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RELATIONAL CONTRACTS IN MORAL HAZARD WITH SUBJECTIVE PERFORMANCE MEASURES

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Abstract
This paper analyzes optimal self-enforcing termination contracts under the assumptions that the agent (e.g. grower) must make relationship-specific investments prior to contracting, that the principal (e.g. integrator or processor) has ex post full bargaining power due to monopsony power, and that performance is subjectively measured. In the optimal self-enforcing termination contract, the principal motivates the agent by rewarding the agent through continuation of the relationship for high levels of performance and penalizes the agent through termination for low levels of performance. Performance bonuses are no longer used. When the agent must make relationship-specific investment, the principal may not pay positive rents. This implies that the relationship-specificity of investment increases the principal's expected payoff, whereas it decreases the agent's.

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I. Introduction

Agribusinesses are increasingly relying on contracts to source and market agricultural commodities. While contracts enable firms (i.e., integrators or processors) to better coordinate the supply chain from the farm gate down to the retailer, many growers, farm advocacy groups, and policy makers have become concerned that contracts may be oppressive to growers (Wu, 2003). One stylized fact that is frequently observed in the livestock sector (e.g. broilers and hogs) is that, in order to secure a contract, growers are often required to make substantial investments in new production facilities (Lewin-Solomons, 2000). These facilities are often relationship-specific as they must meet the exact requirements of each processor and often force growers into debt as they can cost hundreds of thousands of dollars to build.[1] At the same time, processors do not always provide growers with explicit written agreements about the duration of the contract or provisions for termination and renewal, leaving growers vulnerable as the relationship with the processor may end before all debts are paid.

While some studies introduce the problems relating to undue termination of contracts in the livestock sector and proposes measurements or legislations to unravel the problems, attempts to understand the characteristics of optimal contracts.[2]

In this study, after constructing a formal model representing livestock contracting environments, I discuss the characteristics of theory-based optimal contracts. For this, I employ the implicit or relational contracts framework developed by Macleod and Malcomson(1989) and Levin(2003). Relational contracts have been increasingly recognized by economists as important trade mechanisms in the environments where certain aspects of performance are difficult for third parties to verify. Relational contracts fit many of the stylized facts of broiler contracts since broiler contracts typically contain both explicit (e.g. written clauses and payment terms that are legally enforceable) as well

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1 According to Charman (2002), growers must borrow approximately $125,000 per chicken house to build facilities according to the poultry company's specification.

2 Refer to Farmers' Legal Action Group, Inc. 2001. *Assessing the Impact of Integrator Practices on Contract Poultry Growers.*

as implicit components (e.g. verbal agreements and understandings and payment terms that are not legally enforceable). Although explicit contract terms exist to govern short-term obligations and payment terms, integrators' contract renewal policies are often based on implicit agreements made with growers, and the aspects of performance such as growers' degree of cooperation with integrators or growers' willingness to remain flexible and upgrade facilities at integrators' request, etc. are difficult for third parties to verify. In some cases, even explicit written agreements may be difficult to enforce. For example, processors in some livestock sectors weigh the animals themselves and determine mortality rates without a third party present (Hamilton, 1995) so that quality is difficult to enforce even if an explicit contract contains payment schedules that are contingent on quality. In this case, an integrator has the power to renege on promised bonuses or premiums by not reporting quality truthfully.

The main feature of broiler contracts introduced in this study is that some of integrators' measures on growers' performance are subjective. In general, performance such as growers' degree of cooperation with the integrator, or growers' willingness to remain flexible and upgrade facilities at the integrator's request, etc. are subjectively measured only by an integrator. Subjective performance measures are defined as "an indicator used to assess individuals' aggregated perceptions, attitudes, or assessments toward an organizations product or service." (Wang and Gianakis, 1999). In practice, firms often make extensive use of subjective performance reviews such as the opinions of supervisors or managers as their incentive devices.[3]

The Farmers' Legal Action Group, Inc. (2001) reports that in livestock industry many broiler contracts include a document (e.g., Company's Broiler Growing Guide) to be used to set up standards for measuring growers' performances and commonly include the terms that provide the processor/integrator with the authority and discretion to determine the growers' performance and the adequacy of facilities or equipment. Moreover, in some cases, the methods and formulas used to determine performance are held privately by the integrators. Since it is almost impossible for third parties to verify subjective performance measures, there is a concern that integrators have the power to renege on promised bonuses or premiums by not reporting performance

[3] Refer to Baker et al. (1994) for the examples of subjective performance measures.

truthfully.

I extend the work of Levin (2003) by introducing ex post full bargaining power on the part of integrators and asset specificity for investments made by growers. The introduction of the principal's ex post full bargaining power is particularly important for modeling broiler contracting problems as processors often hold monopsony power in input markets and therefore may hold most of the bargaining power.[4] Growers are often required by integrators to make expensive investments in new equipment and housing facilities that meet the exact specifications of integrators so that asset specificity becomes a concern. I consider an industry-wide exogenous shock that affects productivity of contractual relationships. The introduction of an exogenous shock allows us to incorporate undue termination into optimal contracts. An industry-wide negative exogenous shock is assumed to undermine future surplus from contractual relationships; thus, an integrator terminates its contractual relationships with growers. An example is that a negative downstream demand shock may force processors to close processing plants and "lay-off" growers. While I construct the model by taking an example of livestock contracting environment, the model itself is quite general and the results can be applied to either agricultural or outside-agricultural contracting relationships.

When subjective performance measures are incorporated into the model in an optimal relational contract, integrators use termination as an incentive device, and contractual relationship can be terminated although growers actually behave in a favorable way to integrators. This result implies that termination of contractual relationship can be observed when contracts between integrators and growers are optimally designed. Therefore, termination itself is not problematic in the aspect of efficiency of contract relationships. The two extensions affect the self-enforceability of relational contracts and can have consequences for incentive design. Ex post full bargaining power combined with asset specificity induces an integrator to reduce the amount of rents paid to growers and to use the threat of termination as the only incentive device to maintain a contractual relationship without any monetary pay such as bonus.

[4] Farmers' Legal Action Group, Inc. (2001) reports that in the broiler industry, the average number of companies (i.e., integrators or processors) operating in growers' area is 2.48 and this number has been declining. It is also reported that about 28 percent of growers has only one company active in their area.

In what follows, I describe a relational contract framework and model assumptions relating to broiler contracting environment. I then analyze the relational contract model under subjective performance measures, integrators' ex post full bargaining power, asset specificity of investments, and the industry-wide exogenous shock. In the last section, I summarize the characteristics of optimal relational contracts.

II. Model Assumptions

An infinite horizon principal-agent relationship between a risk neutral principal (e.g. integrator) and a risk neutral agent (e.g. grower) is considered. The model of this study is similar to Levin's (2003) with the exception of three major departures. First, it is assumed that the agent must make a relationship-specific investment at the request of the principal prior to initiating the contract. This imposes an ex post separation cost on the agent because if the agent wants to opt out of the contract or is terminated, it becomes difficult for him to convert his assets into an alternative use. Second, I assume that the principal has ex post full bargaining power, which implies that it is costless for the principal to terminate any specific agent because the principal can earn the same payoffs through another agent. This imposes a constraint on the set of self-enforcing contracts since the principal has little incentive to commit to a long-term relationship with any specific agent. For example, in the broiler industry, large processors such as Tyson Foods, Gold Kist, Perdue Farmers, Pilgrim's Pride, etc. dominate input markets so that there are few buyers but many growers lining up for contracts. In this case, a large processor may lose little if separated from a specific grower because there is always another grower waiting to replace the departed grower. In this paper, I assume that any switching cost or reputation cost does not exist on the part of the monopsonistic processor. Third, at the end of each period, and before the start of the next period, I allow for the possibility that an industry-wide negative exogenous shock (bad state of nature) will eliminate future surplus from trade from contracting. In this case, the principal will exit the industry and sever all relationships with agents. An example might be that a negative downstream demand shock, concerns about the safety of the product, or some other exogenous factors might make it unprofitable for processors to continue operations. In this case, the processor will no longer renew contracts as it will exit the industry.

