DYNAMIC INCENTIVES AND AGENT DISCRIMINATION IN BROILER PRODUCTION TOURNAMENTS

PORAMETR LEEGOMONCHAI
Chaikomol Business Co., Ltd.
Pomprab, Bangkok 10100
Thailand
pleegomonchai@yahoo.com

TOMISLAV VUKINA
Department of Agricultural & Resource Economics
North Carolina State University
Raleigh, NC 27695-8109
tom_vukina@ncsu.edu

The objective of this paper is to test whether broiler processors, after observing their contract growers' abilities in the sequences of repeated short-term contracts, strategically allocate production inputs of varying quality. The strategy can either consist of providing high-ability agents with high-quality inputs or providing low-ability agents with high-quality inputs. The first strategy would stimulate the career concerns type of response on the part of the growers, whereas the second strategy would generate a ratchet effect. We test these hypotheses by using the broiler contract production data. The results show no significant input discrimination based on grower abilities that would lead to either career concerns or ratchet effect type of dynamic incentives.

This material was prepared under a cooperative agreement with the Grain Inspection, Packers and Stockyards Administration (GIPSA)–USDA. Any opinions, findings, and conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of GIPSA or the US Department of Agriculture. We wish to thank Federico Ciliberto, Jacques Crémer, Pierre Dubois, Atsushi Inoue, Pascal Lavergne, Armando Levy, Walter Thurman, the participants of the 5th Conference INRA-IDEI "Industrial Organization and the Food Processing Industry," Toulouse, June 14–15, 2002, and the Second Annual Workshop "Economics of Contracts in Agriculture," July 21–23, 2002, Annapolis, Maryland, as well as an anonymous coeditor and two referees for their useful comments and suggestions. We are also greatly indebted to Jan Chvosta for volunteering his SAS programming expertise to this project.

Journal of Economics & Management Strategy, Volume 14, Number 4, Winter 2005, 849–877

1. INTRODUCTION

In many business environments, including agriculture, economic agents often interact with each other repeatedly and business is conducted using a series of short-term contracts. An interesting characteristic of many livestock production contracts is that all agents contracting with the same principal operate under formally identical contract provisions, and contracts cover only one flock or one batch of animals at a time (Levy and Vukina, 2002). Explicitly uniform contracts do not necessarily guarantee that all agents are treated equally. When the principal and agents contract repeatedly, an explicitly uniform but incomplete contract leaves a possibility for the principal to treat agents differently after learning about their abilities (types) over time. For example, the principal may assign more difficult tasks to higher-ability agents or may strategically distribute variable quality inputs such that they end up in the hands of agents who can make the best use of them.

The main motivation for this research came from the documented evidence regarding broiler contract growers complaining about the unfair distribution of variable quality inputs (feed and chicks) they receive from their principals (Ilvento and Watson, 1998; FLAG, 2001). Broiler production in the United States is organized almost entirely via contracts between processing companies (principals) and independent growers (agents). Contracts require growers to construct chicken houses and supply labor and integrators to supply other essential inputs. Growers are compensated by using relative performance schemes (tournaments). A preliminary inspection of the contract settlement data revealed an interesting fact that the substantial number of tournaments is systematically won by the same growers. Given the fact that the bonus payment in broiler tournaments is a zero-sum game, this also meant that some other growers found themselves on the loosing side more frequently than others. A natural question to ask became whether a disproportionate number of tournaments were won by the same growers because those growers were truly better than others, or because they were (for whatever reason) given superior quality inputs.

The reason for the prevalence of short-term contracts in repeated business transactions is the unwillingness or the inability of parties to commit to long-term relationships. Commitment refers to the ability of economic agents to restrict their future actions in advance by pledging to stick to the contract until some predetermined date (Salanie, 1997). In dynamic contracts, the lack of commitment is the source of implicit incentives, which can be positive or negative. In general, implicit incentives arise when a principal has some *ex post* capacity to respond to an agent's performance and when the agent's current performance is informative about his future performance (Meyer, 1995).

Positive implicit incentives are known in the literature as *career concerns* (see e.g., Fama, 1980; Holmstrom, 1999). They occur whenever the principal (or the labor market) uses an agent's current output to update his belief about the agents' ability and then adjusts future compensation in the direction of these updated beliefs. Managers in firms, for example, may be motivated not only by the explicit contractual links between pay and performance but also because good performance today will enhance the labor market's perception of one's ability and henceforth improve future earnings.

Another type of dynamic incentives are perverse implicit incentives known as the *ratchet effect*. Ratchet effect arises in the dynamic models of regulated firms such as Freixas et al. (1985), Baron and Besanko (1987), and Laffont and Tirole (1988). Here, the incentive problem is manifested in a regulated firm not willing to produce efficiently today fearing the regulator might infer that low-cost production is easy to achieve and impose even tighter constraints in the future. The same problem is also present in the design of optimal dynamic schemes for motivating workers where the employer cannot commit not to revise an employee's compensation, holding him to a higher standard tomorrow as a result of his good performance today (e.g., Lazear, 1986; Aron, 1987; Gibbons, 1987; Kanemoto and MacLeod, 1992).

The behavior of an agent under career concerns and ratchet effect type of incentives is quite different. Under career concerns, the agent will try to prove he is efficient, whereas under the ratchet effect, he may try to prove he is inefficient (Laffont and Tirole, 1988).

Despite the substantial theoretical attention that has been given to dynamic contracts with either career concerns or ratchet effect type of implicit incentives, these models have been rarely empirically tested against the contract data. A notable exception is Gibbons and Murphy (1992) who show that the optimal compensation contract optimizes the combination of implicit incentives from career concerns and the explicit incentives from the compensation contract. They predicted that explicit incentives should be the strongest for workers close to retirement (whose career concerns should be the weakest) and found empirical support for this prediction based on the relationship between chief executive compensation and stock market performance. Another example is found in Allen and Lueck (2002) who studied the crop share and cash-rent land contracts and found no evidence of the ratchet effect.

The objective of this paper is to test whether broiler companies, after observing their contract growers' abilities in the sequences of repeated short-term contracts, systematically discriminate among growers by strategically distributing production inputs of varying quality. The discrimination may take one of two forms: (1) a strategy that provides high-ability agents with high-quality inputs and low-ability agents with low-quality inputs, or (2) a reciprocal strategy that provides low-ability agents with high-quality inputs and high-ability agents with low-quality inputs. The first principal's strategy would stimulate a career concerns type of response on the part of the growers, whereas the second strategy would generate a ratchet effect. Which strategy will the principal pursue entirely depends upon the characteristics of the production technology.

Unlike most of the literature on dynamic incentives that is chiefly concerned with the properties of optimal dynamic contracts, the theoretical model in this paper emphasizes the optimal response of an agent faced with a given (observed) short-term contract and future actions of a noncommittal principal. Our two-period model is based on the backward-looking (passive) target setting revision rule similar to Weitzman (1980). We showed that in a career concerns type of environment, the agents' optimal dynamic responses lead to a separating equilibrium where the correct ranking with respect to agent abilities is obtained, enabling the principal to engage in a strategic distribution of inputs. In a ratchet effect type of environment, higher values of the discount factor and the ratchet coefficient increase the likelihood of a pooling equilibrium where all agents exert zero effort in the first period. Separating equilibrium is possible for lower values of the said parameters, but the aggregate effort exerted by agents is smaller than in the full commitment case, so the discrimination of agents would not pay even if the principal could discern their types.

Empirical testing is carried out using the contract production data for broiler chickens. Our econometric model specifies the quality of production inputs received by a grower as a function of his abilities. We measure abilities as the growers' fixed effects in the production function or in the settlement cost panel data regression model. The quality of production inputs is approximated by the quality of chicks delivered to a farm. The results show that there is no significant input discrimination among growers based on their abilities that would lead to either career concerns or ratchet effect type of dynamic incentives.

2. CONTRACTS IN THE BROILER INDUSTRY

The broiler industry is often considered a role model for the industrialization of agriculture. The industry is entirely vertically integrated, from breeding flocks and hatcheries to feed mills, transportation divisions, and processing plants. A large proportion of the value-added created in the poultry industry comes from processing, which explains why processors, also called integrators, became the coordinators of the industry. The finishing stage of the production process is organized almost entirely through contracts between integrators and independent growers.[1] Large national companies, such as Tyson Foods, Gold Kist, and Perdue Farms dominate broiler contract production. These companies run their operations through smaller divisions spread throughout the country.

Modern broiler production contracts are agreements between an integrator and growers that bind growers to tend for the company-owned chickens until they reach market weight by strictly following specific production practices in exchange for monetary compensation. Contracts have two main components: (1) the division of responsibility for providing inputs, and (2) the use of tournaments to determine grower compensation.

