Static and Dynamic Efficiency of Pooled Broiler Contracts:
Relative-Performance Contracts vs. Fixed-Performance Contracts

by

Yanguo Wang
Pennsylvania State University

and

Edward C. Jaenicke
Department of Agricultural Economics and Rural Sociology
Pennsylvania State University
208A Armsby Building
University Park, PA 16802
Tel.: (814) 865-5282
Email: tjaenicke@psu.edu

Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Denver, Colorado, August 1-4, 2004.

Abstract: With the broiler industry as a backdrop, this paper develops theoretical models to compare optimal incentives of pooled relative-performance and fixed-performance contracts in static and dynamic models that account for both adverse selection and moral hazard. In spite of some growers' complaints about the relative-performance contracts used in the broiler industry, model results largely justify the popularity and superiority of relative performance contracts relative to fixed performance contracts.

Static and Dynamic Efficiency of Pooled Broiler Contracts:
Relative Performance Contracts vs. Fixed Performance Contracts

The U.S. broiler industry is one of several agricultural sectors that extensively employ contracts as a method of vertical coordination between processors and producers, and more than 95 percent of chickens are grown under contract (Martinez 1999; USDA/ERS 2000). According to Perry, Banker, and Green (1999), product quality, standardization, product consistency, identification, and risk reduction and risk management in the production process are among the benefits from contracting that accrue directly to broiler processors and growers. A broiler production contract usually contains three types of compensation for grower service: a base payment, a performance payment, and a disaster payment. Contracts that provide proportional bonuses or penalties for above- or below-average grower performance are usually called relative-performance contracts (RPCs). Contracts that instead provide proportional bonuses or penalties when individual performance is above or below some fixed standard are called fixed performance contracts (FPCs). While many broiler growers seem satisfied with most aspects of their contractual arrangements, some have complained about RPCs because they have no way of anticipating how large their performance payments will be (Hayenga et al. 2000). For example, consecutive flocks grown by the same grower, while having similar production costs, can receive substantially different bonus payments depending on the performance of other growers in the settlement group. Some states such as North Carolina have therefore considered legislation that prohibits uses of relative performance contracts. Various forms of legislation aimed at regulating broiler contracts without explicitly targeting tournaments were also passed in Minnesota, Kansas and Wisconsin (Tsoulouhas and Vukina 2001).

A number of recent papers (e.g., Goodhue, 2000; Goodhue et al.,1998; Levy and Vukina, 2001 and 2002; Tsoulouhas and Vukina, 2001; Hegde and Vukina, 2002) study relative performance incentives or tournament contracts in static settings, building on earlier work by Knoeber and Thurman (1994, 1995). One typical result from these papers is that RPCs typically outperform FPCs because the size of common production shocks is generally found to outweigh the size of idiosyncratic shocks (Tsoulouhas and Vukina, 2001). A few additional papers examine contracting in a dynamic context (e.g., Che and Yoo, 2001; Roe and Wu, 2003; Meyers and Vickers, 1997). Roe and Wu, for example, find that while banning tournaments can never be welfare improving in a static setting, a ban can increase total surplus in a dynamic context by mitigating the well-known ratchet effect.

The primary objective of this paper is to compare the efficiency of broiler-industry-style RPCs with FPCs in the presence of both moral hazard and adverse selection, and in both a static and dynamic two-period setting. The moral hazard reflects the fact that growers choose an unobservable effort after a contract is signed, while the adverse selection assumes that heterogeneous unobservable types of growers exist before a contract is signed. Two scenarios of a two-period dynamic RPC are investigated: a "current-period" RPC and a "previous-period" RPC. More precisely, the current-period RPC rewards bonuses to growers using the group average performance in the current period as a standard, while the previous-period RPC rewards each grower by comparing his performance with the average performance of the same group of growers in the previous period. After first developing a relatively standard static model to compare RPCs and FPCs, the paper then extends the model to cover two time periods, first with an assumption of full commitment between grower and processor, and second with a truly dynamic model with no commitment. One of the main differences from Roe and Wu's (2003) work is that this paper investigates the case in which a processor is limited to offering an identical, pooled contract to all growers in one time period. The results and their policy implications are discussed in the final section.

A Static Model for Fixed-Performance and Relative-Performance Contracts

One can assume that broiler output produced by each grower is given by $x_{it} = x(e_{it}, a_i, z_t, u_{it})$, where e_{it} is grower *i*'s effort exerted in period *t*, a_i is grower *i*'s ability realized before the contract is signed, z_t is the common shock borne by all growers in period *t*, and u_{it} is grower *i*'s idiosyncratic risk in period *t*. We assume that u_{it} is an i.i.d normally distributed random variable across growers and periods with mean zero and variance σ_u^2. Moreover, a_i is assumed to be uniformly distributed in the range $[\overline{a}, \underline{a}]$ with $0 < \underline{a} < \overline{a} < \infty$, and a population mean of $a_m = \frac{\overline{a} + \underline{a}}{2}$. Additionally, for the moment, we assume z_t is an i.i.d Normal random variable across periods with mean zero and variance σ_z^2. A more complicated specification of z_t will be discussed in a two-period dynamic model later on. Recall that we assume both growers' abilities and efforts are not directly observable to the processor. However, the distributions specified above are public information to both the processor and the growers.

In particular, the following output structure and payment functions for RPCs and FPCs are commonly used in the literature:[1]

(1) $$x_{it} = a_i + e_{it} + z_t + u_{it}.$$

(2) $$w_{it} = \alpha + \beta[x_{it} - \frac{1}{n}\sum_{j=1}^{n} x_{jt}],$$

(3) $$w_{it} = \alpha + \beta[x_{it} - s] ,$$

[1] Much of the following model's static and dynamic features draw from Levy and Vukina (2002) and Roe and Wu (2003). In this paper, the calculation of the group's average performance includes all growers whose flocks were harvested at approximately the same time. We will assume each grower produces only one flock in each period.

where *s* is the fixed standard. Hence, the variance of x_{it} is $\text{var}(x_{it}) = \sigma_z^2 + \sigma_u^2$ and the covariance between any x_{it} and x_{jt} is $\text{cov}(x_{it}, x_{jt}) = \sigma_z^2$.[2]

The processor is risk neutral and has a profit function, $\pi_t(x,w) = \sum_{i=1}^{n}(x_{it} - w_{it})$. Each grower with ability a_i has a time-separable utility function $U_{it}(w_{it}, e_{it}, a_i) = u(w_{it}) - C(e_{it}, a_i)$, where we assume $C(e_{it}, a_i) = \frac{1}{2a_i}e_{it}^2$. Further, we adopt a commonly used assumption that growers' utility function has the property of constant absolute risk aversion, $u(w_{it}) = -\exp(-rw_{it})]$, where *r* is the Arrow-Pratt coefficient of absolute risk aversion. Thus the expected utility $E_t[U_{it}(\cdot)]$ is tantamount to $E_t[U_{it}(\cdot)] \propto Ew_{it} - \frac{1}{2}r\,\text{var}(w_{it}) - \frac{1}{2a_i}e_{it}^2$. Note that, in this setup, growers differ in their disutility of efforts. Lower ability types incur higher costs relative to higher ability types for a same level of effort. Marginal disutility of efforts decreases with ability as well.

