf{0}$ but $\mathbf{v}_1 \neq \mathbf{0}$, and $v_{21} \geq 0$ throughout the analysis. As allocating the agent's effort across several tasks in the second period does not create an interesting problem in our setting we model second period effort as an one-dimensional action e_2. The agent's performance productivity for the second period θ is a random variable from the ex ante perspective, continuously distributed on a subset of the positive real numbers. The realization of the random variable θ will be jointly observed by both parties at the end of period one, however, θ is assumed to be non verifiable information such that contracting parties cannot write an explicit contract on θ.[10] The additive noise terms η_1 and η_2 are i.i.d. with strictly positive density on $(-\infty, \infty)$[11] and $E(\eta_1) = E(\eta_2) = 0$. η_1 and η_2 are also independently distributed of θ. We restrict compensation contracts to be affine-linear[12] functions of the performance measures: the compensation function of period t is given by $S_t = s_t y_t + F_t$, with F_t as a fixed payment and s_t as the incentive weight of period t. The agent's disutility from performing actions in period 1 is $C_1(\mathbf{e}_1) = \mathbf{e}_1'\mathbf{e}_1/2$, for period 2 it is $C_2(e_2) = e_2^2/2$ and his reservation utility is set to zero in each period without loss of generality.

The principal's firm value is non contractible and given by

$$\pi = g_{11}e_{11} + g_{12}e_{12} + \gamma_2 e_2 + \eta_\pi.$$

Here g_{11} and g_{12} are the marginal productivities of the agent's first period actions e_{11} and e_{12} in firm value π and γ_2 is the agent's second period productivity. Like θ γ_2 is a random variable continuously distributed on some subset of R^+.[13] θ and γ_2 have a joint distribution $f(\theta, \gamma_2)$ with stochastic independence $f(\theta, \gamma_2) = f_\theta(\theta) f_{\gamma_2}(\gamma_2)$ as a special case. The realization of γ_2 will never be detected by the parties, however, the observation of θ may lead to a revision of the distribution of γ_2. The assumption that second period performance productivity θ is learned after the first period but second period effort firm value productivity γ_2 will not be observed is driven by the fact that the influence of the agent's second period action on his second period performance measure is more precisely measurable than its effect on firm value. η_π is a random variable distributed with strictly positive density on $(-\infty, \infty)$ with $E(\eta_\pi) = 0$. γ_2 and η_π are independently distributed of all other random variables of the model.

The principal's expected firm value given his information at $t = 0$ is

$$E(\pi) = g_{11}e_{11} + g_{12}e_{12} + E(\gamma_2 e_2(\theta))$$

[10] As mentioned in the introduction we consider a situation where the agent's productivity is unknown ex ante and will be (internally) learned over time. Consistent with this interpretation the agent's first period productivities might be random as well. As long as all first period productivities are independently distributed of all other random variables of the game there is no loss of generality to consider their means. Hence, to be parsimoneous with notation, we model deterministic first period effort productivities v_{11}, v_{12} and v_{21} taking into account that these productivities might be interpreted as the means of random productivities θ_{11}, θ_{12}, and θ_{21}, respectively.

[11] This assumption ensures that even if v_{21} is zero the observation of θ and y_2 does not reveal action e_2.

[12] Linear contracts are a usual assumption in models of performance measuerement in agencies with risk neutral parties, see for instance Baker (1992) and Budde (2006).

[13] With respect to the interpretation of g_{11} and g_{12} see footnote 10.

and his expectation at $t = 1$ given the observation of y_1 and θ and given his conjecture about the agent's first period actions $\widehat{\mathbf{e}}_1$ (if effort is unobservable) is

$$E\left(\pi|y_1,\theta,\widehat{\mathbf{e}}_1\right) = g_{11}\widehat{e}_{11} + g_{12}\widehat{e}_{12} + E\left(\gamma_2|\theta\right)e_2\left(\theta\right). \tag{1}$$

If the principal observes the agent's action choices we remove the carets in (1). Since the manager knows θ at his second period action choice we write $e_2\left(\theta\right)$. Notice that in contrast to the usual assumption the expected second period firm value productivity is generally not stationary in this model. Expectations at $t = 0$ are $E\left(\gamma_2\right)$ and at $t = 1$ expectations are $E\left(\gamma_2|\theta\right)$.

The distinction between observable and unobservable effort is material only with regard to first period actions. Whether the second period action is observable to the principal or not does not matter as the principal even in case of an observation of actions cannot use this information (since it is non verifiable).

3 Equilibrium Solutions

3.1 Long-term contracts

In this section we consider long-term contracts. We assume that both parties can commit at $t = 0$ to a two period relationship and to not to renegotiate the initial long-term contract $S = (S_1, S_2)$. Long-term commitment is a strong assumption as it assumes contracting parties can stay at the initial contract at later dates even if it is no longer efficient. We interpret long-term commitment as a benchmark and by comparing it to contracting environments with limited commitment we try to identify under which circumstances it is even optimal to seek commitment devices to approach the full commitment solution. Within long-term contracts it is immaterial for the outcome of the game if the agent's actions are observable or not. Even if effort would be observable the principal cannot use this information as he is committed to not to adapt the initial contract.

In long-term contracts the specifics of the contract $S = (S_1, S_2)$ will be fixed at the beginning of the relationship. To solve for the optimal long-term contract we work backwards through the game. At the beginning of the second period the agent (as well as the principal) has observed his second period performance productivity θ. His optimal second period action choice conditional on θ for a given contract $S = (S_1, S_2)$ is given by[14]

$$\begin{aligned} e_2\left(\theta\right) &= \underset{e_2'}{\operatorname{argmax}}\, E\left(F_2 + s_2 y_2|\theta\right) - C_2\left(e_2'\right) \\ &= \underset{e_2'}{\operatorname{argmax}}\, F_2 + s_2\theta e_2' + v_{21}e_{11} - \left(e_2'\right)^2/2 \\ &= s_2\theta. \end{aligned} \tag{2}$$

[14] As y_1 is independent of all other random variables we do not explicitly mention it in expressing conditional expectations in what follows.

The agent's ex ante expected payoff with contract S anticipating his optimal second period effort choice $e_2(\theta)$ is then given by

$$\begin{aligned} E\left(\Pi^A\right) &= E\left(F_1 + s_1 y_1 + F_2 + s_2 y_2\left(e_2(\theta)\right)\right) - C_1(\mathbf{e}_1) - E\left[C_2\left(e_2(\theta)\right)\right] \\ &= F_1 + s_1\left(v_{11}e_{11} + v_{12}e_{12}\right) + F_2 + s_2 v_{21} e_{11} + \frac{s_2^2 E\left(\theta^2\right)}{2} - \frac{e_{11}^2}{2} - \frac{e_{12}^2}{2}. \end{aligned}$$

From the optimality condition $dE\left(\Pi^A\right)/d\mathbf{e}_1 = 0$ we derive the optimal first period actions as

$$\mathbf{e}_1 = \left(s_1 v_{11} + s_2 v_{21}, s_1 v_{12}\right)'.$$

The optimal long-term contract is then the solution of the following optimization problem

$$\begin{aligned} &\max_{F_1,s_1,F_2,s_2} E\left(\pi - s_1 y_1 - F_1 - s_2 y_2 - F_2\right) \\ &\text{s.t.} \\ &\mathbf{e}_1 = \left(s_1 v_{11} + s_2 v_{21}, s_1 v_{12}\right)' \\ &e_2(\theta) = s_2\theta \\ &E\left(\Pi^A\right) \geq 0. \end{aligned} \tag{3}$$

The principal maximizes the net value of the firm taking into account the participation constraint $\left(E\left(\Pi^A\right) \geq 0\right)$ and the incentive constraints for the actions in both periods.

Lemma 1 *The optimal incentive weights* (s_1^*, s_2^*) *and the principal's equilibrium payoff* (Π^L) *in long-term contracts are given by*

$$\begin{aligned} s_1^* &= \frac{v_{21}^2 g_{12} v_{12} + E\left(\theta^2\right)\left(g_{11}v_{11} + g_{12}v_{12}\right) - v_{12}v_{21}E\left(\gamma_2\theta\right)}{E\left(\theta^2\right)\left(v_{11}^2 + v_{12}^2\right) + v_{12}^2 v_{21}^2}, \\ s_2^* &= \frac{E\left(\gamma_2\theta\right)\left(v_{11}^2 + v_{12}^2\right) + v_{12}^2 g_{11} v_{21} - v_{21}v_{11}g_{12}v_{12}}{E\left(\theta^2\right)\left(v_{11}^2 + v_{12}^2\right) + v_{12}^2 v_{21}^2}, \\ \Pi^L &= \frac{v_{21}^2 v_{12}^2\left(g_{11}^2 + g_{12}^2\right) + E\left(\theta^2\right)\left(v_{12}g_{12} + g_{11}v_{11}\right)^2 + 2E\left(\gamma_2\theta\right)v_{21}\left(g_{11}v_{12}^2 - g_{12}v_{11}v_{12}\right)}{2\left[E\left(\theta^2\right)\left(v_{11}^2 + v_{12}^2\right) + v_{12}^2 v_{21}^2\right]} \\ &\quad + \frac{E\left(\gamma_2\theta\right)^2\left(v_{12}^2 + v_{11}^2\right)}{2\left[E\left(\theta^2\right)\left(v_{11}^2 + v_{12}^2\right) + v_{12}^2 v_{21}^2\right]}. \end{aligned}$$

Proof. See appendix. ■

3.2 Short-term contracts

3.2.1 Unobservable effort

Now we assume that principal and agent have only limited commitment power such that they can only agree on short-term one-period contracts. At $t = 0$ the principal offers the first period contract S_1 and at the end of the first period (i.e. after y_1 and θ have been observed), at $t = 1$, the principal offers the second period contract S_2. To establish an equilibrium in short-term contracts we apply the concept of "fair contracts".[15] Fairness refers to a commitment

[15] See Christensen/Feltham/Şabac (2003).

of the principal to offer a second period contract S_2 that is individually rational given the agent has performed the desired (conjectured) first period actions. Given fairness the agent can commit to stay for both periods without running the risk of being exploited by the principal in the second period. Without this assumption the agent might have an incentive to choose a take-the-money-and-run-strategy such that no equilibrium exists.[16] The fairness concept is implicitly or explicitly used in a number of papers[17] and will be introduced in the context of our paper below. Interestingly, Christensen/Feltham/Şabac (2003) show the formal identity of fair short-term contracts and a long-term renegotiation-proof contract in a LEN complete contracting setting. However, as in our model the contracting environment is not complete, renegotiation-proofness is not at work.