Broiler production contracts require growers to construct and equip chicken houses and supply labor and management. They are also responsible for utilities, repair and maintenance, and waste disposal. The integrator's responsibility is to provide baby chicks, feed, medication, and the services of field personnel. The quality and distribution of the integrator-supplied inputs are not stipulated in the contract. Growers usually observe only the quantity of inputs they receive at the time of delivery, but not necessarily the quality of inputs. The quality will be fully revealed to them during the production phase and especially after the performance results are compared against historical averages of previous flocks.[2]

Most of the modern broiler contracts are settled using a two-part piece-rate tournament consisting of a base payment per pound of live meat produced and a bonus payment based on the grower's relative performance. The bonus payment is calculated as a percentage of the difference between group average settlement cost and grower's individual settlement cost. Settlement cost for each grower is the sum of the costs of integrator supplied inputs (chicks, feed, medication, etc.) divided by the total pounds of live broilers produced. The calculation of the group average settlement cost includes growers whose flocks were

---

[1] Finishing is the final stage of the production process where 1-day old chicks are brought to the farm and grown to market weight.

[2] Growers' complaints about an uneven (unfair) distribution of production inputs have been documented in poultry industry surveys. For example, Ilvento and Watson (1988) found that 53% of growers felt that their average chick quality was inadequate (poor or fair, as opposed to good or excellent), 91% of growers were uncertain or definitely did not believe that the quality of chicks was evenly distributed among growers, and over 43% of growers questioned the matching of the feed weight tickets and the actual feed deliveries to farms.

harvested within the same week. For the below-average settlement cost, the grower receives a bonus; for the above-average settlement cost, he receives a penalty. The number of growers in the settlement group ranges between 10 and 35 depending on the size of the integrator as well as other logistical and market conditions. Specifically, the payment to grower k for flock t is calculated as

$$R_{kt} = \left[I + \triangle_t + r \left(\frac{1}{n} \sum_j \frac{c_{jt}}{Y_{jt}} - \frac{c_{kt}}{Y_{kt}} \right) \right] Y_{kt} \tag{1}$$

where I is the base payment; $r \in [0, 1]$ is the slope of the payment scheme that determines the relative importance of the bonus payment in the total grower's compensation; Y_{kt} is the number of live pounds of broilers produced; $\frac{c_{kt}}{Y_{kt}}$ is the individual grower settlement cost; $\frac{1}{n} \sum_j \frac{c_{jt}}{Y_{jt}}$ is the flock average settlement cost; and $\triangle_t$ is the market price adjustment specified as the percentage difference between the market price for broilers and the integrator's average variable production costs.[3]

Another important feature of broiler contracts is that they are explicitly uniform, short-term (one flock at a time), and generally do not specify the number of flocks the grower will receive per year. By delaying or speeding up the delivery of new flocks to growers, the integrators can manipulate supply in response to market signals. In most instances, after one flock is harvested, the contract gets tacitly renewed, and within a couple of weeks the grower receives a new flock. The cases of unilateral contract terminations are quite rare and are typically caused by the grower's massive violation of contract stipulations (e.g., gross negligence or theft of feed or birds) or by the company's closing down a particular division, or bankruptcy. It is not unusual for the contract growers to spend their entire career growing chickens for the same company. Therefore, over time, the integrator can develop a fairly precise knowledge of growers' abilities, yet the explicit contract for all growers in the same division is always the same.

The growers' complaints about unfair distribution of essential inputs may be well founded. Information about growers' abilities may allow the integrator to reduce the production costs by strategically distributing uneven quality inputs among growers. The variation in the quality of inputs can be significant, especially when it comes to baby chicks and feed. The strategy of distributing inputs, assuming that one exists, will depend on the characteristics of the broiler production technology. For the purposes of this research, it is useful to think about

---

[3] The market price clause $\triangle_t$ is a relatively new modification to a standard broiler tournament contract and does not exist in all contracts.

two technological scenarios, which can be defined by the relationships among marginal products. Introducing y_i to symbolize the production of high-ability agent, y_j the production of low-ability agent, x_H the high-quality input, and x_L the low-quality input, *technology A* can be defined by $\frac{\partial y_i}{\partial x_H} \geq \frac{\partial y_j}{\partial x_H}$, $\frac{\partial y_i}{\partial x_L} = \frac{\partial y_j}{\partial x_L}$ and $\frac{\partial y_i}{\partial x_H} > \frac{\partial y_i}{\partial x_L}$, $\frac{\partial y_j}{\partial x_H} > \frac{\partial y_j}{\partial x_L}$; and *technology B* by $\frac{\partial y_i}{\partial x_H} = \frac{\partial y_j}{\partial x_H}$, $\frac{\partial y_i}{\partial x_L} \geq \frac{\partial y_j}{\partial x_L}$ and $\frac{\partial y_i}{\partial x_H} > \frac{\partial y_i}{\partial x_L}$, $\frac{\partial y_j}{\partial x_H} > \frac{\partial y_j}{\partial x_L}$. The first two conditions for technology A indicate that the marginal product of high-quality input when used by a high-ability grower is larger (or equal) than when used by the low-ability grower, whereas the marginal product of the low-quality input is the same for both types. The interpretation of the first two conditions for technology B is exactly the opposite. The last two conditions are the same for both technologies and indicate that both high- and low-ability growers will do better with high-quality input than with low-quality input.

Assuming integrator's profit-maximizing/cost-minimizing behavior and a given distribution of input quality, technology A would imply an obvious strategy of giving high-quality inputs to high-ability growers and low-quality inputs to low-ability growers (strategy A). In contrast, if technology B were the correct representation of the production process, an efficient strategy would require giving high-quality inputs to low-ability growers and low-quality inputs to high-ability growers (strategy B). The integrators will implement strategy A if they know that the high-ability growers can utilize high-quality chicks or feed more effectively than the low-ability growers, whereas their performances are indistinguishable when both use the low-quality chicks and feed. The integrators will implement strategy B if they know that high-ability growers may somehow salvage low-quality chicks from performing very poorly, whereas the high-quality chicks will perform well no matter who tends them. The detailed technological characteristics of the broiler production process are not observable by outsiders, hence we as researchers are unsure which technology more closely describes the broiler production and consequently which strategy is more likely to be pursued by integrators.

In summary, the integrators who are tournament organizers would update their beliefs about grower's abilities based on settlement costs in repeated tournaments, and absent significant transaction costs may have correct incentives to strategically distribute inputs to growers according to their types. If the production of broilers is characterized by technology A, the resulting integrator's strategic allocation of varying quality inputs should create a career concerns type of dynamic incentive for the growers because doing well in the current tournament has double benefits. When a grower manages to produce broilers at below average settlement cost, he will not only earn the current period bonus but will also improve his chances of receiving high-quality inputs in the next period tournament. Contrary to this, the integrator's strategic distribution of inputs aligned with technology B should generate a ratchet effect type of dynamic incentive. This is because the benefits of doing well in the current tournament (thereby signaling one's high ability) are, to a certain degree, offset by an increasing chance of being stuck with low-quality input in the next period tournament.

3. MODEL

The production of broiler chickens is assumed to be a function of the fixed quantity of inputs $X = x_H + x_L$ provided by the integrator to each grower and the grower's effort $e \in [0, \infty]$. For simplicity, we also assume that in each period, the integrator owns $2X$ units of input, half of which is high quality, and half is low quality. The previously discussed technology A is represented by the following production function:

$$y_{kt} = \theta_k e_{kt} x_H + \frac{1}{m} x_L + u_t + \zeta_{kt} \tag{2}$$

and technology B by

$$y_{kt} = \theta_k e_{kt} x_L + \frac{1}{n} x_H + u_t + \zeta_{kt}, \tag{3}$$

where $\theta_i > 1$ and $\theta_j = 1$ is the ability of grower k defined such that grower i has higher ability than grower j, and the difference in abilities between the two growers is reasonably small. The marginal products of "effortless" inputs (x_L in technology A and x_H in technology B), $\frac{1}{m}$ and $\frac{1}{n}$, respectively, are such that $m > n > 0$. The common production shocks u_t and grower idiosyncratic shocks ζ_{kt} are both *i.i.d.* with mean zero and finite variance.

The a priori technology restrictions discussed earlier can be summarized as follows. In the case of technology A, $\frac{\partial y_i}{\partial x_H} \geq \frac{\partial y_j}{\partial x_H}$ will be satisfied if $e_{it} \geq e_{jt}$. Meanwhile, $\frac{\partial y_i}{\partial x_L} = \frac{\partial y_j}{\partial x_L} = \frac{1}{m}$ is automatically satisfied, and $\frac{\partial y_k}{\partial x_H} > \frac{\partial y_k}{\partial x_L}$ requires $\theta_k e_{kt} > \frac{1}{m}$. Similarly, in case of technology B, in order for $\frac{\partial y_i}{\partial x_L} \geq \frac{\partial y_j}{\partial x_L}$ to hold, we need $e_{it} \geq e_{jt}$. Also, $\frac{\partial y_i}{\partial x_H} = \frac{\partial y_j}{\partial x_H} = \frac{1}{n}$ is automatically satisfied, and $\frac{\partial y_k}{\partial x_H} > \frac{\partial y_k}{\partial x_L}$ requires $\frac{1}{n} > \theta_k e_{kt}$.