It is assumed that the principal is attempting to gain a competitive edge on the downstream consumer market by either differentiating its product from those of competitors and/or reducing the costs in its supply chain by exploiting new technologies or improving coordination, although an exact reason is not specified in order to maintain the generality of the model.[5] There are also other reasons for relational contracting. For example, an integrator may contract with growers in order to optimize a processing plant's capacity that requires delivery schedule coordination with growers. In this case, successful coordination may require both parties to "perform" by exhibiting a certain degree of flexibility, adaptability, and cooperation, which are difficult-to-verify performance factors. Integrators also want to reduce costs by exploiting scale effects or new technology, which would require growers to remain "flexible" and upgrade facilities. The point is that there are numerous reasons for relational contracts to be important in agriculture.

To be more formal, two risk neutral parties, the principal and the agent, consider trading during periods t=0, 1, 2,.... At each date t, the principal contracts with the agent to obtain a benefit, a_t, where a_t is drawn from a continuous distribution with a cumulative distribution function $F(\cdot|e)$ on the support $A=[\underline{a}, \overline{a}]$, which is conditional on the level of effort, $e_t \in E=[0, \overline{e}]$ exerted by the agent. I adopt Levin's subjective performance measures model (1999, 2003) in which the agent chooses effort e_t privately and the principal privately observes benefit a_t standing for the agent's performance.[6] Having ob-

[5] I specify several possibilities for contracting so as not to limit the scope of analysis. The model is sufficiently general to allow me to analyze a range of contracting issues in agriculture.

[6] I do not specify what a is exactly to maintain generality. Using the previous examples, if the principal is chiefly concerned with input quality, then a might denote measured quality of the commodity which is not verifiable by a third party. If maintaining plant capacity is the principal's primary aim so that delivery schedule coordination is crucial, then a could be the degree of cooperation and flexibility exhibited by the grower to meet scheduling requirements. The key point is that a represents a measure of performance that is subjectively decided by the principal and is not verifiable by a third party.

served a_t, the principal reports a message, $m_t \in \mathrm{M}$ on the level of benefit, where M is some large set of possible messages. This implies that it is not possible to write an explicit contract that conditions payments on a_t. Instead, it is possible to write an implicit contract that conditions payments on m_t. It is assumed that $F(\cdot|e)$ has the monotone likelihood ratio property (MLRP) and the convexity of the distribution property (CDFC), which allow us to use the first-order approach in specifying incentive compatibility constraints (Rogerson, 1985) to deal with a moral hazard problem. The agent incurs a cost of $c(e_t \mid I)$ with assumptions of $c(0|I)=0$, $c_e(e_t|I) > 0$ for $e > 0$, and $c_{ee}(e_t|I) \geq 0$, where $I \in \{0, I^0\}$ represents a binary valued relationship-specific investment that is specified by the principal during the initial period ($t = 0$) when the relationship is established. While the principal specifies the level of I, the cost of the investment is borne by the agent. Alternatively, one can think of an investment level of $I = I^0$ as a technological requirement for producing a_t so that $c(e_t \mid I = 0) = +\infty \ \forall e > 0$. It is assumed that the investment needs to be carried out once at $t = 0$ but does not need to be done again in all subsequent periods. To maintain notational simplicity, I will henceforth suppress I in the cost function. Finally, to ensure interior solutions, it is assumed that the Inada conditions $c_e(0) = 0$ and $c_e(\bar{e}) = +\infty$ hold.

The assumption that the principal requires the agent to undertake an observable and verifiable investment, I, is consistent with stylized facts in some agricultural sectors. For example, in the livestock sector, it is often the case that, in order to initiate a contract, growers are required to make substantial investments in new production facilities (Lewin-Solomons, 2000). These facilities are often relationship-specific as they must meet the exact requirements of each integrator, and they often force growers into debt as they can cost hundreds of thousands of dollars to build. Because I is observable and verifiable, and must meet the exact specifications of an integrator, it is essentially a choice variable for an integrator. By assuming that the principal's specialized production requirements dictate that the agent must invest in a relationship-specific technology prior to contracting, a technological constraint is essentially imposed on the design of the optimal relational contract.

The principal is also assumed to decide whether to continue to contract with the agent or not at the beginning of any period t in the multi-period relationship. If the principal decides to continue the relationship, she offers a compensation plan that consists of a fixed payment w_t^m, a bonus schedule, $b_t : \mathrm{M} \rightarrow R$ contingent on the principal's non-verifiable message on the grower's performance. Therefore, bonus payments varying in the level of m_t are merely promised but cannot be enforced by a third party such as a court of law.

The payment scheme offered by the principal can be divided into two parts - an explicit component, based on verifiable information, and an implicit component based on non-verifiable performance. In the model, the only verifiable information is whether the relationship continues or separates. Therefore, the explicit part consists of the fixed payment, w_t^m that is to be paid in period t, and the severance payment, w_{t+1}^s to be paid in period $t+1$ if the relationship is terminated at the beginning of $t+1$. The implicit component includes any payments such as bonuses or penalties that are contingent on non-verifiable subjective performance and is captured by the bonus schedule, $b_t(m_t)$, which can be either positive or negative.[7] Therefore, total transfer from the principal to the agent at the end of period t is $w_t(m_t) = w_t^m + b_t(m_t)$. In addition, if termination occurs at the beginning of t+1, an additional amount, w_{t+1}^s would be paid in period $t+1$ as well. However, Macleod and Malcomson (1989) and Levin (1999) show that in the models where the principal's ex post full bargaining power, asset specificity of investment, and an industry-wide exogenous shock are not incorporated, a positive severance payment cannot improve upon the set of allocations that can be implemented with self-enforcing contracts. Therefore, I assume w_{t+1}^s=0 for now as there is no economic justification for private parties to include non-zero severance payments. The agent's payoff for period t is then $w_t(m_t) - c(e_t)$, the principal's payoff is $a_t - w_t(m_t)$, and surplus is $a_t - c(e_t)$.

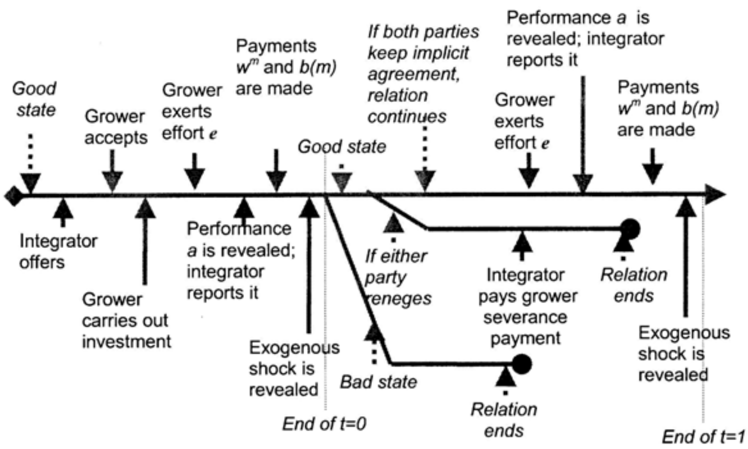
Due to the non-verifiability of m_t, it is not possible to provide incentives contingent on m_t in a static relationship, so that productive trading must be governed by a relational contract that extends beyond a single period.

7 To motivate a negative bonus, consider a case where performance is very low. Then the agent can "compensate" the processor and restore goodwill by granting a discount for poor performance. Indeed, in many buyer-supplier relationships both within agricultural and outside of agricultural, suppliers have been known to grant price discounts when a shipment of goods has failed to meet certain quality standards.

Since the contingent payment, $b_t(m_t)$, cannot be enforced by a third party, the principal does not have an incentive to send the same message as a_t and then to pay $b_t(m_t)$ in a one-shot relationship. The agent also does not have an incentive to take an action that the principal wants. However, when both parties are engaged in a repeated relationship, the promise of future payoffs can provide incentives for parties not to renege, leading to self-enforcing agreements. Bolton and Dewatripont (2005) suggest that agreements are self-enforcing when there are credible future threats (or rewards) that can induce parties to stick to the terms of the informal agreement. More formally, a relational contract is a complete plan of action which describes for every period t and every possible history up to t, (i) the principal's decision to continue or terminate the relationship; (ii) the payment scheme offered by the principal in the case of continuation; (iii) the agent's decision to accept or reject the principal's offer; and (iv) the action (i.e., an effort level) the agent should take.[8]

The figure 1 illustrates the timing of the relationship in first two periods $t=0$ and $t=1$. The timing of the relationship in all periods $t \geq 1$ are identical to that in $t=1$.