Given a second period contract $S_2 = F_2 + s_2 y_2$ the agent selects his second period effort level according to (2) as $e_2(\theta) = s_2\theta$. The agent accepts the second period contract only if his second period payoff conditional on θ and $\mathbf{e}_1$ is at least zero.

$$\begin{aligned} E\left(F_2 + s_2 y_2 | \theta, \mathbf{e}_1\right) - C_2\left(e_2(\theta)\right) &\geq 0. \\ &\Leftrightarrow \\ F_2 + s_2\left(v_{21} e_{11} + \theta e_2(\theta)\right) - \frac{e_2(\theta)^2}{2} &\geq 0. \end{aligned}$$

The principal's optimal second period contract offer at $t = 1$ is then characterized by the solution to the following optimization program:

$$\begin{aligned} &\max_{F_2, s_2} \; E\left(\pi | \theta, \widehat{\mathbf{e}}_1\right) - F_2 - s_2 E\left(y_2 | \theta, \widehat{\mathbf{e}}_1\right) \\ &\text{s.t.} \\ &e_2(\theta) = s_2\theta \\ &E\left(F_2 + s_2 y_2 | \theta, \widehat{\mathbf{e}}_1\right) - C_2\left(e_2(\theta)\right) \geq 0. \end{aligned} \tag{4}$$

Since the principal designs the contract without knowing first period effort we replace $\mathbf{e}_1$ by the conjecture $\widehat{\mathbf{e}}_1$ within the participation constraint. Let $\mathbf{e}_1^*$ denote the conjectured first period equilibrium action, then fairness means that the principal can commit ex ante the second contract to fulfill $E\left(F_2 + s_2 y_2 | \theta, \mathbf{e}_1^*\right) - C_2\left(e_2(\theta)\right) \geq 0$.

Lemma 2 *The optimal second period contract given conjecture $\widehat{\mathbf{e}}_1$ is given by $s_2^{s*} = \frac{E(\gamma_2|\theta)}{\theta}$ and $F_2^{s*} = -\frac{E(\gamma_2|\theta)}{\theta} v_{21}\widehat{e}_{11} - \frac{1}{2}E\left(\gamma_2|\theta\right)^2$.*

Proof. See appendix. ■

Given the anticipated second period action $e_2(\theta)$ and the anticipated second period contract $S_2^{s*} = \left(F_2^{s*}, s_2^{s*}\right)$ we move to the first stage of the game to determine optimal first period

[16] See Christensen/Feltham/Şabac (2003) for a discussion of this problem in light of Indjejikian/Nanda (1999).
[17] See for instance Meyer (1995) and Indjejikian/Nanda (1999).

actions and the optimal first period contract. The agent's expected surplus from the two-period relationship anticipating second period's optimal decisions is given by

$$\begin{aligned} E\left(\Pi^{A}\right) &= E\left(F_{1}+s_{1}y_{1}+F_{2}^{s*}+s_{2}^{s*}y_{2}\right)-C_{1}\left(\mathbf{e}_{1}\right)-E\left[C_{2}\left(e_{2}\left(\theta\right)\right)\right] \\ &= F_{1}+s_{1}\left(v_{11}e_{11}+v_{12}e_{12}\right)+E\left(\frac{\gamma_{2}}{\theta}\right)v_{21}\left(e_{11}-\widehat{e}_{11}\right)-\frac{e_{11}^{2}+e_{12}^{2}}{2}. \end{aligned} \tag{5}$$

Maximizing this objective function for e_{11} and e_{12} yields the following optimal actions for a given incentive weight s_1:

$$\mathbf{e}_{1}=\left(s_{1}v_{11}+E\left(\frac{\gamma_{2}}{\theta}\right)v_{21};s_{1}v_{12}\right)'. \tag{6}$$

Then, the principal's problem in determining the optimal first period contract is characterized by

$$\begin{aligned} &\max_{s_{1},F_{1}}E\left(\pi\right)=g_{11}e_{11}+g_{12}e_{12}+E\left(\gamma_{2}e_{2}\left(\theta\right)\right)-E\left(F_{1}+s_{1}y_{1}+F_{2}^{s*}+s_{2}^{s*}y_{2}\right) \\ &\text{s.t.} \\ &\mathbf{e}_{1}=\left(s_{1}v_{11}+E\left(\frac{\gamma_{2}}{\theta}\right)v_{21};s_{1}v_{12}\right)' \\ &E\left(\Pi^{A}\right)=F_{1}+s_{1}\left(v_{11}e_{11}+v_{12}e_{12}\right)-\frac{e_{11}^{2}+e_{12}^{2}}{2}\geq 0. \end{aligned} \tag{7}$$

Notice that given the principal has determined the first-period incentive constraint (6) his conjecture on e_{11} is correct and the term $E\left(\frac{\gamma_2}{\theta}\right)v_{21}\left(e_{11}-\widehat{e}_{11}\right)$ vanishes within the participation constraint. Given that the optimal second period contract provides the agent with his second period reservation utility of zero his ex ante expected total surplus $E\left(\Pi^{A}\right)$ equals exactly the expected surplus from the first contract. The optimal fixed payment F_1 will be chosen such that the participation constraint of the above program is binding. The optimal incentive weight s_1^{s*} for period one and the equilibrium payoff Π^S of the principal are given in lemma 3:

Lemma 3 [18] $s_{1}^{s*}=\frac{g_{11}v_{11}+g_{12}v_{12}-E\left(\frac{\gamma_{2}}{\theta}\right)v_{21}v_{11}}{v_{11}^{2}+v_{12}^{2}}$,
$\Pi^{S}=\frac{\left(g_{11}v_{11}+g_{12}v_{12}\right)^{2}+2E\left(\frac{\gamma_{2}}{\theta}\right)v_{21}\left(g_{11}v_{12}^{2}-g_{12}v_{12}v_{11}\right)-v_{12}^{2}v_{21}^{2}\left\{E\left(\frac{\gamma_{2}}{\theta}\right)\right\}^{2}}{2\left(v_{11}^{2}+v_{12}^{2}\right)}+\frac{1}{2}E\left\{E\left(\gamma_{2}|\theta\right)^{2}\right\}.$

Proof. See appendix. ■

3.2.2 Observable effort

Whether the agent's actions are observable or not to the principal certainly depends on the terms of the relationship. The assumption of observability of actions is justified if principal and agent work very close together, if there exists a subjective measure that allows the principal to unambiguously infer the action or if the principal is able to implement a monitoring technology that perfectly reveals the agent's actions without serving as a proof from a juridical perspective. In a multi-period incentive problem with spot contracts the observability/unobservability of the

[18] As the optimal first period fixed payment does not influence the agent's incentives we omit it in lemma 3.

agent's actions is crucial as the principal uses observed actions of the previous period to fine-tune the contract for the current period.

When the principal can observe but not verify the agent's effort the only formal difference to the previous section is that the principal can condition the second period contract on his observation of the first period actions $\mathbf{e}_1$ instead of his conjecture $\widehat{\mathbf{e}}_1$. The observation of second period actions does not influence the equilibrium of the game. With observable effort we do not need to apply the fairness concept to sustain an equilibrium as the agent has no incentive to "fool" the principal.[19] According to lemma 2, the anticipated optimal second period contract $S_2^{o*} = (F_2^{o*}, s_2^{o*})$ given observation $\mathbf{e}_1$ is given by $s_2^{o*} = s_2^{s*} = \frac{E(\gamma_2|\theta)}{\theta}$ and $F_2^{o*} = -\frac{E(\gamma_2|\theta)}{\theta} v_{21} e_{11} - \frac{1}{2} E(\gamma_2|\theta)^2$. Now, compared to the analysis in the previous subsection, the term $E\left(\frac{\gamma_2}{\theta}\right) v_{21}(e_{11} - \widehat{e}_{11})$ in the agent's first period optimization problem disappears as the agent knows that the principal will select the second period contract that provides him exactly with his reservation utility (of zero) in the second period for *every* action vector $\mathbf{e}_1$ he performed in period one. Hence, the effect of the agent's first period strategic action e_{11} on second period performance measure does not affect his first period action choice. By observing the agent's first period effort the principal sets the second period fixed payment such that the agent's participation constraint for the second period is binding given his observation $\mathbf{e}_1$. By anticipating the second period fixed payment $F_2^{o*}(\mathbf{e}_1)$ the agent cannot influence his expected second period compensation via $\mathbf{e}_1$ and therefore in equilibrium the strategic effect of first period effort is obsolete.