We start with the static case, where a processor offers either a one-period RPC or FPC to all *n* growers. Thus, the contract offered specifies a payment schedule depending on $\{\alpha, \beta, \mathbf{x}\}$. In the static model, the subscript *t* will be omitted for all variables. Given the assumptions described above, the processor maximizes its expected profits subjected to incentive compatibility constraints and growers' participation constraints. Since only one contract is offered to all growers regardless of their abilities in one period, the processor must offer a pooling contract across all ability levels.

[2] Note that there is significant difference between the interpretation of ability *a* in Roe and Wu (2003) and Meyers and Vickers (1997) and that in this paper. Precisely, Roe and Wu (2003) and Meyers and Vickers (1997) treat *a* as a random variable drawn after the contract is offered. Instead, we treat *a* as a random variable drawn before the contract is offered. Thus, growers' ability *a* , which is unobservable to the processor, is deterministic after the contract is offered and its distribution function is known to both the processor and the growers.

Thus, the processor solves the problem:

(4) $$\max_{\alpha,\beta} E_a\{\sum_{i=1}^{n}(Ex_i - Ew_i)\}, \text{ subject to}$$

(5) $$E_a[EU_i] = E_a[Ew_i - \frac{1}{2}r\,\mathrm{var}(w_i) - \frac{1}{2a_i}e_i^2] \geq 0, \text{ and}$$

(6) $$e_i \in \arg\max\{Ew_i - \frac{1}{2}r\,\mathrm{var}(w_i) - \frac{1}{2a_i}e_i^2\}, \qquad \forall i.$$

The participation constraint (5) states that an average-ability grower obtains his reservation utility of zero under the pooling contract offered by the processor, while the incentive compatibility constraint (6) requires that each grower optimally chooses his effort by maximizing the expected utility.

Standard results from contract theory require that the participation constraint (5) is always binding because otherwise, the processor can always reduce the payment to the growers until it reaches their reservation utility level.[3] Following Roe and Wu (2003) and Meyers and Vickers (1997), and given the binding participation constraint, the processor's objective can be transformed into maximizing the total welfare obtained by the processor and all growers. Precisely, denote the expected total welfare obtained by the processor and all growers as

(7) $$W = E_a\{\sum_{i=1}^{n}(Ex_i - Ew_i)\} = E_a\{\sum_{i=1}^{n}(Ex_i - (\frac{1}{2}r\,\mathrm{var}(w_i) + \frac{1}{2a_i}e_i^2))\}.$$

Thus, the optimal contract chosen by maximizing (7) will be Pareto optimal. However, we should note that maximization of the total welfare W is equivalent to maximizing the processor's expected profit only if the participation constraint is binding.

[3] Good references on this topic include Mas-Collel, Whinston, and Green (1995) and Salanie. (1997)

Static fixed-performance and relative-performance contracts

First, we discuss the optimal incentives under a FPC. Denote the optimal static FPC as $C_F = \{\alpha_F, \beta_F\}$. Solving the processor's problem leads to the following standard results:

(8) $$\beta_F = \frac{1}{1+\frac{r}{a_m}(\sigma_z^2+\sigma_u^2)},$$

(9) $$\alpha_F = \frac{[r(\sigma_z^2+\sigma_u^2)-a_m]}{2[1+\frac{r}{a_m}(\sigma_z^2+\sigma_u^2)]^2} + \frac{s-a_m}{1+\frac{r}{a_m}(\sigma_z^2+\sigma_u^2)}, \text{ and}$$

(10) $$W_F = na_m[1+\frac{1}{2(1+\frac{r}{a_m}(\sigma_z^2+\sigma_u^2))}].$$

Several characteristics are borne in the bonus payment β_F and the base payment α_F. First, since only one contract is offered to all growers regardless of their abilities, the bonus payment β_F is same for all possible levels of grower abilities. Second, because growers bear all production uncertainty under the FPC, both the common shock and the idiosyncratic shock affect the bonus payment. Specifically, the bonus payment decreases with the variance of either of the random shocks. Third, the bonus payment is positively related to the average ability level in the group and negatively related to growers' risk aversion; however, the fixed standard s specified in the contract does not affect the bonus payment. Finally, the fixed standard s is positively related to the base payment due to the binding participation constraint.

Under a RPC, the processor uses the peer average performance as a standard to reward each grower. Denote the optimal static contract as $C_R = \{\alpha_R, \beta_R\}$. The standard solution to the processor's problem now leads to the following results:

(11) $$\beta_R = \frac{a_m}{\frac{n-1}{n} a_m + r\sigma_u^2},$$

(12) $$\alpha_R = \frac{a_m}{2[1 + \frac{r}{a_m}\frac{n}{n-1}\sigma_u^2]}, \text{ and}$$

(13) $$W_R = na_m[1 + \frac{1}{2(1 + \frac{r}{a_m}\frac{n}{n-1}\sigma_u^2)}].$$

The most prominent feature of this bonus payment is that it is independent of the common shock. As a matter of fact, this result is one of the main reasons that researchers favor RPCs under a wide range of circumstances.

Comparing (10) with (13) yields the following standard proposition:

Proposition 1: *a*) $W_R > W_F$ if $\sigma_z^2 > \frac{1}{n-1}\sigma_u^2$, *b*) $W_R < W_F$ if $\sigma_z^2 < \frac{1}{n-1}\sigma_u^2$, *c*) $W_R = W_F$ if $\sigma_z^2 = \frac{1}{n-1}\sigma_u^2$, and *d*) $W_R > W_F$ if $n \to \infty$. The proof is straightforward and not provided.

This proposition is a standard result in the literature on RPCs and rank tournament contracts (e.g., Levy and Vukina 2001). Intuitively, the proposition states that a RPC performs better than a FPC when the common shock dominates the idiosyncratic shock because comparing one grower's performance with other growers at approximately the same time completely eliminates the common production shock borne by all growers.

In addition, it is easy to verify that the optimal bonus has similar properties as the total welfare measure. We summarize it in the following corollary, again without further proof.

Corollary 1.1: *a*) $\beta_R > \beta_F$ if $\sigma_z^2 > \frac{1}{n-1}\sigma_u^2$, *b*) $\beta_R < \beta_F$ if $\sigma_z^2 < \frac{1}{n-1}\sigma_u^2$, *c*) $\beta_R = \beta_F$ if $\sigma_z^2 = \frac{1}{n-1}\sigma_u^2$, and *d*) $\beta_R > \beta_F$ if $n \to \infty$.

In words, when the common shock dominates, not only does a static RPC improve total welfare relative to a static FPC, but it also offers a greater bonus than that under the static FPC.