FIGURE 1. Timing of relational contracts.



8 My definition of a relational contract is closely related to the definition given by Levin (2003). It describes a perfect public equilibrium of the repeated game.

At the conclusion of each period t and prior to the beginning of $t+1$, an exogenous shock that affects productivity of contractual relationships is revealed. The inclusion of such a shock allows us to introduce non-performance related contract termination, which occurs in agriculture and many other industries. Negative economic shocks often induce firms to lay off growers, workers, or suppliers even if these agents performed well in the past.

To model this, I assume a binary exogenous shock, $x=\{x_G, x_B\}$, where x_G and x_B represent respectively good state and bad state. It is assumed that prior to the realization of an exogenous shock, the probability distribution of an exogenous shock such that $p = prob(x = x_G)$ and $1-p = prob(x = x_B)$ is common knowledge and the probability distribution remains stable across periods.

Next, I will specify reservation payoffs for the principal and the agent, which are particularly different from Levin's. If the principal cannot find the agent to produce the benefit at a_t or cannot appropriately incentivize him, then the principal is assumed to pursue an alternative line of business and receive a fixed per-period outside payoff of $\overline{\pi}$, which is called the principal's *ex ante* reservation payoff.[9] Similarly, if the agent does not receive a contract offer or rejects an offer, the agent gets a fixed per-period outside payoff of $\overline{u}$, which is called the agent's *ex ante* reservation payoff. Levin does not need to differentiate ex ante reservation payoffs from ex post reservation payoffs since he does not incorporate the principal's ex post bargaining power and the agent's relationship-specific investment into his model.

If the principal and the agent are separated in any future period after they initiate a contractual relationship in the initial period, their reservation payoffs vary depending on a revealed exogenous shock. Levin also does not need to consider this since he does not introduce the exogenous shock into his model. If they are separated under good state, the principal expects to earn $\pi_{-G|x_G}$ from some other agent. However, the agent earns only fixed per-period

9 For example, in order to produce a high quality consumer product, the principal may have to source input commodity with special quality characteristics. If it cannot incentivize agents to produce the required quality characteristics, then the principal may be better off sourcing inputs from the spot market and producing a generic consumer good for which it will derive profits of $\overline{\pi}$.

outside payoff of $\tilde{u} < \bar{u}$ due to the relationship-specific investment.[10] $\pi_{-G|x_G}$ and $\tilde{u}$ are called the principal's and the agent's *ex post* reservation payoffs conditional on good state. I assume that $\pi_{-G|x_G} \geq \bar{\pi}$, which implies that after the principal terminates a contract with one agent, she prefers contracting for some benefit with some other agent to engaging in some outside option such as operating on spot markets or producing an alternative line of products.[11] On the other hand, the principal and the agent respectively earn and in all future periods after they separate under bad state in any period, which is called the principal's and the agent's ex post reservation payoffs conditional on bad state.

I denote $\pi_{|x_B}$ and $u_{|x_B}$ as the payoffs that the principal and the agent would earn if the contract continues under bad state. The key assumption is that when x_B is realized in any future period after the contract is initiated, $\pi_{|x_B} + u_{|x_B}$ is less than $\bar{\pi} + \tilde{u}$ so that at least one party wants to terminate the relationship.[12] Intuitively, if bad state is realized, it becomes socially efficient for the relationship to be terminated since it can no longer generate sufficient surplus in the future. Moreover, because there is no sufficient surplus from the contract, it will be impossible to reward both parties by using the promise of future payoffs to sustain the relationship. For simplicity, I assume that this holds between the principal and all agents so that the principal is better off exiting the industry and earns $\bar{\pi}$ in all future periods. Under bad state, the relationship breaks off and two parties earn $\bar{\pi}$ and $\tilde{u}$.

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10 Levin's (1999, 2003) does not differentiate the agent' ex ante reservation payoff, $\bar{u}$, from ex post reservation payoff, $\tilde{u}$ since there is no relationship-specific investment.

11 Levin (1999, 2003) assumes that the principal earns the reservation payoff, $\bar{\pi}$ after the separation with the current agent.

12 Since $\pi_{|x_B} + u_{|x_B}$ is less than $\bar{\pi} + \tilde{u}$, at least one party always wants to terminate the relationship ex post after bad state is observed. If $u_{|x_B} \geq \tilde{u}$ ($\pi_{|x_B} \geq \bar{\pi}$), the processor (grower) wants to terminate the relationship since $\pi_{|x_B} < \bar{\pi}$ ($u_{|x_B} < \tilde{u}$). If I assume that $\pi_{|x_B} + u_{|x_B}$ is less than $\bar{\pi} + \bar{u}$, both parties agree on termination ex ante since at least one party's participation constraint cannot be satisfied. However, if $\pi_{|x_B} + u_{|x_B}$ could be larger than $\bar{\pi} + \tilde{u}$, both parties want to continue the relationship ex post even in bad state. Therefore, in order to exclude this case, I assume that $\pi_{|x_B} + u_{|x_B}$ is less than $\bar{\pi} + \tilde{u}$.

III. Optimal Termination Contracts

1. Termination Contracts

I will begin by describing the basic features of Levin's subjective performance measures model. Because a bonus payment must depend on the principal's message, m_t, an optimal contract should induce the principal's truthful reporting about the actual level of benefit. The principal will make distinct messages, m and m', in response to any two distinct benefits, a and a', if two messages yield the same future expected payoffs to the principal. Thus, if a relational contract is to provide the agent with the incentive to exert effort and, at the same time, provide the principal with the incentive to report benefit truthfully, the agent's future expected payoff must vary with performance (i.e., benefit) but the principal's must not. Levin (2003) shows that under subjective performance measures, a stationary contract cannot implement a positive effort level but a termination contract is optimal among all contracts with the full review property.[13] In order to provide both parties with the incentives, the parties can use a combination of instant rewards, such as bonus payments, and the termination of a relationship instead of using continuation payoffs varying with benefit.

Levin (2003) defines a termination contract as follows.

DEFINITION: *A contract is a termination contract if in every period t that trade occurs,* $w_t = w^m + b(a_t), e_t = e, m_t = a_t$, *and trade continues beyond t with probability* $\alpha_t = \alpha(a_t)$ *and otherwise ceases forever, for some* $w^m \in R, b: A \to R, e \in [0, \bar{e}]$, *and* $\alpha : A \to [0,1]$.

A termination contract is similar to a stationary contract in that it requires the same payment plan and effort level in each period that trade occurs,

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13 Full review property means that the principal provides a full performance evaluation after each period. More formally, given any history up to t and payment offer (w_t and b_t: M→ R) at t, any two benefits $a_t \neq a_t'$ must generate distinct messages $m_t \neq m_t'$.(Levin, 2003)

but it also allows for the possibility that the parties will end the relationship for certain levels of performance. A more important finding by Levin is that an optimal termination contract has a "one-step" bonus schedule, $b(a)$, and at the same time, a "one-step" continuation probability schedule, $\alpha(a)$. That is, the principal penalizes the agent by terminating the relationship if the principal's benefit is lower than a certain cut-off point. Otherwise, the principal compensates the agent by paying the promised bonus and continuing the relationship at least into the next period.

2. Ex Post Full Bargaining Power, Asset Specificity, and Exogenous Shocks

In the previous section, I introduced the characteristics of a termination contract developed by Levin (2003) in the special case that there is no ex post bargaining power on the side of the principal, no asset specificity of investment on the side of the agent, and no exogenous shock. In this section, I analyze how a termination contract is impacted by the introduction of ex post full bargaining power, asset specificity, and an exogenous shock. I also characterize optimal termination contracts.