The production of broilers is organized via short-term (one flock at a time) contracts, and payment is based on a piece-rate (cardinal) tournament. Prior to the beginning of production, the integrator offers an identical contract to all growers.[4] For simplicity, we assume that in each tournament the competition takes place only between two growers, $k = i, j$. We also assume that the contract will be automatically renewed for one more flock, such that the total number of time periods (flocks) is two, $t = 1, 2$. The payments that growers receive are determined by

$$R_{kt} = I + r(y_{kt} - y_{-kt}), \tag{4}$$

where R_{kt} is the payment to grower k in period t, I is the base payment, r is the slope of the bonus payment, y_{kt} is the output level of one grower, and y_{-kt} is the output level of the other grower. The bonus payment is determined as a percentage of the difference between the two growers' output levels.[5] It is obvious that the aggregate bonus payment is a wash, that is, the winner's bonus will exactly cancel the loser's penalty and the total integrator's compensation expenditure in a given tournament is only $2 \times I$.

Growers are assumed to be risk neutral with identical utility functions $U(R_{kt} - C(e_{kt}))$, where $C(e_{kt}) = X(\frac{e_{kt}^2}{2})$ represents the total cost (disutility) of effort. The exertion of effort is essential for the cost to exist, $C(e_{kt} = 0) = 0$, cost is increasing in effort, $\frac{\partial C}{\partial e_{kt}} > 0$, and convex, $\frac{\partial^2 C}{\partial e_{kt}^2} > 0$.

3.1 FULL COMMITMENT

The explicit (written) contracts observed in the broiler industry do not specify any particular scheme of input distribution among growers. For simplicity, let us assume that the integrator can credibly commit to an even distribution of inputs. In the framework of this model, this amounts to supplying each grower with half of high-quality input and half of low-quality input in both time periods; that is, $x_H = x_L = \frac{X}{2}$. This scheme serves the purpose of extracting information about grower abilities because it does not bias the outcome of the tournament in favor of either contestant. This scheme is also attractive because it sounds inherently fair.

---

[4] Because we do not address the problem of optimal contract design, the formal treatment of the integrator's optimization problem is conveniently ignored. It will suffice to say that the integrator is interested in maximizing two-period profits by deciding how to allocate the varying quality inputs among growers of different abilities.

[5] Notice that the payment mechanism (4) is a somewhat simplified version of the actual scheme in (1). The main difference comes from our assumption that the total quantity of inputs delivered is fixed, and the competition among growers is about producing more output (heavier birds). The implicit assumption in this approach is that feed utilization is constant across all growers. Other studies dealing with broiler tournaments (e.g., Knoeber and Thurman, 1994; Tsoulouhas and Vukina, 1999, 2001; Levy and Vukina, 2004) have assumed that the output is fixed and that the growers compete for better feed efficiency. This approach implicitly assumes constant percentage mortality across all growers.

Each grower maximizes his utility by solving the following two-period problem,

$$\max_{e_{k1},e_{k2}}([I + r(y_{k1} - y_{-k1}) - C(e_{k1})] \\ + \delta[I + r(y_{k2} - y_{-k2}) - C(e_{k2})]); \quad k = i, j, \tag{5}$$

where $\delta \in [0, 1]$ is a discount factor. Given full commitment on the part of the integrator about not altering the distribution of inputs in the second time period, and given the assumptions about *i.i.d.* shocks, the two-period problem becomes essentially static. This means that the maximization problem that each grower is facing in period $t = 1$ is independent from the problem in $t = 2$. For both technologies specified by the production functions (2) and (3) and grower cost of effort function, the first-order conditions,

$$\frac{r\theta_k}{2} - e_{k1} = 0; \quad k = i, j, \tag{6}$$

$$\frac{r\theta_k}{2} - e_{k2} = 0; \quad k = i, j, \tag{7}$$

are also sufficient and the closed-form solutions for optimal effort levels regardless of technology are $e^*_{k1} = e^*_{k2} = \frac{r\theta_k}{2}; k = i, j$. Because the marginal reward for winning the tournament is the same for both growers regardless of their type and unchanged in both periods, the decision to exert effort depends solely on ability. Because $\theta_j = 1$ and $\theta_i > 1$, it follows that $e^*_{it} > e^*_{jt}$ for all t and the optimal effort level e^*_{kt} increases with grower's ability but is constant across time periods.

It is easy to see that in the full commitment case there are no implicit dynamic incentives of any kind. When exerting effort in the first period, growers are only concerned with winning the tournament in period $t = 1$, ignoring possible implications that this outcome may have for the allocation of inputs in future tournaments. This is because they trust the integrator's commitment not to alter the allocation of inputs based on the information about growers' abilities that may have acquired in the first period.

3.2 CAREER CONCERNS

In this section we assume that the technology of broiler production is adequately represented by production function (2). As mentioned earlier, technology A would create incentives for the integrator to engage in the strategic distribution of inputs such that the high-ability agent ends up with high-quality input and low-ability agent with low-quality input. In particular, we assume that the integrator cannot commit to the even distribution of varying quality input, but instead, operates under a passive target setting rule similar to that of Weitzman (1980). Therefore, the allocation of inputs in the second time period will be determined based on the output levels achieved in the first time period such that

$$x_{H,2} = \frac{X}{2} + \beta(y_{k1} - y_{-k1}), \tag{8}$$

$$x_{L,2} = \frac{X}{2} - \beta(y_{k1} - y_{-k1}). \tag{9}$$

The adjustment coefficient $\beta > 0$ is treated as a behavioral parameter of the integrator that converts the difference in the volume of output between two growers that resulted from the fair distribution of inputs ($\frac{X}{2}$) in the first period into a deviation from the fair distribution in the second period. The magnitude of β measures the strength of the positive implicit incentive effect (i.e., career concerns). The growers do not know the rule exactly. They only know that winning the tournament in the first period means that their share of high-quality input in the second period will improve from $\frac{1}{2}$.

In this environment, each risk-neutral grower solves the problem identical to that in (5). Let $E_k(\beta) = \tilde{\beta}_k$ denote an individual grower's expectation about the distribution rule. In equilibrium, the expectations about β are aligned, such that $\tilde{\beta}_i = \tilde{\beta}_j = \beta$, and expected differences in the two-period outcomes can be calculated as

$$E_k(y_{k1} - y_{-k1}) = \frac{X}{2}(\theta_k e_{k1} - \theta_{-k} e_{-k1}); \quad k = i, j \tag{10}$$

and

$$\begin{aligned} E_k(y_{k2} - y_{-k2}) = {} & \frac{X}{2}(\theta_k e_{k2} - \theta_{-k} e_{-k2}) \\ & + \frac{\beta X}{2}(\theta_k e_{k1} - \theta_{-k} e_{-k1})(\theta_k e_{k2} + \theta_{-k} e_{-k2}) \\ & - \frac{\beta X}{m}(\theta_k e_{k1} - \theta_{-k} e_{-k1}); \quad k = i, j. \end{aligned} \tag{11}$$

Using (10) and (11), the first-order conditions for the growers' maximization problems under career concerns dynamic incentives are

$$\frac{r\theta_k}{2}\left[1 + \delta\beta\left(\theta_k e_{k2} + \theta_{-k} e_{-k2} - \frac{2}{m}\right)\right] - e_{k1} = 0; \quad k = i, j, \tag{12}$$

$$\frac{r\theta_k}{2}[1 + \beta(\theta_k e_{k1} - \theta_{-k} e_{-k1})] - e_{k2} = 0; \quad k = i, j. \tag{13}$$

The comparison of the first-order conditions in the full commitment case (6) and (7) with (12) and (13) reveals the magnitude of the implicit dynamic incentive effect of the career concerns type via the expressions in the square brackets. The effect is caused by the effort exerted in $t = 1$ now affecting the allocation of inputs in $t = 2$. We solve for the equilibrium in the Cournot–Nash sense where each grower takes the other grower's effort as given. Then, each grower's own effort is the best response to the effort he expects his opponent would exert. The closed-form solutions for the optimal effort levels are

$$e_{i1}^{**} = -\frac{r\theta_i\left[2(m-2\beta\delta) + mr\beta\delta\left(\theta_i^2+\theta_j^2\right)\right]}{m\left[-4+r^2\beta^2\delta\left(\theta_i^2-\theta_j^2\right)^2\right]}, \tag{14}$$

$$e_{i2}^{**} = \frac{r\theta_i\left[-2m - r\beta\left(\theta_i^2-\theta_j^2\right)\left(m-2\beta\delta+mr\beta\delta\theta_j^2\right)\right]}{m\left[-4+r^2\beta^2\delta\left(\theta_i^2-\theta_j^2\right)^2\right]}, \tag{15}$$

$$e_{j1}^{**} = -\frac{r\theta_j\left[2(m-2\beta\delta) + mr\beta\delta\left(\theta_i^2+\theta_j^2\right)\right]}{m\left[-4+r^2\beta^2\delta\left(\theta_i^2-\theta_j^2\right)^2\right]}, \tag{16}$$

$$e_{j2}^{**} = \frac{r\theta_j\left[-2m + r\beta\left(\theta_i^2-\theta_j^2\right)\left(m-2\beta\delta+mr\beta\delta\theta_i^2\right)\right]}{m\left[-4+r^2\beta^2\delta\left(\theta_i^2-\theta_j^2\right)^2\right]}, \tag{17}$$

where e^{**} denotes the optimal effort in the noncommitment case. Because technology A is characterized by $\frac{\partial y_k}{\partial x_H} > \frac{\partial y_k}{\partial x_L}$, which requires $\theta_k e_{kt} > \frac{1}{m}$, it immediately follows that $e_{kt}^{**} > 0$, for $k = i, j$ and $t = 1, 2$. In order for all equilibrium efforts to be positive, the integrator has to choose the adjustment coefficient such that it lies in the range $\beta \in (0, \bar{\beta}]$.[6] Based on (14)–(17), we can derive the first proposition.