Two-Period Models

The static model above is extended here to include two time periods. In a dynamic context, ratchet effects might exist due to the presence of asymmetric information.[4] Thus, the optimal contract provided by the processor must account for this potential effect and adjust the intertemporal incentives accordingly. This section consists of three related cases. The first case briefly discusses optimal two-period contracts under "full-commitment " by the processor and growers. The second case investigates a current-period dynamic RPC and a FPC where neither the processor nor growers can commit to an intertemporal scheme. In this case, the relative standard used in the contract is the peer average performance in the current period. While the terms and payments schedules in actual contracts are much more complex than those specified in this part, the current-period dynamic RPC has been widely used in the broiler industry.[5] The third case further extends the model and investigates a dynamic previous-period RPC and FPC. Here, the term "previous-period RPC" is used to indicate that the relative standard used in the contract is the peer average performance from the previous period. Although, this particular type of contract has not been explicitly used in the broiler industry, we examine this scenario here for two reasons. First, this case loosely corresponds to the concept of same-period ban of

[4] Freixas, Guesnerie, and Tirole (1985) states that ratchet effects induce firms to underproduce to avoid more demanding schedule in the future as the central planner revises the scheme over time to take into account information provided by the firm's performance.
[5] Good examples of broilers contracts include the following: Tyson Richmond broiler contract, Pilgrim Pride Contract, ConAgra broiler contract, and MBA broiler contract.

RPC defined in Roe and Wu (2003)[6]; and second, it would be natural to assume that if current-period tournaments were banned, producers may still use data on past performance to set a fixed standard.

Further, it is assumed that the common shock takes the simple form of a stationary process in the dynamic context:

$$z_t = \phi z_{t-1} + \varepsilon_t,\ |\phi| < 1, \text{ where } \varepsilon_t \sim i.i.d.N(0, \sigma_\varepsilon^2). \tag{14}$$

With this specification, it is straightforward to verify $z_t \sim N(0, \sigma_z^2)$, where $\sigma_z^2 = \dfrac{\sigma_\varepsilon^2}{1-\phi^2}$, and $\text{cov}(z_t, z_{t-1}) = \dfrac{\phi\sigma_\varepsilon^2}{1-\phi^2}$. Note that given the stationary process, the relationship between outputs in two periods is similar to that described in Roe and Wu (2003) except for autocorrelation between growers' abilities.

Before we proceed to the dynamic model, we investigate the optimal two-period contracts under full-commitment. Two conditions describe full-commitment: On one hand, the processor promises not to use information revealed in the first period to modify the contract in the second period. On the other hand, growers promise not to breach the contract during the contract period. Thus, under full-commitment, the optimal contracts in each of the two periods are independent and are exact replications of the static contract in each period. Therefore, no dynamic effect exists in this case.

Specifically, under the RPC, the processor offers the contract $C_R = \{\alpha_R, \beta_R\}$ in each period, with α_R and β_R specified by (12) and (11), respectively. Assuming both the processor and the

---

[6] Roe and Wu (2003) define all-periods ban, in a two-period model, as disallowing the principal from using information concerning player j from either period to develop contract parameters for player *i*.

growers discount their profit or utility by a factor δ , the total two-period welfare under the relative-performance contract is the discounted sum of (13):

$$W_R^F = (1+\delta)na_m[1+\frac{1}{2(1+\frac{r}{a_m}\frac{n}{n-1}\sigma_u^2)}]. \tag{15}$$

Similarly, given (8)-(10), the processor's total welfare under the full-commitment FPC is

$$W_F^F = (1+\delta)na_m[1+\frac{1}{2(1+\frac{r}{a_m}(\sigma_z^2+\sigma_u^2))}]. \tag{16}$$

We now impose the assumption that the processor is not fully committed in the second period. Instead, the processor optimally adjusts the second-period incentives using information acquired at the end of the first period. Two scenarios of RPCs will be investigated: a current-period RPC and a previous-period RPC. In addition, the same fixed standard is used in both periods under the dynamic FPC. It is also assumed that the same growers are under contract in both periods in a two-period model throughout this section.

Given the output structure (1) and the distributions of the random shocks, the joint distribution of output $\mathbf{x}$ is

$$\mathbf{x} = \begin{pmatrix} x_{11} \\ \vdots \\ x_{n1} \\ x_{12} \\ \vdots \\ x_{n2} \end{pmatrix} \sim N\left[\begin{pmatrix} a_1+e_{11} \\ \vdots \\ a_n+e_{n1} \\ a_1+e_{12} \\ \vdots \\ a_n+e_{n1} \end{pmatrix}, \sigma_z^2 \begin{pmatrix} \tau & 1 & \cdots & 1 & \phi & \phi & \cdots & \phi \\ 1 & \tau & \cdots & 1 & \phi & \phi & \cdots & \phi \\ \vdots & \vdots & \cdots & \vdots & \vdots & \vdots & \cdots & \vdots \\ 1 & 1 & \cdots & \tau & \phi & \phi & \cdots & \phi \\ \phi & \phi & \cdots & \phi & \tau & 1 & \cdots & 1 \\ \phi & \phi & \cdots & \phi & 1 & \tau & \cdots & 1 \\ \vdots & \vdots & \cdots & \vdots & \vdots & \vdots & \cdots & 1 \\ \phi & \phi & \cdots & \phi & 1 & 1 & \cdots & \tau \end{pmatrix}\right],$$

where $\tau = \dfrac{\sigma_z^2+\sigma_u^2}{\sigma_z^2}$.

Hence, we can compute the following expressions[7]:

(17) $$E[x_{i2} \mid x_{11}, x_{21}, ..., x_{n1}] = a_i + e_{i2} + \frac{\phi(\tau - 1)}{\tau(\tau + n - 2) - (n-1)} \sum_{j=1}^{n} (z_1 + u_{j1}),$$

(18) $$\text{var}[x_{i2} \mid x_{11}, x_{21}, ..., x_{n1}] = \sigma_z^2 (\tau - \frac{n\phi^2(\tau - 1)}{\tau(\tau + n - 2) - (n-1)}),$$

(19) $$\text{var}[x_{i2}, x_{j2} \mid x_{11}, x_{21}, ..., x_{n1}] = \sigma_z^2 \begin{pmatrix} \tau - \frac{n\phi^2(\tau - 1)}{\tau(\tau + n - 2) - (n-1)} & 1 - \frac{n\phi^2(\tau - 1)}{\tau(\tau + n - 2) - (n-1)} \\ 1 - \frac{n\phi^2(\tau - 1)}{\tau(\tau + n - 2) - (n-1)} & \tau - \frac{n\phi^2(\tau - 1)}{\tau(\tau + n - 2) - (n-1)} \end{pmatrix}, \text{ and}$$

(20) $$\text{cov}[x_{i2}, x_{j2} \mid x_{11}, x_{21}, ..., x_{n1}] = \sigma_z^2 (1 - \frac{n\phi^2(\tau - 1)}{\tau(\tau + n - 2) - (n-1)})$$

Under the two-period dynamic FPC without full-commitment, the optimal incentives can be formulated backward using a dynamic programming approach. Additionally, because growers' outputs are correlated in the two periods under the assumption (14), the processor and growers take expectations of the second-period rewards and outputs conditional on the first period outputs.

Denote the second-period optimal contract as $C_{F2} = \{\alpha_{F2}, \beta_{F2}\}$. Again, we assume the fixed standard used to reward growers is s in both periods. Hence, the payment to each grower in the second period becomes $w_{i2} = \alpha_{F2} + \beta_{F2}[x_{i2} - s], \forall i$. Hence,

(21) $$E_2[w_{i2} \mid x_{11}, ..., x_{n1}] = \alpha_{F2} + \beta_{F2}[a_i + e_{i2} + \frac{\phi(\tau - 1)}{\tau(\tau + n - 2) - (n-1)} \sum_{j=1}^{n} (z_1 + u_{j1}) - s], \text{ and}$$

(22) $$\text{var}(w_{i2} \mid x_{11}, ..., x_{n1}) = \beta_{F2}^2 \text{ var}(x_{i2} - s \mid x_{11}, ..., x_{n1}) == \beta_{F2}^2 [\tau - \frac{n\phi^2(\tau - 1)}{\tau(\tau + n - 2) - (n-1)}]$$

Similar to the static model, the processor solves the following problem:

[7] The results in this section are based on calculations found in Greene (2000), p86-87.