First, I explain the conditions for a contract to be self-enforcing.[14] Suppose there exists a full review contract that specifies effort, e, a fixed payment, w^m, a bonus schedule, $b(a)$, and continuation payoffs, $u(a)$ and $\pi(a)$ varying with the benefit, a, in the initial period. A total payment schedule is defined as $w(a) = w^m + b(a)$ and both parties' expected per-period payoffs are $u \equiv (1-\delta)E_a[w(a) - c(e) \mid e] + p\delta E_a[u(a) \mid e] + (1-p)\delta\tilde{u}$,
$\pi \equiv (1-\delta)E_a[a - w(a) \mid e] + p\delta E_a[\pi(a) \mid e] + (1-p)\delta\overline{\pi}$,
and $s \equiv u + \pi$, where $\delta \in [0,1)$ is a common discount factor and $E_a[\bullet \mid e]$ implies $\int_{\underline{a}}^{\overline{a}} \bullet f(a \mid e)da$.

14 The conditions are obtained by applying my model assumptions and notations to Levin's.

This contract is self-enforcing if and only if

(i) $u \geq \bar{u}$ and $\pi \geq \bar{\pi}$ (Participation constraints for A and P)

(ii) $e \in \arg\max_{\tilde{e}} E_a\left[b(a) + p\frac{\delta}{1-\delta}u(a) \mid \tilde{e}\right] - c(\tilde{e})$ (Incentive compatibility constraint)

(iii) $-b(a) + p\frac{\delta}{1-\delta}\pi(a) = -b(a') + p\frac{\delta}{1-\delta}\pi(a'),\ \forall a, a' \in A$ (Truthful reporting constraint)

(iv) $-b(a) + p\frac{\delta}{1-\delta}\pi(a) \geq p\frac{\delta}{1-\delta}\pi_{-G|x_G},\ \forall a \in A$ (Discretionary payment constraint for P)

(v) $b(a) + p\frac{\delta}{1-\delta}u(a) \geq p\frac{\delta}{1-\delta}\tilde{u},\ \forall a \in A$ (Discretionary payment constraint for A)

(vi) for all *a*, a pair of the continuation payoffs, $u(a)$ and $\pi(a)$ correspond to a self-enforcing contract.

The constraint (i) implies that if both parties cannot earn at least as much in the contractual relationship as outside, they will not initiate it. The constraint (ii) implies that since the principal cannot observe the agent's effort, she must provide the agent with incentives enough to make the agent actually exert a level of effort that she wants. When the constraint (iii) is satisfied, this constraint incentivizes the principal to truthfully report the level of *a*. Intuitively, since the principal has an identical expected payoff regardless of which level of benefit the principal reports, the principal has no incentive to make a false report on *a*. If the principal can earn more by reporting *a'* than *a*, she always prefers reporting *a'* even when *a* is true. The conditions specified in (iv) and (v) is called *discretionary payment constraints*. They imply that both the principal and the agent are willing to pay promised bonuses rather than renege when discounted payoffs from paying them exceed those from reneging. For the principal, when she pays the promised bonus, *b*(*a*), to agent and continues the contractual relationship into the future periods, she earns the discounted payoff of $-b(a) + p\frac{\delta}{1-\delta}\pi(a)$. However, when the principal terminates the relationship with the current agent by not paying the promised bonus, she earns the discounted payoff of $p\frac{\delta}{1-\delta}\pi_{-G|x_G}$. A similar interpretation holds for the agent. I will characterize a termination contract as a list $(w^m, w^s, b(a), \alpha(a), e, \pi, u)$. The next proposition allows us to restrict our attention to termination contracts. That is, when any full review contract described above achieves the optimal surplus, s^*, there exists a termination contract that yields the same surplus.

PROPOSITION 1: *When* $\pi \geq \pi_{-G|x_G} \geq \overline{\pi} \geq \pi_{-G|x_B}$, $\overline{u} \geq \tilde{u}$, $\pi_{|x_B} + u_{|x_B} < \overline{\pi} + \tilde{u}$, *and* $x = \{x_G, x_B\}$ *with* $p = prob(x_G)$ *and* $1 - p = prob(x_B)$, *if an optimal full review contract exists, a termination contract can achieve this optimum.*

Proofs for all remarks and propositions are provided in Appendix.

Summarizing the conditions for the self-enforcement of a termination contract used in the proof, a termination contract $(w^m, 0, b(a), \alpha(a), e, \pi, u)$ is self-enforcing if and only if the following conditions hold.

(1) $\pi \equiv (1-\delta)E_a[a - w^m - b(a) \mid e] + p\{\delta\pi_{-G|x_G} + \delta E_a[\alpha(a) \mid e](\pi - \pi_{-G|x_G})\} + (1-p)\delta\overline{\pi} \geq \overline{\pi}$

(Participation constraint for P)

(2) $u \equiv (1-\delta)E_a[w^m + b(a) - c(e) \mid e] + p\{\delta\tilde{u} + \delta E_a[\alpha(a) \mid e](u - \tilde{u})\} + (1-p)\delta\tilde{u} \geq \overline{u}$

(Participation constraint for A)

(3) $e \in \arg\max_{\tilde{e}} E_a\left[b(a) + p\dfrac{\delta}{1-\delta}\alpha(a)(u - \tilde{u}) \mid \tilde{e}\right] - c(\tilde{e})$ (Incentive compatibility constraint)

(4) $p\dfrac{\delta}{1-\delta}\alpha(a)(\pi - \pi_{-G|x_G}) \geq b(a)$, $\forall a \in A$[15] (Discretionary payment constraint for P)

(5) $p\dfrac{\delta}{1-\delta}\alpha(a)(u - \tilde{u}) \geq -b(a)$, $\forall a \in A$[16] (Discretionary payment constraint for A)

(6) $p\dfrac{\delta}{1-\delta}\alpha(a)(\pi - \pi_{-G|x_G}) - b(a)$ is constant in a.[17] (Truthful reporting constraint)

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[15] It is the simplified expression of the following:

$$-b(a) + p\left(\alpha(a)\frac{\delta}{1-\delta}\pi + (1-\alpha(a))\frac{\delta}{1-\delta}\pi_{-G|x_G}\right) + (1-p)\frac{\delta}{1-\delta}\overline{\pi} \geq p\left(\frac{\delta}{1-\delta}\pi_{-G|x_G}\right) + (1-p)\frac{\delta}{1-\delta}\overline{\pi}$$

[16] It is the simplified expression of the following:

$$b(a) + p\left(\alpha(a)\frac{\delta}{1-\delta}u + (1-\alpha(a))\frac{\delta}{1-\delta}\tilde{u}\right) + (1-p)\frac{\delta}{1-\delta}\tilde{u} \geq \frac{\delta}{1-\delta}\tilde{u}$$

[17] It is simplified from:

$$-b(a) + p\left(\alpha(a)\frac{\delta}{1-\delta}\pi + (1-\alpha(a))\frac{\delta}{1-\delta}\pi_{-G|x_G}\right) + (1-p)\frac{\delta}{1-\delta}\overline{\pi} =$$

$$-b(a') + p\left(\alpha(a')\frac{\delta}{1-\delta}\pi + (1-\alpha(a'))\frac{\delta}{1-\delta}\pi_{-G|x_G}\right) + (1-p)\frac{\delta}{1-\delta}\overline{\pi},\ \forall a, a'$$

From now on, I investigate the characteristics of a termination contract in the case that the principal has ex post full bargaining power and there is no asset specificity of investment (i.e., $\pi = \pi_{-G|x_G}$ and $\tilde{u} = \bar{u}$) in order to look into the pure impact of the principal's ex post full bargaining power on a termination contract. Remark 1 states that the agent earns positive rents from a termination contract when the principal has ex post full bargaining power and there is no asset specificity of investment.

REMARK 1: *When the principal has ex post full bargaining power* ($\pi = \pi_{-G|x_G}$) *and there is no asset specificity* ($\tilde{u} = \bar{u}$), *if there exists a termination contract to implement* $e > 0$, *then the agent earns positive rents* ($u - \bar{u} > 0$).

Remark 1 makes the point that the principal must provide the agent with a level of u that exceeds $\bar{u}$ if the principal wants the agent to exert a positive level of effort. Conversely, remark 1 states that if is binding at $\bar{u}$, any termination contract to implement $e > 0$ is not possible. Proving it in brief, we know that only from the truthful reporting constraint that $\frac{p\delta}{1-\delta}\alpha(a)(\pi - \pi) - b(a)$ is constant in a, that a bonus schedule should be constant in a.[18] When $b(a)$ is constant in a and u is equal to $\bar{u}$, (3) is simplified to $e \in \arg\max_{\tilde{e}} - c(\tilde{e})$. Therefore, I can confirm that if $u = \bar{u}$ in (3), the agent does not have any incentive to exert any positive effort. Consequently, although she has ex post full bargaining power, the principal must provide the agent with positive rents in order to maximize her profit by making the agent stay in the relationship. If not, the agent would not accept it and then, the principal would just earn the payoff of $\bar{\pi}$.