Essentially, in equilibrium the observation of (first period) effort leads to a perfect separation of both periods: The second period performance measure y_2 is used to motivate the (ex post) optimal second period action and the first period measure y_1 is used to control $\mathbf{e}_1$. The principal's expected payoff from the second period is identical to the unobservable case and equals $Z_2^* = E(\gamma_2 e_2(\theta)) - E\left(e_2(\theta)^2\right)/2 = E(\gamma_2 \theta s_2^*) - E\left(\theta^2 s_2^{*2}\right)/2 = \frac{1}{2} E\left\{E(\gamma_2|\theta)^2\right\}$.

The principal's ex ante expected payoff from the first period (Z_1^{o*}) is the solution of the following optimization program, which characterizes a standard one shot incentive problem where two actions e_{11} and e_{12} have to be aligned via the performance measures y_1 to the firm value π:

$$\begin{aligned}
&\max_{s_1, F_1} g_{11} e_{11} + g_{12} e_{12} - F_1 - s_1(v_{11} e_{11} + v_{12} e_{12}) \qquad (8)\\
&\text{s.t.}\\
&\mathbf{e}_1' = (s_1 v_{11}, s_1 v_{12})\\
&F_1 + s_1(v_{11} e_{11} + v_{12} e_{12}) - \frac{e_{11}^2}{2} - \frac{e_{12}^2}{2} \geq 0.
\end{aligned}$$

Lemma 4 *The optimal incentive rate resulting from program (8) is* $s_1^{o*} = \frac{g_{11} v_{11} + g_{12} v_{12}}{v_{11}^2 + v_{12}^2}$*, the principal's corresponding first period surplus is* $Z_1^{o*} = \frac{(g_{11} v_{11} + g_{12} v_{12})^2}{2(v_{11}^2 + v_{12}^2)}$ *and his total surplus is* $\Pi^{So} = Z_1^{o*} + Z_2^* = \frac{(g_{11} v_{11} + g_{12} v_{12})^2}{2(v_{11}^2 + v_{12}^2)} + \frac{1}{2} E\left\{E(\gamma_2|\theta)^2\right\}$.

[19] With unobservable effort when the principal conjectures that the agent performs the optimal first period effort if he stays for two periods the agent might have an incentive to leave after the first period.

Proof. See appendix. ■

4 Analyzing the basic trade-off: Early vs. late effort motivation

In this section we analyze the preferability of long- or short-term contracts building on the analyses of the previous section. The general advantage of short-term contracts is that the contracting parties can adapt to new information (here: the agent's true productivity or the observation of first period effort) in the optimal second period contract while the general disadvantage is that rational economic agents will agree on a second period contract that is ex post optimal, i.e. it possibly destroys first period incentives. In long-term agreements without the possibility of renegotiation it is the other way around: The optimal contract is forward looking in the sense that it recognizes the effect of the second period performance measure on first period incentives, i.e. contracting parties can commit to second period contracts that are ex post inefficient. On the other hand they cannot react on new (unverifiable) information. We study this trade-off by comparing the three different contracting regimes introduced in the previous section. Whether the one or the other regime is preferred depends on the "importance" of the second period effort relative to the first period effort with respect to both the agent's performance measures and firm value. In this section we investigate the determinants of "importance" and in the next section we demonstrate implications for performance measurement and accounting information system design.

We first analyze the problem of motivating first period effort in sequentially optimal contracts as given in the two short-term settings. As we do not consider risk-sharing problems the only problem in motivating effort in short-term agreements (compared to long-term agreements) is that the anticipated ex post optimal contract possibly reduces the set of implementable first period actions levels. In short-term contracts second period bonus coefficient will be chosen to exclusively motivate second period effort while in long-term contracts the second period measure can also be used to control first period actions directly. The following proposition states a sufficient condition[20] such that sequentially optimal contracts do not reduce the set of implementable first period actions.

Proposition 1 *If first period effort productivities* $\mathbf{v}_1$ *and* $\mathbf{v}_2$ *are linearly dependent ex ante efficient first period actions can be motivated in sequentially optimal contracts.*

Proof. From (3), (7) and (8) we know induced first period effort in the three contracting regimes is given by $\mathbf{e}_1^L = \mathbf{v}_1 s_1 + \mathbf{v}_2 s_2, \mathbf{e}_1^S = \mathbf{v}_1 s_1 + \mathbf{v}_2 E\left(\frac{\gamma_2}{\theta}\right)$ and $\mathbf{e}_1^{So} = \mathbf{v}_1 s_1$. Let $\mathbf{e}_1^{L*} = \mathbf{v}_1 s_1^* + \mathbf{v}_2 s_2^*$ denote the ex ante efficient first period effort induced via a long-term contract. If $\mathbf{v}_1$ and $\mathbf{v}_2$ are linearly dependent, $\mathbf{e}_1^{L*} = \mathbf{v}_1 \left(s_1^* + \lambda s_2^*\right), \lambda \neq 0$. In the short-term regimes setting $s_1^{s*} = s_1^* + \lambda \left(s_2^* - E\left(s_2^{s*}\right)\right)$ and $s_1^{o*} = s_1^* + \lambda s_2^*$ induces the ex ante efficient first period effort $\mathbf{e}_1^{L*}$. ■

[20] Compare Schöndube (2003) for a similar condition in a model with complete contracts.

The ex ante efficiency condition in proposition 1 is not necessary for implementing ex ante efficient first period actions as even with a constrained set of implementable actions due to sequential optimal contracts the ex ante efficient first period actions might be implementable in some cases. These cases depend on the agent's firm value productivities as well as on the distribution of (γ_2, θ) and can only be interpreted case by case. The condition of proposition 1, however, does only depend on the characteristics of the performance measures and ensures that all first period actions that can be motivated in long-term contracts can be motivated in short-term contracts as well. Regarding proposition 1 from the opposite perspective, a necessary condition for short-term contracts reducing the set of implementable first period actions is that the vectors $\mathbf{v}_1$ and $\mathbf{v}_2$ are linearly independent. Analyzing this condition economically we require strategic consequences of first-period effort as well as a multi-task-problem in period 1 as necessary conditions to constitute a welfare loss in short-term contracts relative to long-term contracting. Assume that there are no strategic consequences, $v_{21} = 0$, which implies linear dependency of $\mathbf{v}_1$ and $\mathbf{v}_2$. Then the first period effort will determined solely by first period performance which can be contracted on ex ante optimal anyway. Even with strategic consequences of first period effort, $v_{21} > 0$, linear independence of $\mathbf{v}_1$ and $\mathbf{v}_2$ requires $v_{12} > 0$. That means, besides the strategic effect of first period effort, there must be more tasks than performance measures in period one (here: two actions e_{11} and e_{12} and one measure y_1); we call this a multi-task-problem in what follows. For $v_{12} = 0$ only the action e_{11} is being implementable in period 1. e_{11} can always be optimally controlled via incentive coefficient s_1: the set of implementable first period actions can be solely spanned the first-period incentive rate s_1 such that the ex ante efficient action will be implemented in either regime. If there is a multi-task-problem plus strategic effort in period 1, however, ex ante efficiency may require to use the second period measure explicitly to control first period effort what is impossible in short-term contracts.

Our model with one performance measure but two actions in the first period gives rise to a potential multi-task-problem in period one and the possibly positive marginal product of e_{11} in y_2, $v_{21} \geq 0$, captures the strategic effect. To keep the model simple we did not model a long term effect of e_{12}.

Given the ex ante efficiency condition in proposition 1 first period effort can be optimally controlled by the first period performance measure and the second period performance measure can be used to motivate the second period effort. Short-term contracts with observable and with unobservable effort generate the same second period allocation. The difference is with regard to first period incentives. With observable effort both periods are perfectly separated in the sense that the two period agency problem can be decomposed in two separate one-shot problems: The first period effort will be motivated solely by y_1 and the e_2 will be induced via y_2. In contrast, with unobservable effort the agent takes the impact of his first period actions on second period performance into account when selecting his actions. As the second period incentive rate will be chosen ex post optimal it is a priori ambiguous which contracting regime is dominant under which circumstances and we will analyze this issue later on. For the condition given in proposition 1, however, short-term contracts with observable and with unobservable effort generate an identical outcome as the ex ante efficient first period actions can be induced anyway. Furthermore, as in long-term agreements second period incentives cannot be based on the actual second period productivity, they are weakly dominated:

Corollary 1 *Given the ex ante efficient first-period actions can be implemented in sequentially optimal contracts, short-term contracts are (weakly) preferred to long-term contracts, i.e.* $\Pi^S = \Pi^{So} \geq \Pi^L$.

The advantage of short-term contracting is that contracting parties can use the observed productivity information θ to define the characteristics of the second period contract whereas in long-term contracts these characteristics must be determined based on prior beliefs on θ. The next proposition identifies when the ability to use the productivity information θ to fine-tune second period incentives in short-term contracts is worthless.