(23) $$\max_{\alpha_{F2},\beta_{F2}} E_a\{\sum_{i=1}^{n}(E_2 x_{i2}-\frac{1}{2}r\,\mathrm{var}(w_{i2})-\frac{1}{2a_i}e_{i2}^2)\mid x_{11},...x_{n1}\},$$

subject to the re-written participation and incentive-compatibility constraints:

(24) $$E_a[E_2U_{i2}\mid x_{11,...,}x_{n1}]=E_a[\alpha_{F2}+\beta_{F2}[a_i+e_{i2}+\frac{\phi(\tau-1)}{\tau(\tau+n-2)-(n-1)}\sum_{j=1}^{n}(z_1+u_{j1})-s] \\ -\frac{1}{2}r\beta_{F2}^2\sigma_z^2[\tau-\frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)}]-\frac{1}{2a_i}e_{i2}^2]\geq 0.$$

(25) $$e_{i2}\in\arg\max\{\alpha_{F2}+\beta_{F2}[a_i+e_{i2}+\frac{\phi(\tau-1)}{\tau(\tau+n-2)-(n-1)}\sum_{j=1}^{n}(z_1+u_{j1})-s] \\ -\frac{1}{2}r\beta_{F2}^2\sigma_z^2[\tau-\frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)}]-\frac{1}{2a_i}e_{i2}^2\},\qquad \forall i.$$

From the constraint (25), each grower chooses the optimal effort such that $e_{i2}=a_i\beta_{F2}$.

Thus, the total welfare in the second period conditional on outputs in the first period is

(26) $$W_{F2}=\sum_{i=1}^{n}(a_m+a_m\beta_{F2}+\frac{\phi(\tau-1)}{\tau(\tau+n-2)-(n-1)}\sum_{j=1}^{n}(z_1+u_{j1})-\frac{1}{2}r\beta_{F2}^2\sigma_z^2[\tau-\frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)}]-\frac{1}{2}a_m\beta_{F2}^2).$$

Differentiating (26) with respect to β_{F2} and solving yields

(27) $$\beta_{F2}=\frac{a_m}{a_m+r\sigma_z^2[\tau-\frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)}]}.$$

From the binding participation constraint (24), we can obtain the optimal base payment,

(28) $$\alpha_{F2}=-\frac{1}{2}a_m\beta_{F2}-a_m\beta_{F2}^2-\beta_{F2}[\frac{\phi(\tau-1)}{\tau(\tau+n-2)-(n-1)}\sum_{j=1}^{n}(z_1+u_{j1})-s].$$

Further, the total welfare in the second period under the FPC can be computed as:

(29) $$W_{F2}=na_m[1+\frac{a_m}{2[a_m+r\sigma_z^2(\tau-\frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)})]}]+\frac{n\phi(\tau-1)}{\tau(\tau+n-2)-(n-1)}\sum_{j=1}^{n}(z_1+u_{j1}).$$

Denote the first-period optimal contract as $C_{F1} = \{\alpha_{F1}, \beta_{F1}\}$. At the beginning of the first period, the processor chooses the optimal bonus and the base payment for the first period by maximizing the total two-period welfare. Similarly to the second-period reward, the first-period reward to each grower takes the form, $w_{i1} = \alpha_{F1} + \beta_{F1}[x_{i1} - s]$, $\forall i$. Hence,

(30) $$E_1[w_{i1}] = \alpha_{F1} + \beta_{F1}[a_i + e_{i1} - s]\text{, and}$$

(31) $$\mathrm{var}(w_{i1}) = \beta_{F1}^2 \,\mathrm{var}(x_{i1} - s) = \beta_{F1}^2 \,\mathrm{var}(x_{i1}) = \beta_{F1}^2 (\sigma_z^2 + \sigma_u^2).$$

Let W_F^D denote the two-period total welfare under the dynamic FPC, W_{F1} denote the first-period welfare, and δ denote the discount factor. The processor solves the following problem in the first period:

$$W_F^D = \max_{\alpha_{F1},\beta_{F1}} \{E_a[\textstyle\sum_{i=1}^n (a_i + e_{i1} - \frac{1}{2} r\beta_{F1}^2(\sigma_z^2 + \sigma_u^2) - \frac{1}{2a_i} e_{i1}^2)] + \delta E_1(W_{F2} \mid x_{11},\ldots,x_{n1})\}$$

subject to

(32) $$E_a[\alpha_{F1} + \beta_{F1}[a_i + e_{i1} - s] - \frac{1}{2} r\beta_{F1}^2(\sigma_z^2 + \sigma_u^2) - \frac{1}{2a_i} e_{i1}^2] + \delta E_1[E_a(E_2 U_{i2} \mid x_{11}\ldots x_{n1})] \ge 0,$$

(33) $$e_{i1} \in \arg\max\{\alpha_{F1} + \beta_{F1}[a_i + e_{i1} - s] - \frac{1}{2} r\beta_{F1}^2(\sigma_z^2 + \sigma_u^2) - \frac{1}{2a_i} e_{i1}^2 + \delta E_1[E_2 U_{i2} \mid x_{11}\ldots x_{n1}]\},\ \forall i.$$

From the constraint (33), the optimal effort in the first period must satisfy $e_{i1} = a_i \beta_{F1}$.

The optimal conditions for the bonus and base payment in the first-period become:

(34) $$\beta_{F1} = \frac{a_m}{a_m + r(\sigma_z^2 + \sigma_u^2)},$$

(35) $$\alpha_{F1} = -\beta_{F1}[a_m + a_m\beta_{F1} - s] + \frac{1}{2} a_m \beta_{F1} = s\beta_{F1} - a_m \beta_{F1}^2 - \frac{1}{2} a_m \beta_{F1}.$$

Further, we can obtain the expected two-period total welfare under the dynamic FPC,

(36) $$W_F^D = na_m(1+\frac{a_m}{2[a_m + r(\sigma_z^2+\sigma_u^2)]}) + \delta na_m(1+\frac{a_m}{2[a_m + r\sigma_z^2(\tau - \frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)})]}).$$

The following proposition compares the total welfare under the dynamic FPC with that under the full-commitment FPC given by (16).

Proposition 2: The total welfare under the two-period dynamic FPC exceeds that under the full-commitment FPC. That is, $W_F^D > W_F^F$.

The proof is straightforward. Recall that $\tau = \frac{\sigma_z^2+\sigma_u^2}{\sigma_z^2} > 1$, hence, the following term in (36) has the property: $\sigma_z^2(\tau - \frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)}) = \sigma_z^2+\sigma_u^2 - \frac{\sigma_z^2 n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)} < \sigma_z^2+\sigma_u^2$

Thus, $W_F^D = na_m(1+\frac{a_m}{2[a_m + r(\sigma_z^2+\sigma_u^2)]}) + \delta na_m(1+\frac{a_m}{2[a_m + r\sigma_z^2(\tau - \frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)})]}) >$

$(1+\delta)na_m(1+\frac{a_m}{2[a_m + r(\sigma_z^2+\sigma_u^2)]}) = W_F^F$. Intuitively, under the dynamic FPC, the processor can obtain more information from growers' first-period performance and raise his expected profit by using the information to provide the second-period incentives.