Proposition 1: *Under a career concerns type of dynamic incentives ($\beta > 0$), the equilibrium effort levels are such that (i) in both periods, the high-ability agent exerts higher effort than the low-ability agent; (ii) in the first period, both agents exert higher effort than in the full commitment case, and in the second period, the high-ability agent exerts higher effort but the low-ability agent exerts lower effort than in the full commitment case; (iii) aggregate two-period output in the noncommitment case is larger than in the full commitment case.*

---

[6] Because e_{j2}^{**} is decreasing, the marginal condition $\theta_j e_{j2}^{**} > \frac{1}{m}$ might be violated. The upper bound on β is obtained by solving (17).

Proof. See Appendix A.

Proposition 1 indicates that even when the agents anticipate the distortion of input allocation in the future, they still exert effort such that the correct ordering of abilities is preserved. By observing the outcome of the tournament in the first period the integrator can decipher growers' types and distribute inputs according to her preferred strategy. Given the fact that the high-ability agent exerts higher effort than the low-ability agent, it follows that the high-ability agent wins the tournament, thereby revealing his type as high-ability type.[7] The integrator will use this information to change the allocation of inputs from $\frac{1}{2} : \frac{1}{2}$ in favor of giving the high-ability type more of the high-quality input in the second period at the expense of giving the low-ability type more of the low-quality input. This strategy turns out to be profitable and therefore the integrator has the correct incentives to discriminate among heterogeneous ability growers.[8]

3.3 RATCHET EFFECT

In this section we assume that the technology of broiler production is adequately represented by production function (3). Technology B may create incentives for the integrator to engage in the strategic distribution of inputs such that high-ability agent ends up with low-quality input and low-ability agent with high-quality input. Similar to the career concerns type of environment, here we assume that the integrator cannot commit to the even distribution of varying quality input but instead operates under the target setting rule similar to (8) and (9),

$$x_{H,2} = \frac{X}{2} - \gamma(y_{k1} - y_{-k1}), \tag{18}$$

$$x_{L,2} = \frac{X}{2} + \gamma(y_{k1} - y_{-k1}). \tag{19}$$

In this case, $\gamma > 0$ measures the strength of the negative implicit incentive effect (i.e., the ratchet effect).

---

[7] In the two-period model such as ours, this statement is not exactly true. Due to the presence of idiosyncratic shocks, it is possible that the high-ability agent even by exerting higher effort than low-ability agent may still lose because of bad luck. This could send a wrong signal to the integrator and his input allocation strategy will end up being erroneous. As the number of tournaments played increases, the idiosyncratic shock will eventually fade, as its mean equals zero, and the ordering of outputs in the tournament would accurately reflect the ordering of abilities.

[8] Notice that within the structure of this model, comparing profits of the integrator between the two scenarios is the same as comparing outputs (efforts) because the total inputs utilized are fixed ($2X$) and so are the total payments to the growers ($2I$).

The first-order conditions for the grower maximization problem are

$$\frac{r\theta_k}{2}\left[1+\delta\gamma\left(\theta_k e_{k2}+\theta_{-k}e_{-k2}-\frac{2}{n}\right)\right]-e_{k1}=0;\quad k=i,\,j, \tag{20}$$

$$\frac{r\theta_k}{2}[1+\gamma(\theta_k e_{k1}-\theta_{-k}e_{-k1})]-e_{k2}=0;\quad k=i,\,j. \tag{21}$$

The closed-form solutions for optimal effort levels are the same as in (14)–(17). Because of the technological requirement that $\frac{1}{n}>\theta_k e_{kt}$, it is actually possible for the equilibrium efforts to be zero. As can be verified from (20), the type of equilibrium that will emerge is determined by

$$\frac{1}{\delta\gamma}<\left(\frac{2}{n}-\theta_i e_{i2}^{**}-\theta_j e_{j2}^{**}\right). \tag{22}$$

Condition (22) can be used to formulate the next two propositions.

Proposition 2a (Pooling Equilibrium): *If condition (22) holds, ratchet effect type of dynamic incentives ($\gamma>0$) generate equilibrium effort levels such that in the first period, both efforts are zero, and in the second period, efforts are at the full commitment levels.*

Proof. If (22) holds, then, $e_{i1}^{**}=e_{j1}^{**}=0$, $e_{i2}^{**}=\frac{r\theta_i}{2}$, and $e_{j2}^{**}=\frac{r\theta_j}{2}$. □

Proposition 2b (Separating Equilibrium): *If condition (22) is violated (i) in both time periods, the high-ability agent exerts higher effort than the low-ability agent; (ii) in the first period, both agents exert lower effort than in the full commitment case, and in the second period, the high-ability agent exerts higher effort and the low-ability agent exerts lower effort than in the full commitment case; (iii) aggregate two-period output with ratchet effect is smaller than in the full commitment case.*

Proof. See Appendix B.

It is easy to see that the likelihood of a pooling equilibrium at zero effort depends on the magnitude of the discount factor δ and the ratchet effect coefficient γ. The values of δ closer to unity mean that future events are less discounted, hence the punishment associated with revealing one's high type and receiving the low-quality input in the second period is more important. Similarly, higher values of γ generate dynamic incentives that make a pooling equilibrium more likely as well.[9] This is because larger γ means stronger departure from the equitable distribution of inputs in the second period based on the tournament outcome in the first period. Again, the incentives not to win the tournament and conceal the high type are strong compared to the benefits associated with winning the tournament in the first period but losing in terms of receiving a large proportion of low-quality input in the second period. Very similar results are obtained by Freixas et al. (1985) in a substantially more complicated model.

The results obtained in this section indicate that if broiler production is adequately described by technology B, then the integrator's incentives to engage in a discriminatory allocation of inputs are rather limited. One situation is described by a pooling equilibrium where the ratchet effect type of dynamic incentives would motivate agents to totally shirk in the first period in order to conceal their types. In this case, discrimination is impossible because the integrator cannot distinguish between high-ability and low-ability types. Another situation is characterized by a separating equilibrium where the correct ordering of types according to abilities is secured. However, by discriminating among agents via delivering low-quality input to the high-ability type, and high-quality input to the low-ability type, the integrator would earn smaller profits than under the full commitment equitable scenario. Therefore, the integrator has no incentive to discriminate and may simply behave as in the full commitment case.

4. EMPIRICAL EVIDENCE

The theoretical model in the previous section enables us to formulate testable hypotheses about the strategic behavior of the integrator when it comes to supplying inputs of varying quality to growers of different abilities. Accepting technology A as an accurate description of efficient broiler production, we hypothesize that the integrator would behave strategically by supplying high-ability growers with high-quality inputs and low-ability growers with low-quality inputs. Accepting technology B as a valid technology, we hypothesize that the integrator would not systematically discriminate among agents by trying to match high types with low-quality inputs and low types with high-quality inputs. To test the above hypotheses, the basic econometric model to be estimated from

---

[9] Notice that, unlike in the career concerns case, there is no upper bound on the value of γ in the ratchet effect type of environment since (22) automatically forces both growers to exert zero effort, and all marginal conditions are satisfied.

the data on individual broiler contract settlements is of the following form:

$$M_{it} = a_0 + a_1 A_i + \epsilon_{it}, \tag{23}$$

with M_{it} representing the quality of inputs supplied by the integrator to grower i in flock t; A_i is the inherent ability of individual grower that is assumed constant across time and ϵ_{it} is the error term. The expected sign of $\hat{a}_1$ is positive indicating the career concerns type of implicit incentives.

4.1 DATA AND THE DEFINITION OF VARIABLES

The data set used to test the hypotheses includes broiler production information gathered from five different production contracts. All five contracts are essentially the same, with the division of responsibilities for supplying inputs and the tournament type settlement formula as described in Section 2. Some smaller modifications in contract specifications are due to the differences in the grow-out technology used and the size of the birds grown.[10] Namely, two of the contracts (RFF1 and RFF2) are for the production of roasters with female fillers, one for roasters with straight run (RSR), one for large broilers (LB), and one for regular size broilers (RB).

Each observation in the data set represents one contract settlement, that is, the payment received and the grower performance associated with one grower and one flock of birds delivered to the integrator's processing plant. The data contain the information on the quantities and costs of various inputs supplied by the integrator (chicks, feed, medication, vaccination etc.), the number of birds placed and harvested, the quantity of broiler meat (live weight) produced, the dates when production started and terminated, mortality rates, and so on.