Proposition 2 *Sequentially optimal second period incentives are implementable in long-term contracts if and only if* $E(\gamma_2|\theta) = c \cdot \theta$, *where* c *is a positive constant.*

Proof. *Sequentially optimal incentives are given by* $s_2^{s*} = \frac{E(\gamma_2|\theta)}{\theta}$. s_2^{s*} *can be implemented in long-term contracts only if* s_2^{s*} *does not depend on* θ *as contracting parameters are determined before* θ *will be observed.* s_2^* *is independent of* θ *if and only if* $E(\gamma_2|\theta) = c \cdot \theta$. *As* γ_2 *and* θ *can take only positive values,* $c > 0$. ■

Corollary 2 *If* $E(\gamma_2|\theta) = c \cdot \theta$, *then* $\Pi^L \geq \Pi^S$.

If the sequentially optimal incentive rate is given by $s_2^{s*} = c$ the principal can motivate the same second period effort in long-term contracts as in short-term contracts. This directly implies that the principal could replicate the outcome of short-term contracts *with unobservable effort* in long-term contracts by setting $s_2 = c$ and then optimizing w.r.t. s_1. Hence, for $E(\gamma_2|\theta) = c \cdot \theta$ the principal could act sequentially optimal in long-term contracts but he need not to do so and therefore $\Pi^L \geq \Pi^S$. On the other hand the equilibrium outcome of the short-term setting with observable actions in general cannot be imitated in long-term contracts as the incentive constraints differ; we will get back to this point later on. Combining proposition 1 and proposition 2 leads to:

Corollary 3 *Given the conditions in proposition 1 and proposition 2 apply simultaneously, this results in:* $\Pi^S = \Pi^{So} = \Pi^L$.

The conditions in proposition 1 and 2 ensure that the comparative advantages of either system long-term or short-term contracts vanish: on the one hand there is no need to use the second period contract for first period effort motivation (which would be possible in long-term contracts but not in short-term contracts) and on the other hand the sequentially optimal second period incentive rate does not depend on the observed productivity information such that sequentially optimal incentives are implementable in long-term contracts.

The next proposition emphasizes the impact of ex ante uncertainty about second period firm value productivity (γ_2) and performance measure productivity (θ) on the profitability of long-term and short-term contracts.

Proposition 3 *Ceteris paribus, short-term contracts are getting (weakly) more attractive a) the higher the prior variance of θ and b) the higher the variance of $E(\gamma_2|\theta)$.*

Proof. Writing $E(\theta^2) = E(\theta)^2 + Var(\theta)$, Π^L as defined in lemma 1 is (weakly) decreasing in $Var(\theta)$ and as Π^S and Π^{So} do not depend on $Var(\theta)$ short-term contracting becomes more attractive. Writing the term $E\left\{E(\gamma_2|\theta)^2\right\}$ in Π^S and Π^{So} as $E(\gamma_2)^2 + Var(E(\gamma_2|\theta))$, $Var(E(\gamma_2|\theta)) = E\left[(E(\gamma_2|\theta) - E(\gamma_2))^2\right]$, both Π^S and Π^{So} as defined in lemma 3 and 4 are increasing in $Var(E(\gamma_2|\theta))$. As Π^L does not depend on $Var(E(\gamma_2|\theta))$ the profitability of short-term contracts rises with $Var(E(\gamma_2|\theta))$. ■

Within long-term agreements the principal fixes second period incentives based on his information at $t = 0$ anticipating future choices by the agent. The agent, however, selects his second period action conditional on his observation θ. As θ is a random variable ex ante the agent's second period effort choice is a random variable as well (ex ante). The higher the dispersion of θ the stronger the problem of motivating a second period effort consistent with θ by an incentive rate independent of θ. Similarly, the relative advantage generated by short-term contracts increases with $Var(E(\gamma_2|\theta)) = E\left[(E(\gamma_2|\theta) - E(\gamma_2))^2\right]$ because with an increasing deviation from the prior mean the advantage of being able to set second period incentives knowing the posterior mean of γ_2 conditional on θ becomes stronger.

In the last part of this section we analyze differences between short-term contracts with observable and with unobservable effort. As both regimes treat first period effort differently there might be different recommendations for optimal performance measurement. We know from proposition 1 that necessary conditions for both regimes being different are that first period effort has long-term consequences and that there must be more tasks in period 1 than performance measures. In the observable effort setting the long-term effect of first period actions is cut and each period is separately controlled by its performance measure whereas with unobservable effort the agent's first period strategic effort is influenced by second period performance, however, in equilibrium the second period performance measure will be optimized only with respect to the second period action. The potential advantage of not observing the agent's action is that the strategic effect of first period effort on second period performance shows up in equilibrium. The disadvantage is that this strategic effect cannot be ex ante controlled as the second period incentive rate will be chosen sequentially optimal. If the misallocation of first period effort due to the uncontrollable strategic effect becomes too strong the principal is better off to fell the long-term effect which corresponds to the observable effort case.

Proposition 4 *Assume the condition in proposition 1 does not apply:*
a)If first period performance measure y_1 is perfectly congruent to π w.r.t. $\mathbf{e}_1$, i.e. $g_{11}/g_{12} = v_{11}/v_{12}$, the observation of actions is strictly advantageous, $\Delta^S = \Pi^{So} - \Pi^S > 0$.
b) If y_1 is not congruent to π w.r.t. $\mathbf{e}_1$, then
b1) Δ^S is decreasing in g_{11} and if g_{11} becomes sufficiently high $\Delta^S < 0$.
b2)If the strategic effect of first period effort, $E\left(\frac{\gamma_2}{\theta}\right)v_{21}$, is sufficiently strong $\Delta^S > 0$.

Proof. From lemma 3 and lemma 4

$$\Delta^S = \Pi^{So} - \Pi^S = \frac{v_{12}v_{21}E\left(\frac{\gamma_2}{\theta}\right)\left[2g_{12}v_{11} - 2g_{11}v_{12} + v_{21}v_{12}E\left(\frac{\gamma_2}{\theta}\right)\right]}{2\left(v_{11}^2 + v_{12}^2\right)}. \tag{9}$$

By assumption: $\mathbf{v}_1$ and $\mathbf{v}_2$ are linerarly independent.
a) For $g_{11}/g_{12} = v_{11}/v_{12}$ $\Delta^S = \frac{\left[v_{12}v_{21}E\left(\frac{\gamma_2}{\theta}\right)\right]^2}{2\left(v_{11}^2+v_{12}^2\right)} > 0$. b1) $d\Delta^S/dg_{11} = \frac{-v_{12}^2v_{21}E\left(\frac{\gamma_2}{\theta}\right)}{v_{11}^2+v_{12}^2} < 0$ and as can be easily seen from (9) if g_{11} is sufficiently high (holding the other parameters constant) Δ^S becomes negative. b2) The strategic effect of first period effort is measured by $E\left(s_2^{s*}\right)v_{21}$, with $E\left(s_2^{s*}\right) = E\left(\frac{\gamma_2}{\theta}\right)$. From (9) if $v_{21}E\left(\frac{\gamma_2}{\theta}\right)$ becomes sufficiently high $\Delta^S > 0$. ■

Congruity of a performance measure with respect to an effort vector as defined in Feltham/Xie (1994) is a necessary condition for the first best effort level being implementable through a performance measurement system. In our model the first best effort level in period 1 is $\mathbf{e}_1^{FB} = (g_{11}, g_{12})'$ and first best effort can be only induced via performance measure y_1 alone (ignoring the second period for the moment), if the quotient of marginal firm value products g_{11}/g_{12} is equal to the quotient of marginal performance products of $y_1, v_{11}/v_{12}$. In this case by setting the optimal first period incentive weight to $s_1^* = g_{11}/v_{11} (= g_{12}/v_{12})$ the first-best effort $\mathbf{e}_1^{FB}$ can be induced with observable effort as there is no strategic effect in equilibrium. With non observable effort, however, action $e_{11} = s_1v_{11} + E\left(\frac{\gamma_2}{\theta}\right)v_{21}$ is influenced by the long-term effect $E\left(\frac{\gamma_2}{\theta}\right)v_{21} > 0$ such that it is never possible to induce $\mathbf{e}_1^{FB}$ and a welfare loss relative to the observable case occurs. If y_1 is not congruent to π w.r.t. $\mathbf{e}_1$ not observing first period effort becomes relatively more advantageous as the productivity g_{11} of e_{11} in π is increasing. Notice, that, holding all other parameters constant, with increasing g_{11} the importance of task e_{11} relative to e_{12} increases. In the observable effort case both tasks will be determined solely by the first period incentive rate s_1 while with unobservable effort task e_{11} is additionally motivated by the strategic term $E\left(\frac{\gamma_2}{\theta}\right)v_{21}$. As the importance of the strategic action increases, measured by g_{11}, using the strategic performance effect becomes - although not controllable ex ante- more valuable. By a similar argument if the strategic effect $E\left(\frac{\gamma_2}{\theta}\right)v_{21}$ is too strong the discrepancy between induced first period actions e_{11} and e_{12} becomes inefficiently high such that the principal prefers an environment where no strategic effect is present: this corresponds to the case where effort is non observable.

5 Implications for performance measurement and information system design

Based on the results derived before in this section we demonstrate implications for performance measurement and information system design, especially related to accounting issues. First, we compare an accrual-accounting system to a cash-accounting system regarding their suitability to induce early and late effort in long- and short-term contracts. Second, we analyze whether it is indeed optimal to install an accounting information system that reports the agent's productivity.