I also confirm that if there exists a full review contract to implement $e > 0$, the agent earns positive rents. Therefore, the positive rents $(u - \bar{u} > 0)$

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18 This property should continue to hold only if the principal has ex post full bargaining power regardless of the asset specificity of investment. It corresponds to MacLeod and Malcomson (1998)'s theory that "any subjective performance pay such as bonus contingent on performance is not credible in a market where a firm can always fill its vacancy without any cost instantly after reneging on the promised bonus since the number of workers who want jobs is greater than that of jobs."

are crucial for the existence of any type of relational contract when the principal has ex post full bargaining power. This result somewhat corresponds to the theory that efficiency wages should be used to motivate employees when firms can find other employees without any loss after firing or quitting. However, there is one critical difference between my results and previous results from the literature. In the literature, possible dismissal of the agent (or employee) works as just a threat and the principal (or employer) does not fire the agent who exerts a required effort level except for some exogenous reasons, as reported in the previous literature (see Shapiro and Stiglitz, 1984; MacLeod and Malcomson,1998)[19]. However, in the model of this essay, dismissal is not just a threat but is actually exercised for some performance contingencies and even if the agent exerts the required effort level.[20]

The next remark shows that if there exists a self-enforcing termination contract, its bonus schedule should be constant in the benefit, *a*, while the continuation probability may vary with *a*.

REMARK 2: *When* $\pi = \pi_{-G|x_G}$ and $\tilde{u} = \bar{u}$, *if there exists a self-enforcing termination contract implementing* $e > 0$, then *i) the continuation probability schedule is not constant in a and ii) the bonus schedule is constant in a and non-positive for* $\forall a \in A$. *Moreover, such a bonus schedule can be replaced by a zero bonus schedule,* $b : A \rightarrow 0$.

The implication of this remark is that since a non-constant bonus schedule is not available as an incentive device to the principal, a combination of the non-constant continuation probability schedule and positive rents should be used to induce the agent to exert a required effort level. The fact that any positive constant bonus schedule can be replaced with a zero bonus schedule allows us to restrict our attention to a zero bonus schedule in later analyses.

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[19] In both Shapiro and Stiglitz's model and MacLeod and Malcomson's model, a worker is never fired unless exogenous factors induce dismissal if he exerts a required effort level. However, in my model, dismissal can occur even if an exogenous shock is favorable to the agent.

[20] Levin's result also shows that termination can actually occur even if an agent does not shirk. However, he does not relate it to the theory of efficiency wages.

From now on, as the main part of this section, I derive the structure of an optimal self-enforcing termination contract when $\pi_{-G|x_G} = \pi$ and $\tilde{u} < \bar{u}$. In this case, a zero bonus schedule, $b: A \rightarrow 0$ should hold as this property can be derived regardless of the asset specificity of investment. Since the zero bonus schedule alone cannot induce the agent to exert any positive effort level, the continuation probability schedule, $\alpha(a)$ varying with a is necessary to motivate the agent. These results are the same as those in the previous case of $\pi_{-G|x_G} = \pi$ and $\tilde{u} = \bar{u}$. However, one important difference is that under $\tilde{u} < \bar{u}$ due to asset specificity, the principal can induce the agent to exert a positive effort through the continuation probability schedule, $\alpha(a)$ varying with a in the incentive compatibility constraint even when the agent's expected per-period payoff is binding at $\bar{u}$. Therefore, the positive rents of $u - \bar{u}$ for the agent is not always necessary.

Since the principal has ex post full bargaining power, it is natural that the principal is assumed to be interested in maximizing the principal's own profit rather than surplus, which is the sum of both parties' payoffs. When a bonus schedule is zero for $\forall a \in A$, an optimal self-enforcing termination contract can be characterized by analyzing the principal's contract design problem:

$$\text{(P1)} \quad \max_{e, w^m, \alpha(a)} E_a[a - w^m \mid e]$$

$$\text{s.t.} \quad u = \tilde{u} + \frac{(1-\delta)(w^m - c(e) - \tilde{u})}{1 - p\delta E_a[\alpha(a) \mid e]} \geq \bar{u} \qquad (\text{PC}_1)$$

$$e \in \arg\max_{\tilde{e}} E_a\left[p\frac{\delta}{1-\delta}\alpha(a)\big(u - \tilde{u}\big) \mid \tilde{e} \right] - c(\tilde{e}) \qquad (\text{IC}_1)$$

$$0 \leq \alpha(a) \leq 1, \forall\, a \in A.$$

The objective function is obtained by substituting $\pi_{-G|x_G} = \pi$ and $b(a) = 0$ for $\forall a \in A$ into the first equality of (1) and simplifying it. The equality of the agent's participation constraint (PC_1) is obtained by substituting $b(a)$ for $\forall a \in A$ into (2) and rearranging it. The incentive compatibility constraint (IC_1) is acquired by substituting $b(a)$=0 for $\forall a \in A$ into (3). Both parties' discretionary payment constraints and truthful reporting constraint are not necessary, since these are naturally satisfied when $\pi_{-G|x_G} = \pi$ and $b(a)$=0 for $\forall a \in A$ are substituted into (4)-(6) and (PC_1) holds. The principal's participation constraint

($\pi \geq \bar{\pi}$) is not included by the assumption that it is satisfied.

Under the Mirrlees-Rogerson condition, (IC_1) can be replaced with

(7) $p\frac{\delta}{1-\delta}(u-\tilde{u})\frac{d}{de}E_a[\alpha(a)\,|\,e]-c'(e)=0$.[21]

(PC_1) can be rewritten as $(1-\delta)(w^m-c(e)-\tilde{u})\geq(\bar{u}-\tilde{u})(1-p\delta E_a[\alpha(a)\,|\,e])$. Then, (P1) is converted into the following program:

(P2) $\max\limits_{\alpha(a),w^m,e} E_a[a-w^m\,|\,e]$

s.t. $(1-\delta)(w^m-c(e)-\tilde{u})-(\bar{u}-\tilde{u})(1-p\delta E_a[\alpha(a)\,|\,e])\geq 0$ (PC_2)

$p\delta(w^m-c(e)-\tilde{u})\frac{d}{de}E_a[\alpha(a)\,|\,e]+p\delta E_a[\alpha(a)\,|\,e]c'(e)-c'(e)=0$ (IC_2)

$0\leq\alpha(a)\leq 1, \forall a\in A.$

(IC_2) is obtained by substituting the equality of (PC_1) into (7) and rearranging it. The following proposition characterizes an optimal self-enforcing termination contract that is derived by solving (P2).

PROPOSITION 2: *When* $\tilde{\pi}=\pi_{-G|x_G}$ and $\tilde{u}<\bar{u}$, *if there exists an optimal self-enforcing termination contract* $(w^m, 0, b(a), \alpha(a), e, \pi, u)$, *it has the following characteristics.*

(i) $b(a)$ *is zero for* $\forall a\in A$.

(ii) $\alpha(a)=0$ *for* $\forall a<\hat{a}$ *and* $\alpha(a)=1$ *for* $\forall a\geq\hat{a}$.

(iii) *the cut-off value,* $\hat{a}$ *is less than the level that satisfies* $f_e(a\,|\,e)/f(a\,|\,e)=0$.

(iv) u *is either equal to or larger than* $\bar{u}$.