The tournaments are separated by the settlement date, which happens to be every Saturday. For three contracts, the settlement dates ranged from July 1995 to July 1997 totaling 104 tournaments each. The time span of the remaining two contracts is somewhat shorter. Each grower typically operates under one type of contract. The total number of growers varies across contracts from 195 in RFF2 to 354 in LB. The number of observations (settlements) per grower varies

---

[10] According to their live weight at harvest, the industry distinguishes broilers (4–5-pound birds) from roasters (5–6.5-pound birds). The technology for growing roasters (male birds) can differ depending on whether *female fillers* or *straight-run fillers* are used. In both cases, the chicken house space gets divided into two compartments, one stocked with male birds who will be harvested as roasters and the other with either single-sex female birds (female fillers) or both sexes (straight run). After about 7 weeks when fillers are harvested, the barrier is removed so that the roasters can use the entire space for another couple of weeks to grow to their marketable weight.

TABLE I.
DATA SUMMARY STATISTICS

			Q_{it} (Pounds)		c_{it} (Cents)		M_{it} (% Dev.)		H_{it} (Chicks)	
Contract	T	*n*	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
LB	104	354	240,475	131,507	31.27	3.21	0.0	0.8249	51,424	27,604
RFF1	104	302	329,660	135,952	32.24	3.32	0.0	0.2915	58,778	23,734
RFF2	67	195	293,375	165,094	33.74	2.80	0.0	0.2575	51,148	28,675
RB	46	208	234,394	120,973	32.38	1.59	0.0	1.0641	50,453	26,220
RSR	104	296	360,993	152,696	32.31	3.37	0.0	0.2006	61,438	25,654

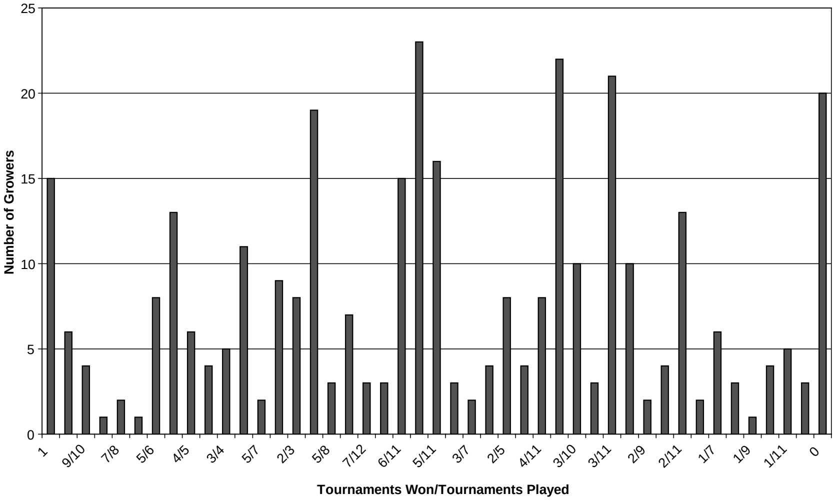

FIGURE 1. DISTRIBUTION OF TOURNAMENT WINNERS (LB CONTRACT)

from 1 to 12 flocks.[11] The total number of usable observations is 6,974 flocks. Table I provides summary statistics of the variables used in estimation.

To illustrate the point that a fairly large number of tournaments is consistently won by the same growers, in Figure 1 we plotted the distribution of tournament winners for growers that participated in minimum of three tournaments in contract LB. The horizontal axis

---

[11] The reasons for unequal number of observations across growers is unknown. We confidently rule out the possibility that the facilities of those growers with only few observations in the data set were idle during that period. It rather appears that the data sample has been randomly extracted from the population of all flocks that have been settled under a particular contract during that time period.

shows the ratios of tournaments won to tournaments played and the vertical axis shows the frequencies. If growers were homogeneous and the outcome of a tournament completely random, the graph would look like a normal distribution. However, as clearly seen from the graph, the distribution of winners has fat tails indicating some yet undetected regularities in tournament outcomes. Other contracts in the data set display rather similar characteristics.

In order to carry out the econometric estimation, we need to decide how to measure the model variables. The right-hand side (RHS) variable in (23) is grower ability. We define the grower ability in a broad sense as inherent or acquired skills resulting from experience, education, age, and so forth, as well as other grower-specific factors such as location, quality, and vintage of the production facilities and equipment.[12] We measure abilities as the growers' fixed effects in the production function or in the settlement cost panel data regression model. In the production function approach, we keep our original assumption that the total quantity of inputs in production is fixed and that the competition among growers is about producing more output. In this case, the variation in grower performance, after correction for the scale of operation, is adequately captured by the variation in the quantity of live weight produced. Alternatively, as, for example, in Levy and Vukina (2004), one can assume that the output level is fixed and that growers compete to produce the targeted level of output at the smallest possible costs. In this case, the differences in grower performance are fully captured by the differences in settlement costs, $\frac{c_{kt}}{Y_{kt}}$. The estimation results based on these two approaches may differ since they rely on different assumptions, but we do not expect the differences to be large.[13]

The dependent variable in (23) is the quality of inputs supplied by the integrator to their growers. Among all inputs that integrators provide, the quality of feed and the quality of baby chicks are the most important. Given the fact that the quality of feed is impossible to measure without laboratory analysis, this type of data is difficult to obtain. Instead, we focus on the quality of chicks.

The quality of baby chicks depend on several factors such as the composition of various breeds in a given flock, the age of the laying

---

[12] For example, one grower may outperform his peers because he is younger and better educated but also because his chicken houses are equipped with tunnel ventilation. Tunnel ventilation is known to work better than the standard curtain ventilation in summer months when the climate is hot and humid.

[13] A careful inspection of the actual payment mechanism in (1) reveals that growers actually compete to produce a larger output and to reduce the inputs use. Therefore, a better approach to estimate grower fixed effects would be to use the actual payments that growers receive. However, the data on grower payments are unreliable and cannot be used with confidence.

hens, the age and vitality of chicks when they arrive on the farm, and so on. Given the information available in the data set, we believe that the quality of chicks can be approximated by the percentage of chicks that died within the first week of arriving at the farm.[14] In particular, the quality will be measured as a percent deviation from the grower-specific average first-week mortality. The assumption employed here is that, given grower ability, a certain percentage of birds will die on the farm in every flock. The departure from this average mortality should measure the departure from the average quality of chicks typically received by contract growers. Hence, a higher-than-average first-week mortality (positive number) means that the flock has a higher proportion of the low-quality input and a lower-than-average first-week mortality (negative number) means the flock has a higher proportion of high-quality input.

4.2 ECONOMETRIC MODEL

The econometric approach to estimate (23) involves two steps. In the first step, we estimate grower abilities as the grower fixed effects in a two-way fixed-effects, panel data regression model. In the second step we regress the quality of inputs supplied by the integrator to the contract growers on the estimated grower abilities from the first step.

The first step involves the estimation of either the production function

$$Q_{it} = \alpha_0 + \alpha_1 M_{it} + \alpha_2 H_{it} + \sum_{k=2}^{n} \mu_k d_{it}^k + \sum_{k=2}^{T} u_k g_{it}^k + \omega_{it}, \tag{24}$$

or the settlement cost equation

$$c_{it} = \alpha_0 + \alpha_1 M_{it} + \sum_{k=2}^{n} \mu_k d_{it}^k + \sum_{k=2}^{T} u_k g_{it}^k + \omega_{it}, \tag{25}$$

where Q_{it} is the number of pounds of live broilers produced by grower i in tournament t and c_{it} is the grower i per pound settlement cost in tournament t. M_{it} is the percent deviation from the grower i average first-week mortality, H_{it} is the number of chicks placed on the grower farm, n

---

[14] This approach makes sense because the nature of the grow-out process is such that chicken farmers cannot do much to prevent chicks from dying when they are only 1 week old. The percentage of them that will die is to large extent determined by their quality, which is exclusively under the control of the integrator. On the other hand, the subsequent mortality that occurs during the production cycle is largely determined by what the grower does (his ability and effort) and not so much by the initial quality of chicks received, because those chicks that were of poor quality had already died in the first week.

is the number of growers operating under particular contract, μ_k is the ability of grower k, d_{it}^k is the dummy variable for grower k defined such that $d_{it}^k = 1$ whenever $i = k$ and 0 otherwise, u_k is the production shock common to all growers who settled their flocks in the same tournament t, g_{it}^k is the dummy variable for the tournament defined as $g_{it}^k = 1$ if $t = k$ and 0 otherwise, T is the number of tournaments in each contract, and ω_{it} is an individual grower idiosyncratic shock.

The key issue involving unobserved (time-constant) effect in panel data analysis is whether or not it is uncorrelated with observed explanatory variables. In equations (24) and (25) μ_i is obviously correlated with M_{it} and perhaps also with H_{it} in (24), so μ_i is clearly the *individual grower fixed effect* as opposed to the *random effect*, which would suggest $\text{Cov}(M_{it}, \mu_i) = 0, t = 1, 2, \ldots, T$. The consistency of the *fixed effects estimator* relies on the strict exogeneity of the explanatory variables conditional on the unobserved effect, $E(\omega_{it} \mid M_i, H_i, \mu_i) = 0, t = 1, 2, \ldots, T$. In other words, for fixed effects analysis $E(\mu_i \mid M_i)$ is allowed to be any function of M_i.[15]

Because we need the actual estimates of individual grower fixed effects, equations (24) and (25) will be in fact estimated using the *dummy variable estimator*.[16] Prior to estimation we sorted flocks by the settlement costs and then picked the grower with the worst settlement cost as the reference point when constructing grower dummies. Therefore, the estimates of μ_i in (24) should be generally positive because, controlling for the number of birds placed, higher-ability growers should produce more pounds of live weight. The expected sign of α_1 is negative as one expects more output from a good-quality input (i.e., lower first-week mortality rate). The expected sign of α_2 is positive since more birds placed will turn into more pounds of live weight broiler meat. On the other hand, all estimated μ_i in (25) should be negative because high-ability growers will have lower settlement costs. The estimate of α_1 should be positive as the lower-than-average mortality rate (good-quality input) should, *ceteris paribus*, result in the lower settlement cost.