One basic element of the model employed in this paper is that first-period effort (potentially) has long-term consequences. This modeling allows us to capture that cash consequences of first period activities (transactions) are realized across both periods. In this case cash and accrual information systems differ in the timeliness of reporting the effect of economic transactions and events. Assuming that part of the cash-flow associated with first-period effort $\mathbf{e}_1$ is realized in period 2 we compare cash-accounting to accrual-accounting. A cash-accounting system reports the effect of a transaction when cash is received. However, if we require financial statements to show the influence of a period's transactions on that period's firm value contribution, independently of its cash consequences, the accrual concept becomes important. Under accrual-accounting transactions are recognized when they occur, i.e. in the period of transaction. Hence, in the context of the economic environment of this paper, under the accrual-accounting system the period 2 cash realization of $\mathbf{e}_1$ will be reported in the period 1 performance measure y_1. Given our model setup we distinguish cash- and accrual-accounting information systems by the following differences in the reported performance measures:

$$\begin{aligned} \text{Accrual-Accounting:} \qquad & y_1 = (v+a)\,e_{11} + v_{12}e_{12} + \eta_1; \quad y_2 = \theta e_2 + \eta_2. \\ \text{Cash-Accounting:} \qquad & y_1 = ve_{11} + v_{12}e_{12} + \eta_1; \quad y_2 = ae_{11} + \theta e_2 + \eta_2, \\ & v, a \geq 0. \end{aligned}$$

In the terminology of the model introduced in section 2 we have $v_{11} = (v+a)$ and $v_{21} = 0$ in the accrual-accounting system and $v_{11} = v$ and $v_{21} = a$ in the cash-accounting system, i.e. the total marginal product of $\mathbf{e}_1$ is equal in both systems but the timing is different. ae_{11} is the accrual component that will be determined by the firm's accountant and we assume (to not leave our model) that there is no measurement error with respect to a.[21] Neither the principal nor the agent can observe ae_{11} in isolation. As a practical example for such a timing of earnings/cash recognition consider a two-period construction contract with completion effort e_{11} in period 1 and e_2 in period 2. The expected payment from the contract at time of completion at the end of period 2 is $ae_{11} + \theta e_2$ and the fraction (on a value basis) completed at the end of the first

[21] Alternatively, one could model the accrual as $ae_{11} + \eta_a$ with $E(\eta_a) = 0$ and η_a not correlated with other random variables of the model and then adapting the performance measures in both systems accordingly. As the contracting parties are risk neutral this modeling would lead to the same results as the approach chosen in the paper.

period is ae_{11}. Then, applying the percentage-of-completion method the first period accrual is ae_{11}. Of course, other examples can be put forward for a revenue recognition occurring before cash recognition, e.g. sales contracts where shipment takes place (a period) before the check is paid.

Our objective is to derive conditions for the dominance of cash- or accrual-accounting to clarify the relevant trade-off between both systems under different contracting environments. If the accrual is zero ($a = 0$) both systems are equivalent by definition. Furthermore, both systems must be equivalent in all contracting environments if $v_{12} = 0$: For $v_{12} = 0$ there is only one action in period 1 that can be always optimally motivated by the first period incentive rate. In fact, $v_{12} = 0$ and/or $a = 0$ ensure for both systems that the ex ante efficiency condition of proposition 1 holds. To exclude trivial cases we assume this condition does not apply in what follows.

Analyzing long-term contracts first, we face a contracting problem where the incentive contract is fixed at $t = 0$ and where the agent's action choices are given by

$$\left.\begin{aligned} e_{11} &= s_1(v+a) \\ e_{12} &= s_1 v_{12} \\ e_2 &= s_2\theta \end{aligned}\right\} \text{ in the accrual-accounting system}$$

$$\left.\begin{aligned} e_{11} &= s_1 v + s_2 a \\ e_{12} &= s_1 v_{12} \\ e_2 &= s_2\theta \end{aligned}\right\} \text{ in the cash-accounting system}$$

As introduced in the model section the principal values the first-period actions with g_{11} and g_{12}, respectively. The ex ante expceted payment from the second period effort is $E(\gamma_2 e_2) = s_2 E(\theta\gamma_2)$.

In short-term contracts the second period incentive rate will be chosen sequentially optimal, $s_2^* = \frac{E(\gamma_2|\theta)}{\theta}$, so that the induced second period effort is independent of the accounting system. The part of the principal's surplus that is related to the second period action is $E\left(\gamma_2 e_2^* - \frac{e_2^{*2}}{2}\right)$ for both information systems. Hence, when comparing accrual- to cash-accounting in short-term contrcats we can without loss of generality compare the induced first period effort. If the agent's effort is not observable the manager's incentive compatibility conditions for $\mathbf{e}_1$ are given by (cf. section 3.2.1)

$$\left.\begin{aligned} e_{11} &= s_1(v+a) \\ e_{12} &= s_1 v_{12} \end{aligned}\right\} \text{ in the accrual-accounting system}$$

$$\left.\begin{aligned} e_{11} &= s_1 v + E\left(\tfrac{\gamma_2}{\theta}\right) a \\ e_{12} &= s_1 v_{12} \end{aligned}\right\} \text{ in the cash-accounting system.}$$

With observable actions the agent's first period incentives in short-term contracts are given by

$$\left.\begin{array}{c} e_{11} = s_1 (v + a) \\ e_{12} = s_1 v_{12} \end{array}\right\} \text{in the accrual-accounting system}$$

$$\left.\begin{array}{c} e_{11} = s_1 v \\ e_{12} = s_1 v_{12} \end{array}\right\} \text{in the cash-accounting system.}$$

As discussed in section 3.2.2 long-term effects on performance measures are cut within short-term contracts with observable effort. As there are no long-term performance effects in the accrual system the principal's payoff with accrual accounting is the same as in the unobservable action setting. Furthermore, the surplus generated in the cash system with observable effort is independent of the accrual a as long-term performance effects vanish and first-period effort is only motivated by the first period performance measure.

Proposition 5 *a)For all contracting regimes: If the operational action e_{12} is sufficiently valuable, cash-accounting dominates accrual-accounting.*
b) In long-term contracts and in short-term contracts with unobservable effort: If the second period action e_2 is sufficiently valuable, accrual-accounting dominates cash-accounting.
c)In short-term contracts: If the strategic action e_{11} is sufficiently valuable, accrual-accounting dominates cash-accounting.

Proof. See appendix. ■

If the operational action e_{12} is very important, particularly compared to the strategic action e_{11}, then the principal would like to differentiate between both first period actions via the incentive system. In the accrual system all financial consequences of first period actions are measured in period 1. Hence, both first period actions are exclusively motivated by the first period incentive weight such that the relation between both actions, the quotient e_{11}/e_{12}, is fixed. With cash accounting, however, the long-term cash effect of the strategic action e_{11} is measured in period 2 such that it is possible to set strong incentives for the operational action via high s_1 without increasing the strategic action proportionally. If the second period action e_2 is sufficiently valuable it is the other way around. Except for the short-term contract setting with observable actions the accrual system dominates the cash system. In the accrual system all cash realizations of first period transactions are drawn into the first period such that the second period measure does only depend on second period effort. If the second period action is sufficiently valuable in the accrual system the principal can set high powered second period incentives without influencing first period actions what explains the dominance for accrual-accounting here. As is the short-term setting with observable actions both periods are perfectly separated the second period incentive rate does not influence first period actions in either system so that both information systems are equivalent.

If the strategic action e_{11} is sufficiently valuable accrual-accounting dominates cash-accounting in short-term contracts. The reason is that in short-term contracts the second period cash effect of strategic effort e_{11} either cannot be controlled ex ante optimal or is simply lost under cash accounting. Under accrual-accounting, however, all effects of the very valuable action e_{11} will be measured in the first period such that it can be controlled optimally.

The second question we want to answer is whether it is indeed optimal for the firm to install an accounting information system that reports the manager's productivity θ. If the principal's information system does not show θ the agent selects his second period action based on his prior belief on θ, (similar to (2)) $e_2 = s_2 E(\theta)$. Furthermore, in short-term contracts if the information system does not report θ the principal sets sequentially optimal second period incentives based on the prior joint distribution of (θ, γ_2). The following proposition provides some elementary conditions for the productivity information θ having positive or negative value in different contracting regimes.

Proposition 6 *a1)In every contracting regime: If the conditions of proposition 1 and proposition 2 apply simultaneously, observing θ is always strictly beneficial. a2)In short-term contracts with observable effort observing θ can never be harmful.*
Assume the conditions of proposition 1 and proposition 2 do not apply:
b)In long-term contracts: Observing θ has negative value if θ and γ_2 are independently distributed.
c) In short-term contracts with unobservable effort: Observing θ has negative value if the following two conditions apply simultaneously: 1) θ and γ_2 are independently distributed and 2) the relative productivity of first period actions in performance measure y_1 exceeds the relative productivity of these actions in firm value π, $v_{11}/v_{12} > g_{11}/g_{12}$.