This proposition outlines the common characteristics (i)-(iii) that any optimal self-enforcing termination contract should take. The fourth of proposition 2 states that the agent's expected per-period payoff is either binding at $\bar{u}$ or not depending on the exogenous parameters such as $p, \delta, \tilde{u},$ and $\bar{u}$. Part (i) means that the principal cannot employ a performance contingent bonus schedule to

[21] Refer Laffont and Martimort (2002) for further details of the condition.

motivate the agent when the principal has ex post full bargaining power. This is the most important distinction with Levin's result (2003). When the principal can change a trading partner without any loss due to ex post full bargaining power and the principal's assessment on the agent's performance is subjective, the agent does not believe that bonus payments contingent on the principal's assessment are actually paid. Therefore, the principal's ex post full bargaining power combined with subjective evaluation on performance can be the reason why "performance pay" is sometimes not employed as an incentive device. Part (ii) states that a one-step continuation probability schedule is essential to motivate the agent. Part (iii) states that the interval of benefit specifying rewards through a continuation probability schedule under moral hazard with subjective performance measures is larger than the interval of benefit specifying rewards through a bonus schedule under moral hazard with common monitoring. These two results are analogous to Levin's. However, while he points out that joint punishment or disputes due to termination is indispensable in equilibrium, in this model, termination punishes only the agent since the principal never takes any loss by making a new contract with another agent. Part (iv) states that the principal in some cases wants to provide the agent with positive rents (i.e., $u-\bar{u}>0$) in order to maximize the principal's own expected per-period payoff by motivating the agent to exert more effort. This is because the agent's choice of effort level depends on u as seen in (IC_1). For any given one-step continuation probability schedule, (IC_1) becomes $e \in \arg\max_{\tilde{e}} \frac{p\delta}{1-\delta}(1-F(\hat{a}\,|\,\tilde{e}))(u-\tilde{u})-c(\tilde{e})$. The first order condition is $-\frac{p\delta}{1-\delta}F_e(\hat{a}\,|\,e)(u-\tilde{u})-c_e(e)=0$. By implicit function theorem, we know $\frac{de}{du}=-\frac{p\delta}{1-\delta}F_e(\hat{a}\,|\,e)\Big/\left\{\frac{p\delta}{1-\delta}(u-\tilde{u})F_{ee}(\hat{a}\,|\,e)+c_{ee}(e)\right\}>0$, which implies that as more rents are provided to the agent, the effort level chosen by the agent increases so the principal's expected benefit also increases. However, the principal's expected payoff may decrease due to increased rents. Therefore, when positive rents are optimal $(u-\bar{u}>0)$, the marginal benefit of the agent's rents is equal to the marginal cost of it. On the other hand, when no rents are optimal ($u=\bar{u}$), the marginal benefit of the agent's rents is less than the marginal cost of it. In this case, the principal actually would want to reduce u more but cannot do that due to the agent's participation constraint.

IV. Conclusion and Implication

This paper analyzes optimal self-enforcing termination contracts under the assumptions that the agent (e.g. grower) must make relationship-specific investments prior to contracting, that the principal (e.g. integrator or processor) has ex post full bargaining power due to monopsony power, and that performance is subjectively measured.

My primary findings are that, in the optimal self-enforcing termination contract, the integrator motivates the grower by rewarding the grower through continuation of the relationship for high levels of performance and penalizes the grower through termination for low levels of performance. The principal cannot use performance bonuses any longer. This is the main difference with Levin's model where the principal's ex post full bargaining power is not incorporated. This result is purely due to the principal's ex post bargaining power combined with subjective performance measures. This implies that when performance can not be measured objectively and the principal can change the agent without any cost, the threat of termination is used as an incentive device instead of performance pay.

When no relationship-specific investment is necessary, the principal must pay positive rents to the agent in order to incentivize him. However, when the agent must make relationship-specific investment, the principal may not pay positive rents. Therefore, relationship-specific investment can sometimes eliminate positive rents that the agent would earn if investment was not relationship-specific. This implies that the relationship-specificity of investment increases the principal's expected payoff, whereas it decrease the agent's. In Levin's model, he does not point out this since he does not incorporate the relationship-specific investment and assumes that the distribution of surplus from the contractual relationship is determined by bargaining between two parties.

These results can be applied to any contractual relationships including the relationships between broiler growers and integrators and between farmers and discount stores or food integrators. Recently in the Korean broiler industry, the proportion of the supply of broilers through production contracts has increased. In the Korean fruit and vegetable industry, production and marketing through contractual relationships has been emphasized as the transaction method that can stabilize the supply and price of agricultural products and then farmers' income. Therefore, it will become more important to investigate which form of contract is optimal in various economic environments taking different characteristics. In this context, the model used in this paper cannot be consistent with all Korean agricultural contracting environments, but this study is meaningful in the respect of introducing one analytical method to investigate contracting environments.

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APPENDIX: PROOFS OF REMARKS AND PROPOSITIONS

Proof of Proposition 1: Suppose the full review contract to achieve optimal surplus, s^* such that:

(B1) $s^* \equiv (1-\delta)E_a[a-c(e)\,|\,e]+p\delta E_a[s(a)\,|\,e]+(1-p)\delta(\tilde{u}+\overline{\pi})$.

Since s^* is optimal, $s(a)=u(a)+\pi(a)\le s^*$ and moreover, $\tilde{u}+\overline{\pi}\le s^*$. Therefore, one knows $E_a[a-c(e)\,|\,e]\ge s^*$. Now, let the agent's expected per-period payoff from the contract, $u^*\in[\overline{u},s^*-\overline{\pi}]$ be given and define the principal's expected per- period payoff, $\pi^*\equiv s^*-u^*$. Then, I construct a termination contract that gives the same expected per-period payoffs as the original full review (non-termination) contract. Suppose that I construct a termination contract that specifies effort *e*, a fixed payment w^{m*}, a bonus schedule $b^*(a)$, and a continuation probability schedule $\alpha^*(a)$, such that the expected continuation surplus following any benefit *a* is the same as *s*(*a*) under the original contract. That is, we have:

(B2) $\tilde{s}+\alpha^*(a)(s^*-\tilde{s})\equiv s(a)$ where $\tilde{s}=\pi_{-G|x_G}+\tilde{u}$.

Let $u^*(a)\equiv\tilde{u}+\alpha^*(a)(u^*-\tilde{u})$ and $\pi^*(a)\equiv\pi_{-G|x_B}+\alpha^*(a)(\pi^*-\pi_{-G|x_B})$ be the expected continuation payoffs contingent on the benefit, *a*. Define $b^*(a)$ so that the agent's expected future payoff following contingent on the benefit, *a* is the same as that under the original contract; i.e., so as to satisfy

(B3) $b^*(a)+p\dfrac{\delta}{1-\delta}u^*(a)\equiv b(a)+p\dfrac{\delta}{1-\delta}u(a)$

Substituting $u^*(a)\equiv s^*(a)-\pi^*(a)$ and $u(a)\equiv s(a)-\pi(a)$ into (B3) yields

(B4) $-b^*(a)+p\dfrac{\delta}{1-\delta}\pi^*(a)\equiv -b(a)+p\dfrac{\delta}{1-\delta}\pi(a)$ for all *a*,

since $s^*(a)\equiv u^*(a)+\pi^*(a)\equiv\tilde{u}+\alpha^*(a)(u^*-\tilde{u})+\overline{\pi}+\alpha^*(a)(\pi^*-\overline{\pi})$

$$=\tilde{s}+\alpha^*(a)(s^*-\tilde{s})\equiv s(a)\equiv u(a)+\pi(a).$$

Then, the condition for that the principal reports truthfully is satisfied.

I define a fixed payment w^{m*} such that

(B5) $w^{m*} \equiv -E_a[b^*(a)-c(e)\mid e]+\frac{1}{1-\delta}u^* - \frac{p\delta}{1-\delta}E_a[u^*(a)\mid e]-\frac{(1-p)\delta}{1-\delta}\tilde{u}$

so that the agent's expected per-period payoff u^* is

$u^* \equiv (1-\delta)E_a[w^{m*}+b^*(a)-c(e)\mid e]+p\delta E_a[u^*(a)\mid e]+(1-p)\delta\tilde{u}$.

Now I show that this termination contract $\left(w^{m*}, 0, b^*(a), \alpha^*(a), e, \pi^*, u^*\right)$ yields surplus s^* and is self-enforcing. To see this, note that the surplus s generated from the termination contract satisfies

(B6) $s \equiv (1-\delta)E_a[a-c(e)\mid e]+p\delta\{\tilde{s}+E[\alpha^*(m)\mid e](s-\tilde{s})\}+(1-p)\delta(\tilde{u}+\bar{\pi})$, where m is the level of benefit which the principal reports.