In the second step, we use $\hat{\mu}_i$ from (24) and (25) to estimate

$$M_{it} = \beta_0 + \beta_1 \hat{\mu}_i + \sum_{k=2}^{T} \beta_k \left(\hat{\mu}_i g_{it}^k\right) + \nu_{it}, \tag{26}$$

---

[15] In addition, in order to insure that the fixed effects estimator is well behaved asymptotically, we need a standard condition that the matrix of time-demeaned explanatory variables is full rank (Wooldridge, 2002, pp. 265–279).

[16] There is a subtle difference between fixed effects estimator *(within estimator)* and the dummy variable estimator. The fixed effects estimator is consistent with fixed T as $N \longrightarrow \infty$, whereas $\hat{\mu}_i$ is unbiased as long as the assumptions on the exogeneity of the explanatory variables conditional on the unobserved effect and the finite sample analogue of the rank condition hold.

where β_1 represents the direct ability effect on the distribution of inputs, β_k represents the secondary ability effect in a particular tournament that captures the effect of the integrator's learning about the agent's type over time, and $\frac{\partial M_{it}}{\partial \hat{\mu}_i} = \beta_1 + \beta_k$ in tournament $t = k$, represents the total ability effect. Using $\hat{\mu}_i$ from the production function (24), the strategic behavior of the integrator in line with technology A and consequently with the career concerns type of dynamic incentives will survive the empirical test if the estimates of (26) satisfy $\beta_1 + \beta_k < 0, \forall k = 2, \ldots, T$. On the other hand, using $\hat{\mu}_i$ from the settlement costs equation (25), the career concerns type of dynamic response should be empirically supported if the estimates of (26) satisfy $\beta_1 + \beta_k > 0, \forall k = 2, \ldots, T$.

Econometric issues associated with estimation of models with generated regressors have been documented by Pagan (1984). It follows that since our estimates of μ_i from (24) and (25) are unbiased, replacing μ_i with $\hat{\mu}_i$ in running the OLS regression on (26) should produce consistent estimates of all parameters in (26). It can be easily shown that the usual OLS assumption that ν is uncorrelated with the RHS variables in (26) suffices for the two-step procedure to be consistent. Because the input quality variable M appears in both steps, as an independent variable in (24) and (25) and as a left-hand side (LHS) variable in (26), the above assumptions obviously translate into a requirement that ω and ν be orthogonal. However, things are more complicated when it comes to inference. The standard errors and test statistics obtained from the OLS regression of (26) are generally invalid because they ignore the sampling variation in $\hat{\mu}_i$ (see Wooldridge, 2002, pp. 115–118). To correct the problem we base our inference on the bootstrap confidence intervals. The procedure involves estimating both stages of the model with each of the 1,000 bootstrap replications (for a general reference see Efron and Tibshirani, 1993).

4.3 ESTIMATION RESULTS AND TESTING

The estimation results of the model (24) are presented in Table II and that of the model (25) in Table III. The estimated abilities of each grower μ_i are suppressed for brevity. Most of the individual grower t-statistics (also not reported) are significant in both specifications. All F-tests reject the null that growers are homogeneous in ability at a 5% significance level in all five contracts. We also found that common production shocks (results not reported) are significant in all five contracts. The obtained results are in line with the previous research in this area; see, for example, Knoeber and Thurman (1994) and Levy and Vukina (2004). The estimated coefficients on the quality of inputs, M_{it}, in both specifications have the predicted signs and are generally significant at 5% level in the

TABLE II.
ESTIMATION OF ABILITIES: PRODUCTION FUNCTION APPROACH (24)

Contract	Const.	M_{it}	H_{it}	Adj. R^2	F-test
LB	−13,986	−3,198.064*	4.613*	0.9883	3.53
	(7,508)	(336.027)	(0.0517)		(p-value < 0.0001)
RFF1	−47,968*	−7,757.769*	5.594*	0.9896	1.52
	(13,045)	(1,652.349)	(0.0849)		(p-value < 0.0001)
RFF2	−44,019*	−5,107.717*	5.586*	0.9962	1.46
	(12,636)	(1,597.816)	(0.0889)		(p-value < 0.0005)
RB	−16,404*	−1,619.533*	4.759*	0.9920	2.10
	(8,063)	(422.723)	(0.1426)		(p-value < 0.0001)
RSR	−184,513*	−4,042.242	5.741*	0.9878	1.45
	(20,216)	(3,240.154)	(0.1122)		(p-value < 0.0001)

Estimation of μ_k, u_k, are suppressed for brevity.
Standard deviations are given in parentheses.
F-test is testing $H_0 : \mu_2 = \mu_3 = \cdots = \mu_k$.
An asterisk marks the coefficient that is significant at a 5% level.

TABLE III.
ESTIMATION OF ABILITIES: SETTLEMENT COST APPROACH (25)

Contract	Const.	M_{it}	Adj. R^2	F-test
LB	37.847*	0.04224*	0.9223	2.96
	(0.4512)	(0.0212)		(p-value < 0.0001)
RFF1	41.735*	0.0743	0.8920	1.36
	(0.9579)	(0.1302)		(p-value < 0.0001)
RFF2	39.963*	0.1577	0.9556	2.59
	(0.6972)	(0.0932)		(p-value < 0.0001)
RB	35.404*	(0.505)	0.7800	3.42
	0.0502	(0.0291)		(p-value < 0.0001)
RSR	45.632*	0.1386	0.9208	1.67
	(1.059)	(0.1826)		(p-value < 0.0001)

Estimation of μ_k, u_k, are suppressed for brevity.
Standard deviations are given in parentheses.
F-test is testing $H_0 : \mu_2 = \mu_3 = \cdots = \mu_k$.
An asterisk marks the coefficient that is significant at a 5% level.

production function specification and insignificant in the settlement cost estimation.

The estimation results for the second-step model in (26) and the hypotheses testings are reported in two tables. Table IV contains the results based on $\hat{\mu}$ coming from the production function model (24), and Table V contains results based on $\hat{\mu}$ coming from the settlement

TABLE IV.
ESTIMATION OF DISCRIMINATION EQUATION (26) WITH ESTIMATED ABILITIES FROM PRODUCTION FUNCTION MODEL (TABLE II)

					t-tests		
Contract	$\hat{\beta}_0 \times 10^{-3}$	$\hat{\beta}_1 \times 10^{-6}$	Adj. R^2	*F*-test	H_0	CC	RE
LB	8.73	−18.6	0.0859	3.8197	44	40	19
	(1.35)	(0.23)		$F^*_{0.95} = 3.4926$			
RFF1	−26.71	−3.1	0.1596	3.1581	70	12	21
	(1.96)	(0.14)		$F^*_{0.95} = 5.6255$			
RFF2	1.82	1.2	0.1563	3.2725	56	9	1
	(1.39)	(0.36)		$F^*_{0.95} = 5.7358$			
RB	10.23	−0.23	0.0659	2.3181	25	11	9
	(2.49)	(0.14)		$F^*_{0.95} = 7.9550$			
RSR	18.22	−0.27	0.0925	1.9337	97	6	0
	(1.92)	(0.032)		$F^*_{0.95} = 1.3191$			

Estimates of $\beta_k; k = 2, \ldots, T$ are suppressed for brevity. Bootstrap standard errors are given in parentheses.
F-tests are testing $H_0 : \beta_1 + \beta_2 = \beta_1 + \beta_3 = \cdots = \beta_1 + \beta_T = 0$. $F^*_{0.95}$ represents the 95 percentile of the bootstrap *F*-distribution.
T-tests are testing $H_0 : \beta_1 + \beta_k = 0$ versus $H_1 : \beta_1 + \beta_k < 0, \forall k = 2, \ldots, T$ in the career concerns (CC) case, or $H_0 : \beta_1 + \beta_k = 0$ versus $H_1 : \beta_1 + \beta_k > 0, \forall k = 2, \ldots, T$ in the ratchet effect (RE) case, at 5% level of significance.

cost model (25). The estimates $\beta_2, \ldots, \beta_T$ are suppressed for brevity. The numbers in parentheses are the bootstrap standard errors. The actual testing of discrimination hypotheses is carried out in the following way. First we test that $\beta_1 + \beta_2 = \beta_1 + \beta_3 = \cdots = \beta_1 + \beta_T = 0$ with an F-test. This is done by estimating the unrestricted model (26) and the restricted model (which is simply the mean of the M_{it}) 1,000 times, calculating the *F*-statistics in each of the 1,000 replicates and sorting them. Then, we use the original *F*-statistics computed from the data to see whether it is inside or outside the 95 percentile of the bootstrap *F*-distribution.