Proof. See appendix. ■

ad a) Under the conditions of the propositions 1 and 2 the three different contracting regimes are equivalent and generate exactly the same surplus for the agency. Furthermore the conditions ensure that the observation of θ has no negative effect on first period effort (prop.1) and at the same time as posterior second period firm value productivity is a linear function of θ (prop.2) observing θ is strictly beneficial with respect to second period effort. As in short-term contracts with observable effort both periods are perfectly separated there exist no negative effects from the second period incentive rate on first period effort that might be mitigated by not observing θ.

ad b) The potential advantage of observing θ in long-term contracts is that the agent is induced to select a second period action that depends on the observed performance productivity which is valuable if performance productivity θ is closely related to firm value productivity γ_2. If the observed productivity is not related to firm value, the variation of e_2 in θ is costly for the firm and the principal is doing better without observing the signal. Not related means that γ_2 and θ are independently distributed. In this case the observation of θ does not help to direct the second period action towards firm value. Rather, as the agent selects $e_2 = s_2\theta$ the induced action is a random variable from the ex ante perspective. Due to the agent's convex cost of effort it can never be optimal[22] to induce different action-levels across different realizations of performance productivities that are independent of the firm value (the proof follows directly from Jensen's inequality). Hence, with independent productivities θ and γ_2 an information system that does not reveal θ dominates an information system that reports θ.

ad c) In short-term contracts besides the agent's action choice conditional on θ the principal can use θ to align second period incentives with firm value. If effort is unobservable first period incentives might be influenced by the second period incentive rate. In this case not observing the productivity signal might be beneficial to avoid too strong distortions in first period effort. Indeed, independence of θ and γ_2 is not sufficient for the productivity information being harmful in short-term contracts with unobservable effort: Given independence, observing θ does not influence the second period problem, the induced second period action is $e_2 = E(\gamma_2)$ with and without observing θ. The only difference is that with observable θ $e_2 = s_2\theta = E(\gamma_2)$ is motivated via $s_2 = \frac{E(\gamma_2)}{\theta}$ whereas the corresponding bonus coefficient without θ ($e_2 = s_2 E(\theta)$) is $s_2 = \frac{E(\gamma_2)}{E(\theta)}$. Induced first period strategic action $e_{11} = s_1 v_{11} + E(s_2) v_{21}$ is in the first case $e_{11} = s_1 v_{11} + E(\gamma_2) E\left(\frac{1}{\theta}\right) v_{21}$ and in the latter case it is $e_{11} = s_1 v_{11} + \frac{E(\gamma_2)}{E(\theta)} v_{21}$ while the operational action is always $e_{12} = s_1 v_{12}$: the long-term effect of strategic effort makes the difference. Since $E\left(\frac{1}{\theta}\right) > \frac{1}{E(\theta)}$ the induced strategic action with observable θ is always higher than without θ. If the relation of first period firm value productivities g_{11}/g_{11} is less than the corresponding relation of productivities in performance measure y_1,v_{11}/v_{12}, the induced relation of first period actions via s_1 *alone* v_{11}/v_{12} is already too high from the principal's view. Now, the optimal relation is further distorted by the long-term incentive effect of the strategic action e_{11}. As the long-term incentive effect is always lower if θ is not observed an information system not reporting θ is preferred if $g_{11}/g_{12} < v_{11}/v_{12}$.

The general lesson from this analysis is that an accounting information system that reports the manager's productivity in a dynamic agency need not be beneficial for the outcome of the relationship. The value of unverifiably observing the agent's performance productivity in short-term contracts depends on the gains from possibly improved second period incentives compared to the first period effect of observing θ. The second period incentive effect of θ cannot be negative and as the first period effect disappears with observable effort observing the productivity information is always weakly beneficial in this case. With unobservable effort, the first period effect might create costly misallocations of first period actions such that the overall effect of observing θ can become negative. In addition, in long-term contracts the second period effect of θ can also be negative as the principal can not react on the observation of θ such that e_2 may be a costly random variable from the ex ante perspective.

[22] A similar effect arises in Baker's (1992) private pre-decision information model.

6 Summary and conclusions

In this paper we analyzed a dynamic agency relationship where contracting parties learn the agent's second period performance productivity at the end of the first period. Firm value is not contractible such that effort incentives must be motivate via a performance measurement system. The agent's second period performance productivity was assumed to be non verifiable information. We considered three different contracting regimes: long-term full commitment contracts, short-term contracts with observable (but not verifiable) effort and short term contracts with unobservable actions. In long-term contracts the principal can commit to second period incentives that are not ex post optimal but he cannot react on the observation of the agent's performance productivity. In short-term contracts the principal can always use the productivity information to fine-tune second period incentives, however, setting second period incentives sequentially optimal might harm first period effort incentives. We determined the equilibrium solution for each contracting regime and based on these results we analyzed the trade-off of motivating first and second period effort both between and within the three regimes.

We first show that if first period effort productivities in first period performance and in second period performance are linearly dependent it is always possible to induce the ex ante efficient first period actions in short-term contracts. If this ex ante efficiency condition applies the induced surplus in short-term contracts is always at least as high as in long-term contracts. On the other hand, if the sequentially optimal second period incentive rate does not depend on the observed performance productivity there is no gain of short-term contracting. The equilibrium second period incentive weight is independent from the observed productivity only if the posterior mean of second period firm value productivity is a linear function of the observation. Furthermore, an increasing variance of the second period performance productivity makes short-term contracts more profitable relative to long-term contracts as with increasing dispersion it gets more difficult to control the desired second period action without knowing its performance productivity in long-term contracts. For similar reasons long-term contracts are becoming worse relative to short-term contracts if the variance of the posterior mean of second period effort firm value productivity is increasing.

The difference between short-term contracts with observable and with unobservable effort is that with observable actions in equilibrium both periods are perfectly separated (the first period effort is solely motivated by first period performance measures) while in the unobservable action case strategic effort consequences are influenced by the sequentially optimal incentive rate. By comparing both regimes it becomes clear that the observation of the agent's effort need not be beneficial to the principal in a dynamic agency. As the principal observes the agent's first period effort he offers a second period contract that exactly meets the agent's second period reservation utility given the observed first period actions. Hence, in equilibrium the second period compensation does not create incentives for the first period action choice even if there are strategic (i.e. long-term) performance effects. However, if the agent has to perform several tasks in the first period using the strategic performance effect might be helpful to control first period effort efficiently such that not observing the agent's effort is optimal.

Based on the results regarding the trade-off between motivating first and second period effort we presented implications for performance measurement and accounting information system design. First, we compared an accrual-accounting information system to a cash-accounting information system. The differentiating feature of both systems is that under accrual-accounting all financial consequences resulting from first period effort are reported in the first period while the cash system recognizes financial consequences of transactions at the time of payment. Given the trade-off between motivating first and second period actions the timing of information is important as it crucially influences this trade-off via changing the performance productivity vectors of the two periods. We derived conditions for the dominance of the one or the other accounting information system, depending on the value of the manager's actions.

Second, we asked the question whether it is indeed optimal to install an accounting information system that (internally) reports the manager's performance productivity. The observation of the performance productivity has two effects. First, the agent selects his second period action based on the reported productivity and second, (in short-term contracts) the principal will determine the optimal second period incentive weight based on the observed productivity. In short-term contracts with observable effort not reporting the productivity signal can never be of any value as both periods are perfectly separated and for the second period problem it is always (weakly) optimal to observe the information. In long-term contracts and in short-term contracts with unobservable effort, however, the effect of the agent's reaction on the anticipated use of the observation by the principal may distort first period incentives in a way that it would be better not to observe the signal. In addition, in long-term contracts installing an information system that reports the agent's productivity may have strictly negative value as it motivates a costly second period random effort.

Appendix: Proofs

Proof of lemma 1

The principal's problem to determine the equilibrium solution in long-term contracts is given in program (3). By substituting all constraints into the objective function (the participation constraint must bind at the optimum) this problem can be simplified as

$$\max_{s_1,s_2} Z^L = g_{11}(s_1v_{11}+s_2v_{21}) + g_{12}s_1v_{12} - \frac{1}{2}(s_1v_{11}+s_2v_{21})^2 - \frac{1}{2}s_1^2v_{12}^2 + s_2E(\theta\gamma_2) - \frac{E(\theta^2)s_2^2}{2}.$$

From

$$\begin{aligned}\frac{\partial Z^L}{\partial s_1} &= g_{11}v_{11}+g_{12}v_{12}-(s_1v_{11}+s_2v_{21})v_{11}-s_1v_{12}^2=0\\ \frac{\partial Z^L}{\partial s_2} &= g_{11}v_{21}+E(\theta\gamma_2)-(s_1v_{11}+s_2v_{21})v_{21}-s_2E\left(\theta^2\right)=0\end{aligned}$$

we obtain the optimal incentive weights as

$$\begin{aligned}s_1^* &= \frac{v_{21}^2g_{12}v_{12}+E\left(\theta^2\right)(g_{11}v_{11}+g_{12}v_{12})-v_{12}v_{21}E(\gamma_2\theta)}{E\left(\theta^2\right)\left(v_{11}^2+v_{12}^2\right)+v_{12}^2v_{21}^2}\\ s_2^* &= s_2^* = \frac{E(\gamma_2\theta)\left(v_{11}^2+v_{12}^2\right)+v_{12}^2g_{11}v_{21}-v_{21}v_{11}g_{12}v_{12}}{E\left(\theta^2\right)\left(v_{11}^2+v_{12}^2\right)+v_{12}^2v_{21}^2}\end{aligned}$$

and the principal's equilibrium surplus is

$$\begin{aligned}\Pi^L \equiv\ & Z^L(s_1^*,s_2^*) = \frac{v_{21}^2v_{12}^2\left(g_{11}^2+g_{12}^2\right)+E\left(\theta^2\right)(v_{12}g_{12}+g_{11}v_{11})^2+2E(\gamma_2\theta)v_{21}\left(g_{11}v_{12}^2-g_{12}v_{11}v_{12}\right)}{2\left[E\left(\theta^2\right)\left(v_{11}^2+v_{12}^2\right)+v_{12}^2v_{21}^2\right]}\\ & \frac{+E(\gamma_2\theta)^2\left(v_{12}^2+v_{11}^2\right)}{2\left[E\left(\theta^2\right)\left(v_{11}^2+v_{12}^2\right)+v_{12}^2v_{21}^2\right]}.\end{aligned}$$