A dynamic RPC based on current-period performance

We now turn towards investigating a dynamic current-period RPC. The two-period dynamic RPC can be solved in the similar fashion to the dynamic FPC.

Denote the second-period optimal contract as $C_{R2} = \{\alpha_{R2}, \beta_{R2}\}$. Each grower's payment in the second period becomes $w_{i2} = \alpha_{R2} + \beta_{R2}[x_{i2} - \frac{1}{n}\sum_{j=1}^{n} x_{j2}]$, $\forall i$. Hence,

(37) $$E_2[w_{i2} \mid x_{11},...,x_{n1}] = \alpha_{R2} + \beta_{R2}[a_i + e_{i2} - \frac{1}{n}\sum_{j=1}^{n}(a_j + e_{j2})], \text{ and}$$

(38) $$\mathrm{var}(w_{i2} \mid x_{11},...,x_{n1}) = \beta_{R2}^2 \frac{n-1}{n}\sigma_z^2(\tau-1) = \beta_{R2}^2 \frac{n-1}{n}\sigma_u^2.$$

The variance of the second period payment depends only on the idiosyncratic shock without being affected by the common shock. Similar to the static model, the processor solves

(39) $$\max_{\alpha_{R2},\beta_{R2}} E_a\{\sum\nolimits_{i=1}^n (E_2 x_{i2} - \frac{1}{2} r\,\mathrm{var}(w_{i2}) - \frac{1}{2a_i} e_{i2}^2) \mid x_{11},...x_{n1}\}\text{, subject to}$$

(40) $$E_a[\alpha_{R2} + \beta_{R2}[a_i + e_{i2} - \frac{1}{n}\sum\nolimits_{j=1}^n (a_j + e_{j2})] - \frac{1}{2} r\beta_{R2}^2 \frac{n-1}{n}\sigma_u^2 - \frac{1}{2a_i} e_{i2}^2] \geq 0\text{, and}$$

(41) $$e_{i2} \in \arg\max\{\alpha_{R2} + \beta_{R2}[a_i + e_{i2} - \frac{1}{n}\sum\nolimits_{j=1}^n (a_j + e_{j2})] - \frac{1}{2} r\beta_{R2}^2 \frac{n-1}{n}\sigma_u^2 - \frac{1}{2a_i} e_{i2}^2\},\quad \forall i$$

From (41), the optimal effort from each grower must satisfy $e_{i2} = \frac{n-1}{n} a_i \beta_{R2}$. Thus, conditional on first-period output, the second-period bonus, base pay, and second-period total welfare are:

(42) $$\beta_{R2} = \frac{a_m}{\frac{n-1}{n} a_m + r\sigma_u^2},$$

(43) $$\alpha_{R2} = \frac{1}{2}\frac{n-1}{n}\frac{(a_m)^2}{r\sigma_u^2 + \frac{n-1}{n} a_m} = \frac{a_m}{2[1 + \frac{r}{a_m}\frac{n}{n-1}\sigma_u^2]}.\text{ and}$$

(44) $$W_{R2} = na_m[1 + \frac{1}{2(1 + \frac{r}{a_m}\frac{n}{n-1}\sigma_u^2)}] + \frac{n\phi(\tau-1)}{\tau(\tau+n-2)-(n-1)}\sum\nolimits_{j=1}^n (z_1 + u_{j1}).$$

Denoting the first-period optimal contract as $C_{R1} = \{\alpha_{R1}, \beta_{R1}\}$, the first-period reward to each grower takes the form, $w_{i1} = \alpha_{R1} + \beta_{R1}[x_{i1} - \frac{1}{n}\sum\nolimits_{j=1}^n x_{j1}]$, $\forall i$.

Hence,

(45) $$E_1[w_{i1}] = \alpha_{R1} + \beta_{R1}[a_i + e_{i1} - \frac{1}{n}\sum\nolimits_{j=1}^n (a_j + e_{j1})]\text{, and}$$

(46) $$\operatorname{var}(w_{i1}) = \beta_{R1}^2 \frac{n-1}{n}(\sigma_z^2 + \sigma_u^2 - \sigma_z^2) = \beta_{R1}^2 \frac{n-1}{n}\sigma_u^2 .$$

Similar to the dynamic FPC, the processor chooses the first-period optimal bonus and the base payment by maximizing the total two-period welfare, W_R^S, where the superscript *S* stands for current or same period, the subscript *R* stands for RPC, and W_{R1} denotes the first-period welfare. The processor solves the following problem in the first period:

(47) $W_R^S = \max_{\alpha_{R1}, \beta_{R1}} \{W_{R1} + \delta E_1(W_{R2} \mid x_{11}, ..., x_{n1})\}$, subject to

(48) $$E_a[E_1 U_{i1} + \delta E_1(E_2 U_{i2})] = E_a[E_1 w_{i1} - \frac{1}{2} r \operatorname{var}(w_{i1}) - \frac{1}{2a_i} e_{i1}^2] + \delta E_1[E_a(E_2 U_{i2})] \geq 0,$$

(49) $$e_{i1} \in \operatorname{argmax}\{\alpha_{R1} + \beta_{R1}[\frac{n-1}{n}(a_i + e_{i1}) - \frac{1}{n}\sum\nolimits_{j=1, j\neq i}^{n}(a_j + e_{j1})] - \frac{1}{2} r \beta_{R1}^2 \frac{n-1}{n}\sigma_u^2 - \frac{1}{2a_i} e_{i1}^2 + \delta E_1[E_2 U_{i2}]\},\ \forall i .$$

From (49), the optimal effort in the first period must satisfy $e_{i1} = \frac{n-1}{n} a_i \beta_{R1}$. We also obtain the following results:

(50) $$\beta_{R1} = \frac{a_m}{\frac{n-1}{n} a_m + r\sigma_u^2},$$

(51) $$\alpha_{R1} = \frac{a_m}{2[1 + \frac{r}{a_m}\frac{n}{n-1}\sigma_u^2]},$$

Further, we can obtain the expected two-period total welfare,

(52) $$W_R^S = (1+\delta) n a_m (1 + \frac{1}{2(1 + \frac{r}{a_m}\frac{n}{n-1}\sigma_u^2)}).$$

First, note that the two-period total welfare under this dynamic current-period RPC will be exactly same as that under the full-commitment RPC and is exactly a repetition of the static

RPC. That is, the intertemporal relationship between the incentives in the two periods does not alter the optimal choice of rewards offered by the processor and the optimal efforts provided by growers. Thus, under the dynamic current-period RPC, both the processor and growers are myopic. This result is a special feature of the current-period relative-performance contract.

Second, we can compare performance of the dynamic current-period RPC with the dynamic FPC. However, it is not straightforward to show whether or not one is superior to the other. We summarize some plausible results in the following proposition.