Second, we perform a battery of one-sided *t*-tests for every tournament with $H_0 : \beta_1 + \beta_k = 0, \forall k = 2, \ldots, T$. This is done by computing the *t*-statistics in each of the 1,000 replicates as

$$t = \frac{(\hat{\beta}_1^* + \hat{\beta}_k^*) - (\hat{\beta}_1 + \hat{\beta}_k)}{\sqrt{(\mathrm{var}(\hat{\beta}_1^*) + \mathrm{var}(\hat{\beta}_k^*) + 2\mathrm{cov}(\hat{\beta}_1^*, \hat{\beta}_k^*))}},$$

where $\hat{\beta}_k^*$ denote parameter estimates from each replicate and $\hat{\beta}_k$ denote estimates from the original data. Then we use the original *t*-value computed from the data to see whether it lies inside or outside the 95 percentile of the bootstrap *t*-distribution. Based on the production function estimates of abilities (24), in cases where we reject H_0 in favor

TABLE V.
ESTIMATION OF DISCRIMINATION EQUATION (26) WITH ESTIMATED ABILITIES FROM THE SETTLEMENT COST MODEL (TABLE III)

					t-Tests		
Contract	$\hat{\beta}_0 \times 10^{-3}$	$\hat{\beta}_1 \times 10^{-3}$	Adj. R^2	F-test	H_0	CC	RE
LB	24.27	150.74	0.1298	5.5002	58	37	8
	(3.9)	(5.77)		$F^*_{0.95} = 4.7016$			
RFF1	3.3	37.97	0.1762	3.4291	79	13	11
	(2.38)	(1.31)		$F^*_{0.95} = 5.6267$			
RFF2	13.27	−8.39	0.1559	3.2577	66	0	0
	(3.39)	(2.74)		$F^*_{0.95} = 5.7699$			
RB	0.91	0.09	0.2123	5.9760	24	11	10
	(4.35)	(2.00)		$F^*_{0.95} = 11.3272$			
RSR	−67.94	−3.63	0.0911	1.9190	81	8	14
	(3.26)	(0.35)		$F^*_{0.95} = 1.3459$			

Estimates of $\beta_k; k = 2, \ldots, T$ are suppressed for brevity. Bootstrap standard errors are given in parentheses.
F-tests are testing $H_0 : \beta_1 + \beta_2 = \beta_1 + \beta_3 = \cdots = \beta_1 + \beta_T = 0$. $F^*_{0.95}$ represents the 95 percentile of the bootstrap F-distribution.
T-tests are testing $H_0 : \beta_1 + \beta_k = 0$ versus $H_1 : \beta_1 + \beta_k > 0, \forall k = 2, \ldots, T$ in the career concerns (CC) case, or $H_0 : \beta_1 + \beta_k = 0$ versus $H_1 : \beta_1 + \beta_k < 0, \forall k = 2, \ldots, T$ in the ratchet effect (RE) case, at 5% level of significance.

of $H_1 : \beta_1 + \beta_k < 0$, we talk about the career concerns type of response. In cases where we reject in favor of $H_1 : \beta_1 + \beta_k > 0$, we talk about the ratchet effect. Based on the settlement cost function estimates of abilities (25), the inequalities in the alternative hypotheses are reversed.

The results obtained are fairly similar for both specifications of the fixed effects model, yet they exhibit some differences across contracts. Testing that all $\beta_1 + \beta_k$ are jointly zero with an F-test shows that the null hypothesis of no discrimination (i.e., full commitment) is rejected only for contracts for the production of large broilers (LB) and roasters with straight run fillers (RSR). Computing the number of cases where the individual one-sided t-test rejects the null in favor of the career concerns hypothesis shows 40 out of 103 such cases in the production function approach and 37 in the settlement cost approach for the LB contract, and 6 out of 103 cases in the production function approach and 8 in the settlement cost approach for the RSR contract.

These results could be interpreted as showing some empirical support for the career concerns type of dynamic incentives implicitly present in the broiler contracts. However, the results are diluted by the fact that in the LB contract one-sided t-tests also reject the null hypothesis in favor of the ratchet effect (a result that is not supported by the theory) 19 times in the production function approach and 8 times in the settlement cost approach. In the RSR contract there are no rejections in favor of the ratchet effect in the production function approach, but there are 14 such cases when the second-stage model is estimated with the settlement cost model predictions of grower abilities.

In the remaining three contracts where the full commitment hypothesis could not be rejected based on an F-test, individual t-tests in both specifications produce rather similar results. Typically, the number of cases where the null cannot be rejected prevails, the number of rejections in favor of career concerns generally outnumber the rejections in favor of the ratchet effect, but the number of *wrong* rejections is oftentimes too large to be ignored. Overall, the results seem to be pointing toward the conclusion that there is not enough empirical evidence that the integrator strategically distributes inputs of varying quality to growers of different abilities.

5. CONCLUSIONS

This research has been motivated by the frequent complaints of contract broiler growers that they have been treated unfairly at the hands of the integrators. Specifically, we investigated a problem of post-contractual opportunism (lack of long-term commitment) on the part of the principal that can manifest itself in a strategic allocation of variable quality inputs among growers of different abilities. The problem stems from the fact that the integrator–grower relationship is long term (as determined by the useful life of the contract-specific fixed assets acquired by both sides), yet it is governed by repeated short-term contracts. Observing the performance of contract growers over time, the integrator can make reasonably precise conjectures about grower abilities. Having this information, she may be tempted to deviate from the original explicit contract provisions and discriminate among growers when it comes to supplying them with the production inputs of varying quality.

From the theory developed in Section 3, we believe that the incentives clearly exist only for the integrator to supply high-ability growers with high-quality inputs and low-ability growers with low-quality inputs. This strategy would generate a career concerns type of dynamic response from the growers, who would be eager to win in the current period tournament not only because of the direct incentives they face, but also because winning in the current period improves their chances of obtaining the high-quality inputs in the subsequent tournaments. In cases where a production technology might dictate the strategy of supplying high-ability agents with low-quality inputs and low-ability agents with high-quality inputs, our theoretical results show that such strategy would not be profitable for the integrator even if correct ordering of agents according to abilities could be established. This is because the aggregate two-period profits under discrimination are less than those under full commitment (i.e., when integrator commits to distribute inputs equitably).

Our results show no empirical support for the proposition that broiler processors may be systematically discriminating among contract growers of different abilities when supplying them with variable quality production inputs. Consequently, the available data set on individual contract settlements provides no convincing evidence for either career concerns or ratchet effect type of dynamic grower response. Whereas the rejection of ratchet effect hypothesis conforms with the theoretical model prediction, the lack of empirical support for the career concerns hypothesis perhaps warrants additional discussion. There are at least two plausible explanations for what is essentially a negative result.

First, an important caveat of the presented model is the fact that it ignores potentially significant transaction costs associated with strategic allocation of inputs. The transaction costs in this context would include the tangible costs of segregating inputs into categories (high or low) and the costs of matching different categories of inputs with different ability growers. The size of the transaction costs associated with the implementation of discrimination strategy may eliminate all potential benefits that the discrimination strategy could generate. Similarly, the benefits associated with strategic distribution of variable quality inputs as captured by the improved cost efficiency or larger output may be rather small. The high transaction costs (or small benefits) may prevent the integrator from engaging in this type of strategic behavior and may force him to stay committed to distribute inputs fairly as implicitly understood in the short-term contract.

The second and more general explanation has to do with the reputation effect. The noncommittal principal may be faced not only with tangible transaction costs associated with strategic allocation of inputs, but also with hidden costs associated with the loss of goodwill and reputation for honesty among growers. True, there is ample anecdotal evidence originating from the growers circles about the contract settlements being unfair because of the integrators gaming the process to their advantage. However, those complaints may not be representative of all growers and all processors. If information about integrators' practices is reasonably inexpensive to obtain, then the noncommittal integrator may face significant reputation costs, which would limit his ability to sign up new growers. In an industry, as rapidly expanding as the broiler industry has been in the last couple of decades, the inability to sign up enough agents as a consequence of the tarnished record may be a significant deterrent to strategic discrimination of growers based on their past performance.

Finally, what are the lessons to be learned for empirical work on dynamic incentives generally? In another empirical study of dynamic incentives in agriculture, Allen and Lueck (2002) have shown that even in the limited cases in which there is support for the ratchet effect in the private crop share contracts, it tends to be economically insignificant. Whether the absence of empirically detectable implicit incentives is unique to agriculture or is it ubiquitous is too early to say. More empirical research is surely needed to answer this question.

APPENDIX A

Proof of Proposition 1.

(i) From the closed-form solution in (14) and (16), it follows that $\frac{e_{i1}^{**}}{e_{j1}^{**}} = \frac{\theta_i}{\theta_j}$, where $\theta_i > 1$, and thus, $e_{i1}^{**} > e_{j1}^{**}$. From the first-order condition in (13) and $e_{i1}^{**} > e_{j1}^{**}$, it is obvious that the second-period effort of grower *i* is higher than that of grower *j* (i.e., $e_{i2}^{**} > e_{j2}^{**}$).