Proof of lemma 2

The optimization problem for the optimal second period contract is given by (4):

$$\begin{aligned}&\max_{F_2,s_2} E(\pi|\theta,\widehat{\mathbf{e}}_1)-F_2-s_2E(y_2|\theta,\widehat{\mathbf{e}}_1)\\ &\text{subject to}\\ &e_2(\theta)=s_2\theta\\ &E(F_2+s_2y_2|y_1,\theta,\widehat{\mathbf{e}}_1)-C_2(e_2(\theta))\geq 0.\end{aligned}$$

The objective function can be written as $g_{11}\widehat{e}_{11}+g_{12}\widehat{e}_{12}+E(\gamma_2|\theta)e_2(\theta)-F_2-s_2(v_{21}\widehat{e}_{11}+\theta e_2(\theta))$. Removing terms that do not influence the optimization and substituting the incentive constraint and the binding participation constraint $F_2+s_2(v_{21}\widehat{e}_{11}+\theta e_2(\theta))-\frac{e_2(\theta)^2}{2}=0$ into the objective function the principals objective function gets

$$\max_{s_2} s_2\theta E(\gamma_2|\theta)-\frac{s_2^2\theta^2}{2}.$$

From the optimality condition $\theta E(\gamma_2|\theta) - s_2\theta^2 = 0$ we get $s_2^{s*} = \frac{E(\gamma_2|\theta)}{\theta}$ and substituting s_2^{s*} into the binding participation constraint and solving for F_2 yields $F_2^{s*} = -\frac{E(\gamma_2|\theta)}{\theta} v_{21}\widehat{e}_{11} - \frac{1}{2}E(\gamma_2|\theta)^2$.

Proof of lemma 3

Given the anticipated second period contract as defined in lemma 2 with $\widehat{\mathbf{e}}_1 = \mathbf{e}_1$ the principal determines the optimal first period contract. The corresponding program is given by (7). By substituting the binding participation constraint into the principal's objective function we obtain

$$\max_{s_2} Z^S = g_{11}(s_1 v_{11} + E(s_2^{s*}) v_{21}) + g_{12}s_1 v_{12} - \frac{1}{2}(s_1 v_{11} + E(s_2^{s*}) v_{21})^2 - \frac{1}{2}s_1^2 v_{12}^2 + \frac{1}{2}E\left\{E(\gamma_2|\theta)^2\right\} \tag{10}$$

with $E(s_2^{s*}) = E\left(\frac{\gamma_2}{\theta}\right)$. From the optimality condition

$$\frac{\partial Z^S}{\partial s_1} = g_{11}v_{11} + g_{12}v_{12} - (s_1 v_{11} + s_2^{s*} v_{21})v_{11} - s_1 v_{12}^2 = 0$$

we get the optimal first period incentive rate as

$$s_1^{s*} = \frac{g_{11}v_{11} + g_{12}v_{12} - E\left(\frac{\gamma_2}{\theta}\right) v_{21}v_{11}}{v_{11}^2 + v_{12}^2}.$$

Substituting s_1^{s*} into (10) yields the following equilibrium surplus for the principal:

$$\Pi^S = \frac{(g_{11}v_{11} + g_{12}v_{12})^2 + 2E\left(\frac{\gamma_2}{\theta}\right) v_{21}\left(g_{11}v_{12}^2 - g_{12}v_{12}v_{11}\right) - v_{12}^2 v_{21}^2 \left\{E\left(\frac{\gamma_2}{\theta}\right)\right\}^2}{2\left(v_{11}^2 + v_{12}^2\right)} + \frac{1}{2}E\left\{E(\gamma_2|\theta)^2\right\}.$$

Proof of lemma 4

Program (8) can be simplified to

$$\max_{s_1} Z^1 = g_{11}s_1 v_{11} + g_{12}s_1 v_{12} - \frac{(s_1 v_{11})^2}{2} - \frac{(s_1 v_{12})^2}{2}.$$

The optimal solution to this program is given by $s_1^{o*} = \frac{g_{11}v_{11}+g_{12}v_{12}}{v_{11}^2+v_{12}^2}$ and the principal's corresponding first period equilibrium surplus is $Z_1^{o*} = \frac{(g_{11}v_{11}+g_{12}v_{12})^2}{2\left(v_{11}^2+v_{12}^2\right)}$.

Proof of proposition 5

The principal's surpluses: Substituting $v_{11} = (v + a)$ and $v_{21} = 0$ for accrual-accounting and $v_{11} = v$ and $v_{21} = a$ for cash-accounting into the principal's surplus functions given in lemma 1, lemma 3, and lemma 4, we get the following equilibrium payoffs

$$\Pi^L_{ACC} = \frac{E\left(\theta^2\right)\left(v_{12}g_{12} + g_{11}(v+a)\right)^2 + E(\gamma_2\theta)^2\left(v_{12}^2 + (v+a)^2\right)}{2\left[E\left(\theta^2\right)\left((v+a)^2 + v_{12}^2\right)\right]}$$

$$\Pi^L_{CASH} = \frac{a^2 v_{12}^2\left(g_{11}^2+g_{12}^2\right) + E\left(\theta^2\right)\left(ag_{12}+g_{11}v\right)^2 + 2E(\gamma_2\theta)\,a\left(g_{11}v_{12}^2 - g_{12}vv_{12}\right) + E(\gamma_2\theta)^2\left(v_{12}^2+v^2\right)}{2\left[E\left(\theta^2\right)\left(v^2+v_{12}^2\right) + v_{12}^2a^2\right]}$$

$$\Pi_{ACC}^{S} = \frac{\left(g_{11}\left(v+a\right)+g_{12}v_{12}\right)^2}{2\left(\left(v+a\right)^2+v_{12}^2\right)}+\frac{1}{2}E\left\{E\left(\gamma_2|\theta\right)^2\right\} \tag{11}$$

$$\Pi_{CASH}^{S} = \frac{g_{11}^2v^2+2g_{11}vg_{12}v_{12}+g_{12}^2v_{12}^2+2E\left(\frac{\gamma_2}{\theta}\right)a\left(g_{11}v_{12}^2-vg_{12}v_{12}\right)-v_{12}^2a^2E\left(\frac{\gamma_2}{\theta}\right)^2}{2\left(v^2+v_{12}^2\right)} \tag{12}$$

$$+\frac{1}{2}E\left\{E\left(\gamma_2|\theta\right)^2\right\}$$

$$\Pi_{ACC}^{So} = \frac{\left(g_{11}\left(v+a\right)+g_{12}v_{12}\right)^2}{2\left(\left(v+a\right)^2+v_{12}^2\right)}+\frac{1}{2}E\left\{E\left(\gamma_2|\theta\right)^2\right\}$$

$$\Pi_{CASH}^{So} = \frac{\left(g_{11}v+g_{12}v_{12}\right)^2}{2\left(v^2+v_{12}^2\right)}+\frac{1}{2}E\left\{E\left(\gamma_2|\theta\right)^2\right\}.$$

Define $\Delta^k \equiv \Pi_{ACC}^k - \Pi_{CASH}^k$, $k = L, S, So$.

a) Sketch: We can show that for each regime k there exists a critical value $g_{12}^{k\prime}$ such that $\partial\Delta^k/\partial g_{12} < 0$ if $g_{12} > g_{12}^{k\prime}$. Furthermore, $\lim_{g_{12}\to\infty}\Delta^k = -\infty$ for all k. Hence, for each regime there exists a critical value g_{12}^k such that for all $g_{12} > g_{12}^k$, $\Delta^k < 0$.