Substituting $(1-\delta)E_a[a-c(e)\mid e]+(1-p)\delta(\tilde{u}+\bar{\pi}) \equiv s^* - p\delta E_a[s(a)\mid e]$ obtained from (B1) into (B6) yields

(B7) $s \equiv s^* - p\delta E_a[s(a)\mid e]+p\delta\{\tilde{s}+E[\alpha^*(m)\mid e](s-\tilde{s})\}$.

Substituting (B2) into (B7) yields

(B8) $s \equiv s^* - p\delta E_a[\tilde{s}+\alpha^*(a)(s^*-\tilde{s})\mid e]+p\delta\{\tilde{s}+E[\alpha^*(m)\mid e](s-\tilde{s})\}$.

Since the principal reports benefits truthfully (i.e., $m=a$), (B8) is simplified as $s=s^*$. Moreover, this termination contract $\left(w^{m*}, 0, b^*(a), \alpha^*(a), e, u^*, \pi^*\right)$ satisfies the constraints (i)-(vi) for self-enforcement.

Proof of Remark 1: Assume a termination contract (w^m, 0, $b(a)$, e, u, π) satisfies the following recursive equations,

(B9) $\pi \equiv (1-\delta)E_a[a-w^m-b(a)\mid e]+p\{\delta\pi_{-G|x_G}+\delta E_a[\alpha(a)\mid e](\pi-\pi_{-G|x_G})\}+(1-p)\delta\bar{\pi}$ and

(B10) $u \equiv (1-\delta)E_a[w^m+b(a)-c(e)\mid e]+p\{\delta\tilde{u}+\delta E_a[\alpha(a)\mid e](u-\tilde{u})\}+(1-p)\delta\tilde{u}$.

When $\pi_{-G|x_G}=\pi$ and $\tilde{u}=\bar{u}$, if the agent earns no positive rents (i.e., $u=\bar{u}$), (B9) and (B10) are simplified respectively as

(B11) $\pi \equiv \frac{1-\delta}{1-\delta p}E_a[a-w^m-b(a)\mid e]+\frac{\delta-\delta p}{1-\delta p}\bar{\pi}$ and

(B12) $\bar{u} \equiv E_a[w^m+b(a)-c(e)\mid e]$.

Therefore, the expected per-period payoffs, $\bar{u}$ and π depend on effort but not on a continuation probability schedule $\alpha(a)$. Whatever the continuation probability schedule $\alpha(a)$ is, the bonus schedule that satisfies the following three constraints (from 4-6), (B13) $\frac{\delta}{1-\delta}\alpha(a)(\pi - \pi) \geq b(a)$, $\forall a \in A$ (Discretionary payment constraint for P)

(B14) $\frac{\delta}{1-\delta}\alpha(a)(\bar{u} - \bar{u}) \geq -b(a)$, $\forall a \in A$ (Discretionary payment constraint for A)

(B15) $\frac{\delta}{1-\delta}\alpha(a)(\pi - \pi) - b(a)$ is constant in a (Truthful reporting constraint)

can only be $b(a) = 0$, $\forall a \in A$. This bonus schedule cannot motivate the agent to choose any positive effort in the following incentive compatibility constraint

(B16) $e \in \arg\max_{\tilde{e}} E_a[b(a) \mid \tilde{e}] - c(\tilde{e})$.

Proof of Remark 2: Consider a self-enforcing termination contract (w^m, 0, $b(a)$, $\alpha(a)$, e, u, π). One knows from truthful reporting constraint (B15), that $b(a)$, should be constant in *a*. One also knows from the discretionary payment constraint for P (B13), that $b(a)$, should be non-positive for all *a*. Then, one can conclude from the following discretionary payment constraint for A,

(B17) $\frac{\delta}{1-\delta}\alpha(a)(u - \bar{u}) \geq -b(a)$, $\forall a \in A$,

that if $\alpha(a)$ is zero for at least one $a \in A$, a bonus schedule is $b(a) = 0$, $\forall a \in A$. On the other hand, if $\alpha(a)$ is larger than zero for $\forall a \in A$, a negative constant bonus schedule such that $b: A \to -\beta$, where $\beta > 0$ is possible. However, such a bonus schedule can be replaced with a bonus schedule, $b: A \to 0$ by decreasing a fixed payment, w^m, by β so that both parties' expected per-period payoffs are unchanged and self-enforcement is satisfied. Therefore, one can restrict attention to $b(a) = 0$, $\forall a \in A$.
Finally, one can conclude from the following agent's incentive compatibility constraint:

(B18) $e \in \arg\max_{\tilde{e}} E_a\left[p\frac{\delta}{1-\delta}\alpha(a)(u - \bar{u}) \mid \tilde{e}\right] - c(\tilde{e})$,

that a continuation probability schedule should not be constant in *a* to ensure that the principal can motivate the agent.

Proof of Proposition 2: Part (i) follows from Remark 1. To show parts (ii)-(iv), denote the multipliers of (PC_2) and (IC_2) by λ_1 and λ_2, respectively, and the multipliers of the first and second inequalities in the double-sided boundary constraints by $\xi(a)$ and $\mu(a)$, respectively. I can write Lagrangian *L* of (P2) as:

$$L(\alpha(a), w^m, e, \lambda_{1,}, \lambda_2, \mu(a), \xi(a))$$
$$= \int (a - w^m) f(a|e)da + \lambda_1 \left\{ (1-\delta)\left(w^m - c(e) - \tilde{u}\right) - (\bar{u} - \tilde{u})(1 - p\delta \int \alpha(a) f(a|e)da) \right\}$$
$$+ \lambda_2 \left\{ p\delta (w^m - c(e) - \tilde{u}) \int \alpha(a) f_e(a|e)da + p\delta \int \alpha(a) f(a|e)dac'(e) - c'(e) \right\}$$
$$- \int \mu(a)\{\alpha(a) - 1\}da + \int \xi(a)\alpha(a)da$$

The first-order conditions are

(B19) $\frac{dL}{d\alpha(a)} = \lambda_1\{p\delta(\bar{u} - \tilde{u}) f(a|e)]\} + \lambda_2\{p\delta(w^m - c(\tilde{e}) - \tilde{u}) f_e(a|e) + p\delta\, f(a|e)c'(e)\} - \mu(a) + \xi(a) = 0$, $\forall a \in A$,

(B20) $\frac{dL}{dw^m} = -1 + \lambda_1(1-\delta) + \lambda_2 p\delta \int \alpha(a) f_e(a|e)da = 0$,

(B21) $\frac{dL}{de} = \int (a - w^m) f_e(a|e)da + \lambda_1 \left\{ -(1-\delta)c'(e) + (\bar{u} - \tilde{u}) p\delta \int \alpha(a) f_e(a|e)da \right\}$,

$+ \lambda_2 \left\{ p\delta (w^m - c(e) - \tilde{u}) \int \alpha(a) f_{ee}(a|e)da + p\delta c''(e) \int \alpha(a) f(a|e)da - c''(e) \right\} = 0$,

(B22) $\lambda_1 \left\{ (1-\delta)\left(w^m - c(e) - \tilde{u}\right) - (\bar{u} - \tilde{u})[1 - p\delta \int \alpha(a) f(a|e)da] \right\} = 0$; $\lambda_1 \geq 0$;

$(1-\delta)\left(w^m - c(e) - \tilde{u}\right) - (\bar{u} - \tilde{u})\left(1 - p\delta E_a[\alpha(a)|e]\right) = 0$,

(B23) $\mu(a)\{\alpha(a) - 1\} = 0$; $\mu(a) \geq 0$; $\alpha(a) \leq 1$ for $\forall a \in A$, and

(B24) $\xi(a) \cdot \alpha(a) = 0$; $\xi(a) \geq 0$; $\alpha(a) \geq 0$ for $\forall a \in A$.