Proposition 3: *a*) $W_R^S < W_F^D$ if $\sigma_z^2 \le \frac{1}{n-1}\sigma_u^2$, *b*) $W_R^S > W_F^D$ if $\sigma_z^2 >> \frac{1}{n-1}\sigma_u^2$.

Proof: Part *a* is straightforward. From (36), $W_F^D = na_m(1+\frac{a_m}{2[a_m + r(\sigma_z^2+\sigma_u^2)]})+$

$$\delta na_m(1+\frac{a_m}{2[a_m + r\sigma_z^2(\tau - \frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)})]}) > (1+\delta)na_m(1+\frac{a_m}{2[a_m+r(\sigma_z^2+\sigma_u^2)]})$$

Thus, similar to Proposition 1, $W_R^S < W_F^D$ if $\sigma_z^2 \le \frac{1}{n-1}\sigma_u^2$. However, we only provide intuition for part *b*. That is, only if the variance of common shocks is sufficiently greater than that of the idiosyncratic shocks would the dynamic RPC perform better than the dynamic FPC.

Additionally, comparing Proposition 3 with Proposition 1 shows that the FPC becomes more beneficial in a dynamic setting than in a static setting because the processor can effectively use the information obtained in the first period to provide incentives in the second period. However, under the current-period RPC, comparing one grower's performance to others' completely eliminates the common uncertainty without being affected by their intertemporal relationship. Consequently, the optimal dynamic current-period RPC mimics a sequence of optimal static RPC although the second period incentives under this contract do account for the growers' first-period information.

A dynamic RPC based on previous-period performance

As discussed above, this scenario corresponds to the concept of an same-period ban defined in Roe and Wu (2003). Later on, when the performance of the dynamic FPC is compared to the dynamic previous-period RPC, readers could think of the possibility of eliminating the dynamic previous-period RPC as an all-period ban of RPC. Finally, to investigate the dynamic effects on the optimal incentives, it is necessary to assume that the processor signs a contract with the same group of growers in both periods.

Denote the second-period optimal contract as $C_{L2} = \{\alpha_{L2}, \beta_{L2}\}$ where the subscript denotes the last or previous period. Using group average performance in the last period as a standard, the processor rewards each grower according to $w_{i2} = \alpha_{L2} + \beta_{L2}[x_{i2} - \frac{1}{n}\sum_{j=1}^{n} x_{j1}]$, $\forall i$. Hence,

(53) $$E_2[w_{i2} \mid x_{11},...,x_{n1}] = \alpha_{L2} + \beta_{L2}[a_i + e_{i2} + \frac{\phi(\tau-1)}{\tau(\tau+n-2)-(n-1)}\sum_{j=1}^{n}(z_1 + u_{j1}) - \frac{1}{n}\sum_{j=1}^{n} x_{j1}],$$ and

(54) $$\mathrm{var}(w_{i2} \mid x_{11},...,x_{n1}) = \beta_{L2}^2 \sigma_z^2 [\tau - \frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)}].$$

Similar to the static model, the processor solves

(55) $$\max_{\alpha_{L2},\beta_{L2}} E_a\{\sum_{i=1}^{n}(E_2 x_{i2} - \frac{1}{2} r\,\mathrm{var}(w_{i2}) - \frac{1}{2a_i} e_{i2}^2) \mid x_{11},...x_{n1}\}.$$ subject to

(56) $$\begin{aligned} &E_a\{\alpha_{L2} + \beta_{L2}[a_i + e_{i2} + \frac{\phi(\tau-1)}{\tau(\tau+n-2)-(n-1)}\sum_{j=1}^{n}(z_1 + u_{j1}) - \frac{1}{n}\sum_{j=1}^{n} x_{j1}] \\ &-\frac{1}{2} r\beta_{L2}^2 \sigma_z^2 (\tau - \frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)}) - \frac{1}{2a_i} e_{i2}^2\} \geq 0 \end{aligned}$$, and

(57)
$$e_{i2} \in \arg\max \{\alpha_{L2} + \beta_{L2}[a_i + e_{i2} + \frac{\phi(\tau-1)}{\tau(\tau+n-2)-(n-1)}\sum_{j=1}^{n}(z_1 + u_{j1}) - \frac{1}{n}\sum_{j=1}^{n} x_{j1}]$$
$$-\frac{1}{2} r\beta_{L2}^2 \sigma_z^2 (\tau - \frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)}) - \frac{1}{2a_i} e_{i2}^2\}, \qquad \forall i.$$

The first-order condition to the constraint (57) leads to $e_{i2} = a_i \beta_{L2}$ and the following results:

(58)
$$\beta_{L2} = \frac{a_m}{a_m + r\sigma_z^2(\tau - \frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)})}.$$

(59)
$$\alpha_{L2} = -\frac{1}{2} a_m \beta_{L2} - a_m \beta_{L2}^2 - \beta_{L2}[\frac{\phi(\tau-1)}{\tau(\tau+n-2)-(n-1)}\sum_{j=1}^{n}(z_1 + u_{j1}) - \frac{1}{n}\sum_{j=1}^{n} x_{j1}], \text{ and}$$

(60)
$$W_{L2} = na_m[1 + \frac{a_m}{2[a_m + r\sigma_z^2(\tau - \frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)})]}] + \frac{n\phi(\tau-1)}{\tau(\tau+n-2)-(n-1)}\sum_{j=1}^{n}(z_1 + u_{j1}).$$

However, at the beginning of the first period, the processor does not have the information of growers' performance in the previous period. Thus, for simplicity, we assume that the same fixed standard *s* used in the fixed-performance contract will be adopted for the first-period contract of the dynamic previous-period RPC. Under this assumption, each grower receives a reward in the first period, $w_{i1} = \alpha_{L1} + \beta_{L1}[x_{i1} - s]$, $\forall i$. Denoting the first-period optimal contract as $C_{L1} = \{\alpha_{L1}, \beta_{L1}\}$ leads to the following:

(61)
$$E_1[w_{i1}] = \alpha_{L1} + \beta_{L1}[a_i + e_{i1} - s], \text{ and}$$

(62)
$$\text{var}(w_{i1}) = \beta_{L1}^2 \text{ var}(x_{i1} - s) = \beta_{L1}^2 \text{ var}(x_{i1}) = \beta_{L1}^2(\sigma_z^2 + \sigma_u^2).$$