b) The ex ante expected second period action firm value productivity is $E\left(\gamma_2\right)$. In $\Pi_{(\cdot)}^L$ and $\Pi_{(\cdot)}^S$ we can write $E\left(\gamma_2\theta\right) = Cov\left(\gamma_2,\theta\right)+E\left(\theta\right)E\left(\gamma_2\right)$ and $E\left(\frac{\gamma_2}{\theta}\right) = Cov\left(\gamma_2,\frac{1}{\theta}\right)+E\left(\frac{1}{\theta}\right)E\left(\gamma_2\right)$, respectively. From $\partial\Delta^L/\partial E\left(\gamma_2\right) = -\frac{v_{12}aE(\theta)\left(E\left(\theta^2\right)(v_{12}g_{11}-vg_{12})-av_{12}Cov(\gamma_2,\theta)-av_{12}E(\theta)E(\gamma_2)\right)}{E\left(\theta^2\right)\left(z^2\left(v^2+v_{12}^2\right)+av_{12}^2\right)}$ and $\partial\Delta^S/\partial E\left(\gamma_2\right) = -\frac{E\left(\frac{1}{\theta}\right)av_{12}\left(-Cov\left(\frac{1}{\theta},\gamma_2\right)av_{12}-v_{12}a\left(E\frac{1}{\theta}\right)E(\gamma_2)+v_{12}g_{11}-vg_{12}\right)}{v^2+v_{12}^2}$ it follows that for each contracting regime $k = L, S$ there exists a critical value $E\left(\gamma_2\right)^{k\prime}$such that $\partial\Delta^k/\partial E\left(\gamma_2\right) > 0$ if $E\left(\gamma_2\right) > E\left(\gamma_2\right)^{k\prime}$. Furthermore, $\lim_{E(\gamma_2)\to\infty}\Delta^L = +\infty$ and $\lim_{E(\gamma_2)\to\infty}\Delta^S = +\infty$. Hence, there exists a critical value $E\left(\gamma_2\right)^k$ such that $\Delta^k > 0$ for all $E\left(\gamma_2\right) > E\left(\gamma_2\right)^k$.

c) From $\partial\Delta^{So}/\partial g_{11} = \frac{\left\{g_{11}(2vv_{12}+av_{12})-g_{12}\left(v^2+v_{12}^2+va\right)\right\}av_{12}}{\left(a^2+2av+v^2+v_{12}^2\right)\left(v^2+v_{12}^2\right)}$and $\partial\Delta^S/\partial g_{11} = \frac{\left\{2g_{11}vv_{12}+g_{12}v_{12}^2+g_{11}av_{12}-g_{12}v^2-vg_{12}a-E\left(\frac{\gamma_2}{\theta}\right)\left(a^2v_{12}+v_{12}^3+2av_{12}v+v_{12}v^2\right)\right\}av_{12}}{\left(a^2+2av+v^2+v_{12}^2\right)\left(v^2+v_{12}^2\right)}$and it follows that for each $k = S, So$ there exists $g_{11}^{k\prime}$ such that $\partial\Delta^k/\partial g_{11} > 0$ for all $g_{11} > g_{11}^{k\prime}$. Furthermore, $\lim_{g_{11}\to\infty}\Delta^{So} = +\infty$ and $\lim_{g_{11}\to\infty}\Delta^S = +\infty$. Hence, there exists a critical value g_{11}^k such that for all $g_{11} > g_{11}^k$, $\Delta^k > 0$.

Proof of proposition 6

a1) From corollary 3 we know that if the conditions of proposition 1 and proposition 2 apply simultaneously $\Pi^L = \Pi^S = \Pi^{So}$. The condition of proposition 1 ensures that for the payoff and the incentives generated in period 1 it is immaterial whether or not θ is observed. The principal's surplus from period 2 is $\Pi_2 = E\left(\gamma_2 e_2\right) - E\left(e_2^2\right)/2$ with $e_2 = s_2\theta$ if θ is observable and $e_2 = s_2E\left(\theta\right)$ if not. Given the condition in proposition 2, $s_2 = c$, $\Pi_2^{obser.} - \Pi_2^{unobser.} = \frac{c^2}{2}Var\left(\theta\right) > 0$.

a2) In short-term contracts with observable effort the principal's equilibrium payoff according to lemma 4 is $Z^{o*} = Z_1^{o*} + Z_2^*$, where Z_1^{o*} is independent of any characteristics of the second period and $Z_2^* = E\left\{E\left(\gamma_2|\theta\right)^2\right\} = E\left(\gamma_2\right)^2 + Var\left(E\left(\gamma_2|\theta\right)\right)$. If θ is non observable the principal's second period payoff is $Z_2^{*'} = E(\gamma_2)^2$. Hence, the value of observing θ is $Var(E(\gamma_2|\theta)) \geq 0$. Assume the conditions of proposition 1 and proposition 2 do not apply for the rest of the proof.

b) The principal's equilibrium payoff Π^L in long-term contracts with observable θ is given in lemma 1

$$\begin{aligned}\Pi^L &= \frac{v_{21}^2 v_{12}^2 \left(g_{11}^2 + g_{12}^2\right) + E\left(\theta^2\right)\left(v_{12}g_{12} + g_{11}v_{11}\right)^2 + 2E\left(\gamma_2\theta\right) v_{21}\left(g_{11}v_{12}^2 - g_{12}v_{11}v_{12}\right)}{2\left[E\left(\theta^2\right)\left(v_{11}^2 + v_{12}^2\right) + v_{12}^2 v_{21}^2\right]} \\ &\quad + \frac{E\left(\gamma_2\theta\right)^2\left(v_{12}^2 + v_{11}^2\right)}{2\left[E\left(\theta^2\right)\left(v_{11}^2 + v_{12}^2\right) + v_{12}^2 v_{21}^2\right]}.\end{aligned}$$

Solving program (3) with $e_2 = s_2 E(\theta)$ instead of $e_2(\theta) = s_2\theta$ leads to the following payoff for unobservable θ:

$$\begin{aligned}\Pi^{L\prime} &= \frac{v_{21}^2 v_{12}^2 \left(g_{11}^2 + g_{12}^2\right) + E(\theta)^2 \left[\left(v_{12}g_{12} + g_{11}v_{11}\right)^2 + g_{12}^2 v_{12}^2 + v_{12}^2 E\left(\gamma_2\right)^2\right]}{2\left[E(\theta)^2\left(v_{11}^2 + v_{12}^2\right) + v_{12}^2 v_{21}^2\right]} \\ &\quad + \frac{2E\left(\gamma_2\right) E(\theta) v_{21}\left(g_{11}v_{12}^2 - g_{12}v_{11}v_{12}\right)}{2\left[E(\theta)^2\left(v_{11}^2 + v_{12}^2\right) + v_{12}^2 v_{21}^2\right]}\end{aligned}$$

If θ and γ_2 are independent we have $E(\theta\gamma_2) = E(\theta) E(\gamma_2)$ in Π^L.Then the difference $\Pi^L - \Pi^{L'}$ is given by

$$\Pi^L - \Pi^{L'} = -\frac{Var(\theta)\left(E(\theta) E\left(\gamma_2\right)\left(v_{11}^2 + v_{12}^2\right) + v_{12}^2 g_{11}v_{21} - v_{21}v_{11}g_{12}v_{12}\right)^2}{2\left(E\left(\theta^2\right)\left(v_{11}^2 + v_{12}^2\right) + v_{12}^2 v_{21}^2\right)\left(E(\theta)^2\left(v_{11}^2 + v_{12}^2\right) + v_{12}^2 v_{21}^2\right)} \leq 0.$$

c) In lemma 3 the principal's surplus in short-term contracts with unobservable effort is given by

$$\Pi^S = \frac{\left(g_{11}v_{11} + g_{12}v_{12}\right)^2 + 2E\left(\frac{\gamma_2}{\theta}\right) v_{21}\left(g_{11}v_{12}^2 - g_{12}v_{12}v_{11}\right) - v_{12}^2 v_{21}^2 \left\{E\left(\frac{\gamma_2}{\theta}\right)\right\}^2}{2\left(v_{11}^2 + v_{12}^2\right)} + \frac{1}{2}E\left\{E\left(\gamma_2|\theta\right)^2\right\}$$

If θ will not be reported the corresponding surplus is

$$\Pi^{S'} = \frac{\left(g_{11}v_{11} + g_{12}v_{12}\right)^2 + 2\frac{E(\gamma_2)}{E(\theta)} v_{21}\left(g_{11}v_{12}^2 - g_{12}v_{12}v_{11}\right) - v_{12}^2 v_{21}^2 \left\{\frac{E(\gamma_2)}{E(\theta)}\right\}^2}{2\left(v_{11}^2 + v_{12}^2\right)} + \frac{1}{2}E\left(\gamma_2\right)^2$$

Stochastic independence of θ and γ_2 yields

$$\begin{aligned}\Pi^S - \Pi^{S'} &= \frac{2v_{21}\left(g_{11}v_{12}^2 - g_{12}v_{12}v_{11}\right) E\left(\gamma_2\right)\left[E\left(\frac{1}{\theta}\right) - \frac{1}{E(\theta)}\right] - v_{12}^2 v_{21}^2 E\left(\gamma_2\right)^2 \left[E\left(\frac{1}{\theta}\right)^2 - \frac{1}{E(\theta)^2}\right]}{2\left(v_{11}^2 + v_{12}^2\right)} \\ &= \frac{v_{21}v_{12} \cdot \left\{2\left(g_{11}v_{12} - g_{12}v_{11}\right) E\left(\gamma_2\right)\left[E\left(\frac{1}{\theta}\right) - \frac{1}{E(\theta)}\right] - v_{12}v_{21}E\left(\gamma_2\right)^2 \left[E\left(\frac{1}{\theta}\right)^2 - \frac{1}{E(\theta)^2}\right]\right\}}{2\left(v_{11}^2 + v_{12}^2\right)}\end{aligned}$$

From Jensen's inequality it follows that $E\left(\frac{1}{\theta}\right) - \frac{1}{E(\theta)} > 0$ such that both brackets $[\cdot]$ are positive. For $g_{11}/g_{12} < v_{11}/v_{12}$ $\Pi^S - \Pi^{S\prime}$ is always negative.

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