(ii) The proof of $e_{i1}^{**} > e_{i1}^{*}$ and $e_{j1}^{**} > e_{j1}^{*}$ follows from equation (12). The value of the marginal benefit from exerting effort in $t = 1$ for both growers increases compared to that of the full commitment scenario by $\frac{r\beta\delta\theta_k}{2}(\theta_k e_{k2}^{**} + \theta_{-k} e_{-k2}^{**} - \frac{2}{m})$. This is because of the technological restriction requiring that $\theta_k e_{kt} > \frac{1}{m}$ and hence $(\theta_k e_{k2}^{**} + \theta_{-k} e_{-k2}^{**} - \frac{2}{m}) > 0$. To prove $e_{i2}^{**} > e_{i2}^{*}$ and $e_{j2}^{**} < e_{j2}^{*}$, we use equation (13). The low-ability grower loses the tournament in the first period and therefore, his second-period effort will be reduced from the full commitment level by $\frac{r\beta\theta_j}{2}(\theta_i e_{i1}^{**} - \theta_j e_{j1}^{**})$. The high-ability grower wins the tournament in the first period and therefore, his second-period effort will be increased by $\frac{r\beta\theta_i}{2}(\theta_i e_{i1}^{**} - \theta_j e_{j1}^{**})$ from the full commitment level.

(iii) Positive dynamic incentives increase the aggregate output in the first period because both efforts are higher relative to the full commitment case. They also increase the output of the high-ability agent in the second period (because of both higher proportion of x_H and higher effort) at the expense of decreasing the output of the low-ability agent. To prove that the aggregate two-period output is larger than in the full commitment case, it is sufficient to show that the second-period aggregate output is larger than in the full commitment case. From the target setting rules (8) and (9) and the first-order condition in (13), the expression for the expected aggregate production in the second period is $y_{i2} + y_{j2} = \frac{rX}{4}(\theta_i^2 + \theta_j^2) + \frac{rX\beta}{2}(\theta_i e_{i1}^{**} - \theta_j e_{j1}^{**})(\theta_i^2 - \theta_j^2) + \frac{rX\beta^2}{4}(\theta_i e_{i1}^{**} - \theta_j e_{j1}^{**})(\theta_i^2 + \theta_j^2) + \frac{X}{m}$. If $\beta = 0$, the above expression would reduce to the full commitment case level of second-period output. In this case only the first and the last elements of the sum on the RHS survive and the rest of them equal zero. Clearly, the aggregate second-period output in the noncommitment case is larger than in the full commitment case because all terms in the above sum containing β are positive.

APPENDIX B

Proof of Proposition 2b.

(i) From (20), it follows that $[1 + \delta\gamma(\theta_k e_{k2} + \theta_{-k} e_{-k2} - \frac{2}{n})] > 0$ and $\frac{e_{i1}^{**}}{e_{j1}^{**}} = \frac{\theta_i}{\theta_j}$ where $\theta_i > 1$ and thus $e_{i1}^{**} > e_{j1}^{**}$. From (21) and $\theta_i > 1$ and thus $e_{i1}^{**} > e_{j1}^{**}$; it follows that $e_{i2}^{**} > e_{j2}^{**}$.

(ii) In the separating equilibrium, e_{i1}^{**} and e_{j1}^{**} always decrease from the full commitment level because from (20) and (21), it follows that $e_{i1}^{*} - e_{i1}^{**} = \frac{r\delta\gamma\theta_i}{2}(\frac{2}{n} - \theta_i e_{i2} - \theta_j e_{j2}) > 0$ and $e_{j1}^{*} - e_{j1}^{**} = \frac{r\delta\gamma\theta_j}{2}(\frac{2}{n} - \theta_i e_{i2} - \theta_j e_{j2}) > 0$ whereas $(\theta_k e_{k2} + \theta_{-k} e_{-k2} - \frac{2}{n}) < 0$ because of the technological restriction associated with technology B. To prove that $e_{j2}^{**} < e_{j2}^{*}$ and $e_{i2}^{**} > e_{i2}^{*}$, one needs to observe that, based on (21), grower j reduces his effort from the full commitment level by $\frac{r\gamma\theta_j}{2}(\theta_i e_{i1}^{**} - \theta_j e_{j1}^{**})$, whereas grower i increases his effort by $\frac{r\gamma\theta_i}{2}(\theta_i e_{i1}^{**} - \theta_j e_{j1}^{**})$.

(iii) The aggregate outputs are $y_{i1} + y_{j1} = \frac{rX}{4}(\theta_i^2 + \theta_j^2) - \frac{r\delta\gamma X}{4}(\theta_i^2 + \theta_j^2) \times [\frac{2}{n} - \theta_i e_{i2}^{**} - \theta_j e_{j2}^{**}] + \frac{X}{n}$ and $y_{i2} + y_{j2} = \frac{rX}{4}(\theta_i^2 + \theta_j^2) + \frac{r\gamma X(\theta_i^2 - \theta_j^2)}{2} \times \{\frac{r(\theta_i^2 - \theta_j^2)}{2}[\delta\gamma(\frac{2}{n} - \theta_i e_{i2}^{**} - \theta_j e_{j2}^{**})]\} + \frac{rX\gamma^2(\theta_i^2 + \theta_j^2)}{4}\{\frac{r(\theta_i^2 - \theta_j^2)}{2}[\delta\gamma(\frac{2}{n} - \theta_i e_{i2}^{**} - \theta_j e_{j2}^{**})]\} + \frac{X}{n}$. It can easily be verified that the second term in the expression for $y_{i1} + y_{j1}$ will always outweigh the second and third term in the expression for $y_{i2} + y_{j2}$.

REFERENCES

Allen, D.W. and D. Lueck, 2002, *The Nature of the Farm: Contracts, Risk and Organization in Agriculture*, Cambridge, MA: The MIT Press.

Aron, D., 1987, "Worker Reputation and Productivity Incentives," *Journal of Labor Economics*, 5(4) Part 2, 87–106.

Baron, D. and D. Besanko, 1987, "Commitment and Fairness in a Dynamic Regulatory Relationship," *Review of Economic Studies*, 54, 413–436.

Efron, B. and R. Tibshirani, 1993, *An Introduction to the Bootstrap*, New York: Chapman and Hall.

Fama, E., 1980, "Agency Problems and Theory of the Firm," *Journal of Political Economy*, 88, 288–307.

Farmer's Legal Action Group Inc. (FLAG), 2001, "Assessing the Impact of Integrator Practices on Contract Poultry Growers," Available: www.flaginc.org/pubs/poultry/poultryrpt.pdf

Freixas, X., R. Guesnerie, and J. Tirole, 1985, "Planning Under Incomplete Information and the Ratchet Effect," *Review of Economic Studies*, 52, 173–191.

Gibbons, R., 1987 "Piece-Rate Incentive Schemes," *Journal of Labor Economics*, 5, 413–429.

—— and K. Murphy, 1992, "Optimal Incentive Contracts in the Presence of Career Concerns: Theory and Evidence," *Journal of Political Economy*, 100, 468–505.

Holmstrom, B., 1999, "Managerial Incentive Contracts: A Dynamic Perspective," *Review of Economic Studies*, 66, 169–182.

Ilvento, T. and A. Watson, 1998, *Poultry Growers Speak Out: A Survey of Delmarva Poultry Growers*, Newark, DE: University of Delaware.

Kanemoto, Y. and W. McLeod, 1992, "The Ratchet Effect and the Market for Secondhand Workers," *Journal of Labor Economics*, 10, 85–98.

Knoeber, C. and W. Thurman, 1994, "Testing the Theory of Tournaments: An Empirical Analysis of Broiler Production," *Journal of Labor Economics*, 12, 155–179.

Laffont, J. and J. Tirole, 1988, "The Dynamics of Incentive Contracts," *Econometrica*, 56, 1153–1175.

Lazear, E., 1986, "Salaries and Piece Rate," *Journal of Business*, 59, 405–431.

Levy A. and T. Vukina, 2002, "Optimal Linear Contracts with Heterogeneous Agents," *European Review of Agricultural Economics*, 29, 205–217.

—— and ——, 2004, "League Composition Effect in Tournaments with Heterogeneous Players: An Empirical Analysis of Broiler Contracts," *Journal of Labor Economics*, 22, 353–377.

Meyer, M., 1995, "Cooperation and Competition in Organizations: A Dynamic Perspective," *European Economic Review*, 39, 709–772.

Pagan, A.R., 1984, "Econometric Issues in the Analysis of Regressions with Generated Regressors," *International Economic Review*, 25, 221–247.

Salanie, B., 1987, *The Economics of Contracts: A Primer*, Cambridge, MA: The MIT Press.

Tsoulouhas, T. and T. Vukina, 1999, "Integrator Contracts With Many Agents and Bankruptcy," *American Journal of Agricultural Economics*, 81, 61–74.

—— and ——, 2001, "Regulating Broiler Contracts: Tournaments versus Fixed Performance Standards," *American Journal of Agricultural Economics*, 83, 1062–1073.

Weitzman, M., 1980, "The "Ratchet Principle" and Performance Incentives," *Bell Journal of Economics*, 11, 302–308.

Wooldridge, J.M., 2002, *Econometric Analysis of Cross Section and Panel Data*, Cambridge, MA: The MIT Press.