Let W_R^L denote the two-period total welfare under the previous-period RPC, where the superscript *L* stands for last- or previous-period and the subscript *R* stands for relative-performance contract, and W_{L1} denote the first-period welfare. The processor chooses the first-period optimal incentives by maximizing the total two-period welfare. Specifically,

$$(63)\quad W_R^L = \max_{\alpha_{L1},\beta_{L1}} \{E_a[\sum_{i=1}^n (a_i + e_{i1} - \frac{1}{2} r\beta_{L1}^2(\sigma_z^2 + \sigma_u^2) - \frac{1}{2a_i} e_{i1}^2)] + \delta E_1(W_{L2} \mid x_{11},\ldots,x_{n1})\},$$

subject to

$$(64)\quad \begin{aligned} &E_a\{\alpha_{L1} + \beta_{L1}[a_i + e_{i1} - s] - \frac{1}{2} r\beta_{L1}^2(\sigma_z^2 + \sigma_u^2) - \frac{1}{2a_i} e_{i1}^2 + \delta E_1[\alpha_{L2} + \beta_{L2}(a_i + e_{i2} \\ &+ \frac{\phi(\tau-1)}{\tau(\tau+n-2)-(n-1)} \sum_{j=1}^n (z_1 + u_{j1}) - \frac{1}{n}\sum_{j=1}^n x_{j1}) \\ &- \frac{1}{2} r\beta_{L2}^2 \sigma_z^2 (\tau - \frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)}) - \frac{1}{2a_i} e_{i2}^2]\} \geq 0 \end{aligned} \text{, and}$$

$$(65)\quad \begin{aligned} &e_{i1} \in \arg\max\{\alpha_{L1} + \beta_{L1}[a_i + e_{i1} - s] - \frac{1}{2} r\beta_{L1}^2(\sigma_z^2 + \sigma_u^2) - \frac{1}{2a_i} e_{i1}^2 + \delta E_1[\alpha_{L2} + \beta_{L2}(a_i + e_{i2} \\ &+ \frac{\phi(\tau-1)}{\tau(\tau+n-2)-(n-1)} \sum_{j=1}^n (z_1 + u_{j1}) - \frac{1}{n}\sum_{j=1}^n x_{j1}) - \frac{1}{2} r\beta_{L2}^2 \sigma_z^2 (\tau - \frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)}) - \frac{1}{2a_i} e_{i2}^2]\}, \forall i. \end{aligned}$$

Note that in the above expression, $x_{j1} = a_j + e_{j1} + z_1 + u_{j1}$, $\forall j \in [1,n]$. Thus, (65) requires that the first-period optimal effort satisfy $e_{i1} = a_i(\beta_{L1} - \frac{1}{n}\delta\beta_{L2})$, and leads to the following results:

$$(66)\quad \beta_{L1} = \frac{a_m + a_m \delta\beta_{L2}/n}{a_m + r(\sigma_z^2 + \sigma_u^2)},$$

$$(67)\quad \alpha_{L1} = -\beta_{L1}[a_m + a_m(\beta_{L1} - \frac{1}{n}\delta\beta_{L2}) - s] + \frac{1}{2} r\beta_{L1}^2(\sigma_z^2 + \sigma_u^2) + \frac{1}{2} a_m(\beta_{L1} - \frac{1}{n}\delta\beta_{L2})^2 \text{, and}$$

$$(68)\quad \begin{aligned} W_R^L = &\, na_m[1 + \frac{a_m}{2[a_m + r(\sigma_z^2 + \sigma_u^2)]} + \delta(1 + \frac{a_m}{2[a_m + r\sigma_z^2(\tau - \frac{n\phi^2(\tau-1)}{\tau(\tau+n-2)-(n-1)})]})] \\ &- na_m \frac{r(\sigma_z^2 + \sigma_u^2)}{2[a_m + r(\sigma_z^2 + \sigma_u^2)]}[(\frac{1}{n}\delta\beta_{L2} + 1)^2 - 1]. \end{aligned}$$

The following proposition compares the total welfare under the dynamic previous-period RPC with that under the dynamic FPC.

Proposition 4: The total welfare under the dynamic FPC exceeds that under the dynamic previous-period RPC. Precisely, $W_F^D > W_R^L$.

Proof: The proof is straightforward. The last term in (68), $na_m \frac{r(\sigma_z^2+\sigma_u^2)}{2[a_m+r(\sigma_z^2+\sigma_u^2)]}[(\frac{1}{n}\delta\beta_{L2}+1)^2-1]$, is always positive. Therefore, comparing (68) with (36) concludes the proposition.

This proposition and the results on which it is based lead to two general comments about the dynamic previous-period contract: First, under the previous-period dynamic RPC, growers exert less effort, optimally, in the first period when offered the same bonus as in a static RPC. In turn, from (66), the processor has to offer a greater bonus in the first period to induce more effort from growers. This result is the manifestation of the ratchet effect that discourages growers to provide efforts in the first period because they know the processor will use their first-period performance as a standard for their second-period performance. Second, it is assumed that the processor adopts a FPC in the first period because no information is available about the growers' performance before the first period. This assumption contributes to Proposition 4. However, if instead a current-period RPC is used in the first period under this contract, the relative superiority of the dynamic FPC and the dynamic previous-period RPC will depend on the relative magnitude of σ_z^2, σ_u^2, and possibly other parameters.

Conclusions and Discussion

Comparisons between various scenarios of RPC and FPC are summarized in Table 1. Major findings include the following five general results:

First, under the static RPC and FPC, the efficiency results depend on the relative magnitude of the common shocks and idiosyncratic shocks. Specifically, the static RPC performs better if the common shock is sufficiently large, while the static FPC is better if the idiosyncratic shock dominates.[8] Similarly, since the full-commitment contracts are exactly a sequence of static

[8] This result is consistent with most of the previous studies except Roe and Wu (2003), who find that banning RPC in a static model can never increase total surplus. Their results are different because of their model specifications:

contracts, the full-commitment RPC and the full-commitment FPC have the same properties as the static contracts.

Second, the dynamic FPC performs better than the full-commitment FPC because under the dynamic FPC, the processor improves the second-period contract by taking advantage of the new information acquired at the end of the first period. By providing a greater bonus in the second period under the dynamic FPC, the processor induces more efforts from the growers, and hence, increases total welfare.

Third, regardless of the autocorrelation of common shocks in the two periods, the dynamic current-period RPC eliminates the contemporary common shocks. Thus, the dynamic RPC is exactly a repetition of the static RPC. Comparing the dynamic current-period RPC with the dynamic FPC indicates that the dynamic current-period RPC performs better than the dynamic FPC only if the common shock is sufficiently large, and vice versa. However, Proposition 3 demonstrates that the FPC becomes more beneficial in the sense that the dynamic FPC is favored against relative-performance contracts under more circumstances relative to the static FPC. In other words, in a dynamic setting, a FPC becomes more effective at gathering information and improving the efficiency of the incentives relative to the static case.

Fourth, the dynamic FPC performs better than the dynamic previous-period RPC under any conditions. In addition, under this contract, significant ratchet effects are present in the sense that growers exert less effort in the first period in anticipation of a higher standard in the second period based on their first-period performance. In turn, at the equilibrium, the processor must offer a greater bonus in the first period to induce more effort. However, readers should note that the assumption of the first-period FPC under the dynamic previous-period RPC is critical to lead

in particular, the formulation and interpretation of the payment schedules and the assumptions of the random variables in the output structure contribute to their results.

to the conclusion. If, instead, a static RPC is adopted in the first period under the dynamic previous-period RPC, the dynamic previous-period RPC would perform better than the dynamic FPC if the common shock is sufficiently large.

The results in this essay provide some important policy implications and practical guidelines. First, except for the dynamic previous-period RPC, comparisons between relative-performance contracts and fixed-performance contracts under each scenario justify the superiority of relative-performance contracts both in a static setting and in a dynamic setting when common shocks dominate idiosyncratic shocks. Roe and Wu (2003) corroborate this result. As for the dynamic previous-period RPC, it could still perform better than the dynamic FPC if the first-period contract is specified with a current-period RPC. However, unlike Roe and Wu (2003), this essay does not account for the possibility of changing bargaining powers of growers in future periods as their abilities are revealed in previous periods. Therefore, in the principal-agent framework, the results from this essay cannot demonstrate the favorability of one contract against the other from growers' point of view because growers always receive their expected reservation utility under each type of contract. In the real world, however, growers possibly have bargaining power due to competition among processors. We have shown that relative-performance contracts improve total welfare when the common shock dominates and, thus, growers could capture a share of the surplus and still favor relative-performance contracts against fixed-performance contracts.