Rearranging (B20), one can get $\lambda_1(1-\delta) + \lambda_2 p\delta \int \alpha(a) f_e(a|e)da = 1$. It follows immediately that both λ_1 and λ_2 cannot be jointly zero since the LHS of the equation must be positive. Thus, we have to consider two cases. First, I consider the case of $\lambda_1 = 0$. In the extreme case where the equality of (PC_2) is excluded, (PC_2) is unbinding. Notice from (B20) that both λ_2 and $\int \alpha(a) f_e(a|e)da$ cannot be zero simultaneously; thus, (B22) can be rearranged to get,

(B25) $\lambda_2 = \frac{1}{p\delta \int \alpha(a) f_e(a|e)da}$.

If $\lambda_2 > 0$ is assumed, $\int \alpha(a) f_e(a|e)da$ should be positive.[22] Since $\lambda_1 = 0$, (B19) becomes

22 If $\lambda_2 < 0$, $\alpha(a)$ is also one step but reversed compared to the case where $\lambda_2 > 0$. Therefore, such a continuation probability schedule cannot provide the agent with incentives.

(B26) $\lambda_2\{p\delta(w^m - c(e) - \tilde{u}) f_e(a \mid e) + p\delta c'(e) f(a \mid e)\} = \mu(a) - \xi(a)$, $\forall a \in A$.

Note that $w^m - c(e) - \tilde{u} > 0$ should be satisfied in (PC_2) since the second term of the LHS of (PC_2) is negative.

Since $\lambda_2 > 0$, $w^m - c(e) - \tilde{u} > 0$, and $c'(e) > 0$, if either $f_e(a \mid e) \geq 0$ or $p\delta(w^m - c(e) - \tilde{u}) f_e(a \mid e) + p\delta c'(e) f(a \mid e) > 0$ and $f_e(a \mid \mathrm{e}) < 0$, then for some $a \in A$ in (B26), it must be true that $\mu(a) > 0$ and $\xi(a) = 0$. Therefore, one can conclude that $\alpha(a) = 1$ from (B23) and (B24). If $p\delta(w^m - c(e) - \tilde{u}) f_e(a \mid e) + p\delta c'(e) f(a \mid e) = 0$ and $f_e(a \mid e) < 0$ for some $a \in A$ in (B26), $\mu(a) = \xi(a) = 0$ should be satisfied since $\mu(a)$ and $\xi(a)$ cannot be positive simultaneously. Hence, $\alpha(a)$ can be any value between 0 and 1 but I set it to zero arbitrarily. If $p\delta(w^m - c(e) - \tilde{u}) f_e(a \mid e) + p\delta c'(e) f(a \mid e) < 0$ and $f_e(a \mid e) < 0$, it should be essential that $\mu(a) = 0$ and $\xi(a) > 0$. Therefore, one can conclude $\alpha(a) = 0$ from (B23) and (B24).

Next, that a continuation probability schedule is one-step can be shown by using MLRP, $\frac{\partial}{\partial a}\left(\frac{f_e(a \mid e)}{f(a \mid e)}\right) > 0$ for $\forall a \in A$. For some w^m, and e, let a cut-off point, $\hat{a}$ be such that

(B27) $p\delta(w^m - c(e) - \tilde{u}) f_e(\hat{a} \mid e) + p\delta c'(e) f(\hat{a} \mid e) = 0$.

Rearranging (B27) yields $\frac{c'(e)}{w^m - c(e) - \tilde{u}} = -\frac{f_e(\hat{a} \mid e)}{f(\hat{a} \mid e)}$. Since the LHS is positive, $f_e(\hat{a} \mid e)$ should be negative. Therefore, $\hat{a}$ should be lower than the level of a that satisfies $f_e(a \mid e) = 0$ since $f_e(\hat{a} \mid e)/f(a \mid e)$ is increasing in a by the MRLP. For $\forall a > \hat{a}$, one has $\frac{c'(e)}{w^m - c(e) - \tilde{u}} > -\frac{f_e(a \mid e)}{f(a \mid e)}$ and $\alpha(a) = 1$. On the other hand, for $\forall a < \hat{a}$, one has $\frac{c'(e)}{w^m - c(e) - \tilde{u}} < -\frac{f_e(a \mid e)}{f(a \mid e)}$ and $\alpha(a) = 0$. This establishes (ii) and (iii).

Applying, $\int f_e(a \mid e) da = 0$, $\int \alpha(a) f(a \mid e) da = 1 - F(\hat{a} \mid e)$, $\int \alpha(a) f_e(a \mid e) da = -F_e(\hat{a} \mid e)$ and $\int \alpha(a) f_{ee}(a \mid e) da = -F_{ee}(\hat{a} \mid e)$ into the equation obtained by substituting (B25) into (B21) yields

(B28) $p\delta F_e(\hat{a}\mid e)\int af_e(a\mid e)da + p\delta(w^m - c(e) - \tilde{u})F_{ee}(\hat{a}\mid e) + (1 - p\delta(1 - F(\hat{a}\mid e)))c''(e) = 0$.

(IC_2) can be rewritten as

(B29) $-\delta(w^m - c(e) - \tilde{u})F_e(\hat{a}) + \delta(1 - F(\hat{a}\mid e))c'(e) - c'(e) = 0$.

Then, one can solve w^m, e, and $\hat{a}$ from (B27), (B28), and (B29).

Now I consider the case where $\lambda_1 > 0$ in which (PC_2) should be binding. I also assume $\lambda_2 > 0$ (see footnote 13). Dividing the equation obtained by integrating (B19) with a by $\int\{\mu(a) - \xi(a)\}da$ yields

(B30) $$\lambda_2 \frac{p\delta c'(e)}{\int \mu(a) - \xi(a)da} + \lambda_1 \frac{p\delta(\bar{u} - \tilde{u})}{\int \mu(a) - \xi(a)da} = 1.$$

Comparing (B30) with (B20), one can observe two conditions,

$$\frac{p\delta c'(e)}{\int \mu(a) - \xi(a)da} = p\delta\int \alpha(a) f_e(a\mid e)da \text{ and } \frac{p\delta(\bar{u} - \tilde{u})}{\int \mu(a) - \xi(a)da} = 1 - \delta.$$

Then, one can unite the two conditions into the following

(B31) $$\int \mu(a) - \xi(a)da = \frac{c'(e)}{\int \alpha(a) f_e(a\mid e)da} = \frac{p\delta(\bar{u} - \tilde{u})}{1 - \delta}.$$

Dividing (B19) by $f(a\mid e)$ yields

(B32) $$\lambda_2\left\{p\delta(w^m - c(\tilde{e}) - \tilde{u})\frac{f_e(a\mid e)}{f(a\mid e)} + p\delta c'(\tilde{e})\right\} + \lambda_1 p\delta(\bar{u} - \tilde{u}) = \frac{\mu(a) - \xi(a)}{f(a\mid e)}, \forall a \in A.$$

Substituting $\lambda_1 p\delta(\bar{u} - \tilde{u}) = -\lambda_2 p\delta c'(e) + \int \mu(a) - \xi(a)da$ from (B30) and $\int \mu(a) - \xi(a)da = \frac{p\delta(\bar{u} - \tilde{u})}{1 - \delta}$ from (B31) into (B32) produces

$$\lambda_2\left\{\delta(w^m - c(\tilde{e}) - \tilde{u})\frac{f_e(a\mid e)}{f(a\mid e)}\right\} + \frac{p\delta(\bar{u} - \tilde{u})}{1 - \delta} = \frac{\mu(a) - \xi(a)}{f(a\mid e)}.$$

Then, let a cut-off point $\hat{a}$ be such that $\mu(\hat{a}) = \xi(\hat{a}) = 0$ and

(B33) $$\lambda_2\left\{\delta(w^m - c(\tilde{e}) - \tilde{u})\frac{f_e(\hat{a}\mid e)}{f(\hat{a}\mid e)}\right\} + \frac{p\delta(\bar{u} - \tilde{u})}{1 - \delta} = 0.$$

One can derive $\alpha(a) = 1$ for all $a > \hat{a}$ and $\alpha(a) = 0$ for all $a \le \hat{a}$ by following the procedure used in the case of $\lambda_1 = 0$. From (B20), (B21), (B33), (IC_2), and binding (PC_2), one can solve $\lambda_1, \lambda_2, \hat{a}, w^m$, and e. Finally, part (iv) is shown because one of two solution candidates from the cases $\lambda_1 = 0$ and $\lambda_1 > 0$ will be an optimal self-enforcing termination contract.