Table 1 Comparisons of fixed-performance contracts and relative-performance contracts

		Static FPC			Static RPC			Full Commitment FPC			Full Commitment RPC		
		α_F	β_F	W_F	α_R	β_R	W_R	α_F	β_F	W_F^F	α_R	β_R	W_R^F
Static FPC	α_F				n/a			=			n/a		
	β_F					$<^*$			=			$<^*$	
	W_F						$<^*$						$<^*$
Static RPC	α_R							n/a			=		
	β_R								$^*>$			=	
	W_R												
Full Commitment FPC	α_F										n/a		
	β_F											$<^*$	
	W_F^F												$<^*$
Full Commitment RPC	α_R												
	β_R												
	W_R^F												
Dynamic FPC	α_{F1}												
	β_{F1}												
	α_{F2}												
	β_{F2}												
	W_F^D												
Dynamic current-period RPC	α_{R1}												
	β_{R1}												
	α_{R2}												
	β_{R2}												
	W_R^S												

Table 1 (Cont.)

		Dynamic FPC					Dynamic current-period RPC					Dynamic previous-period RPC				
		α_{F1}	β_{F1}	α_{F2}	β_{F2}	W_F^D	α_{R1}	β_{R1}	α_{R2}	β_{R2}	W_R^S	α_{L1}	β_{L1}	α_{L2}	β_{L2}	W_R^L
Static FPC	α_F	=		>			n/a		n/a			n/a		n/a		
	β_F		=		<			$<^*$		$<^*$			<		<	
	W_F															
Static RPC	α_R						=		=							
	β_R							=		=						
	W_R															
Full Commitment FPC	α_F	=		>												
	β_F		=		<											
	W_F^F					<										
Full Commitment RPC	α_R						=		=							
	β_R							=		=						
	W_R^F										=					
Dynamic FPC	α_{F1}						n/a					n/a				
	β_{F1}							$<^{**}$					<			
	α_{F2}								n/a					n/a		
	β_{F2}									n/a					=	
	W_F^D										$<^{**}$					>
Dynamic current-period RPC	α_{R1}															
	β_{R1}															
	α_{R2}															
	β_{R2}															
	W_R^S															

Notes:

a) Each cell in the table compares the corresponding parameter in the second column and the corresponding parameter in the second row. For example, a " < " sign means that the corresponding parameter in the second column is less than that in the second row.

b) The cells with one asterisk (*) depend on the relative magnitude of the common shock and the idiosyncratic shock. The explicit conditions are derived in Proposition 1 and Corollary 1.1. The cells with (**) depend on the condition derived in Proposition 3.

c) The matrix in the table is symmetric except the last scenario, i.e., Dynamic previous-period RPC. Thus, only the upper triangle of the table is filled.

d) We use the symbol "n/a" to indicate that these cells are indeterminate and use empty cells to indicate that these are irrelevant or not the interest of this paper.

References

Che, Y.K. and Yoo, S. W. "Optimal incentives for teams." *American Economic Review* (June 2001):525-541.

ConAgra broiler contract. Retrieved on Dec, 2003 from http://www.state.ia.us/government/ag/ag_contracts/conagra_index.html

Freixas, X, R. Guesnerie, and J. Tirole. "Planning under incomplete information and the ratchet effects." *The Review of Economics Studies* 52(2)(1985):173-191.

Goodhue, R. E., G. C. Rausser, and L. K. Simon. "Understanding production contracts: Testing an agency theory model." Paper presented at AAEA annual meeting, August,1998.

Goodhue, R. E. "Broiler production contracts as a multi-agent problem: common risks, incentives, and heterogeneity." *American Journal of Agricultural Economics* 82 (2000):606-622.

Greene, W. H. 2000. *Econometric Analysis*. 4th Edition. Prentice-Hall, Inc.

Hayenga, M., T. Schroeder, J. Lawrence, D. Hayes, T. Vukina, C. Ward, and W. Purcell. "Meat packer vertical integration and contract linkages in the beef and pork industries: An economic perspective." Staff General Research Papers. Department of Economics. Iowa State University, 2000.

Hegde, S. A., and T. Vukina. "Risk sharing in broiler contracts: A welfare comparison of payment mechanisms." Washington DC: U.S. Department of Agriculture: GIPSA. 2002.

Knoeber, C. R. and W. N. Thurman. "Testing the theory of tournaments: An empirical analysis of broiler production." *J. of Labor Economics* 12(2)(1994):155-179.

Knoeber, C. R. and W. N. Thurman. "Do not count your chickens...: Risk and risk shifting in the broiler industry." *American Journal of Agricultural Economics* 77(1995):486-496.

Levy, A. and T. Vukina. "The league composition effect in tournaments with heterogeneous players: An empirical analysis of broiler contracts." Working Paper. Raleigh, NC: North Carolina State University. 2001. Retrieved on Dec, 2003 from http://www.ag-econ.ncsu.edu/faculty/vukina/leagues_SSRN.pdf

Levy, A. and T. Vukina. "Optimal linear contracts with heterogeneous agents." *European Review of Agricultural Economics*. Vol. 29(2)(2002):205-217.

Martinez, S. W. *Vertical coordination in the pork and broiler industries: Implications for pork and chicken products*. Washington DC: U.S. Department of Agriculture, ERS. Report No. 777. 1999.

Mas-Collel, A., M. D. Whinston, and J. R. Green. *Microeconomic theory*. New York: Oxford University Press. Inc. 1995.

MBA Broiler contract. Retrieved on Dec, 2003 from http://www.state.ia.us/government/ag/ag_contracts/MBA/mba_index.html

Meyers, M. A. and J. Vickers. "Performance comparison and dynamic incentives." *Journal of Political Economy*. 105(1997):347-351.

Perry, J., D. Banker, and R. Green. Broiler farms' organization, management, and performance. Washington DC: U.S. Department of Agriculture ERS, Information Bulletin No. 748. March 1999.

Pilgrim Pride Contract. Retrieved on Dec, 2003 from http://www.web-span.com/~pga/contracts/PPcontract.html

Roe, B. and S. Wu. "The welfare effect of banning tournaments with commitment if impossible: Some results from the broiler sector." Paper presented at AAEA annual meeting, Montreal, Quebec. 2003.

Salanié, Bernard. *The Economics of Contracts: A Primer*. Cambridge: The MIT press. 1997.

Tsoulouhas, Theofanis and T. Vukina. "Regulating broiler contracts: tournaments versus fixed performance standards." American Journal of Agricultural Economics 83 (November 2001): 1062-73.

Tyson Richmond broiler contract. Retrieved on Dec, 2003 from http://www.web-span.com/~pga/contracts/tysn1.html

U.S. Department of Agriculture/Economic Research Service (USDA/ERS). "Contracting Changes How Farms Do Business." *Rural Conditions and Trends* 10 (June 2000): 50-56.