The League Composition Effect in Tournaments with Heterogeneous Players: An Empirical Analysis of Broiler Contracts

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We compare welfare effects of tournaments and piece rates in contracts with heterogeneous ability agents and demonstrate that tournaments that mix players of unequal abilities create a league composition effect. When leagues are fixed and the time horizon sufficiently long, piece rates improve welfare over tournaments. Using contract production data for broiler chickens, we estimate the variances of growers' abilities, common production shock, and grower's idiosyncratic shock. Growers' abilities are heterogeneous, and common production shocks are significant. Leagues in broiler tournaments disintegrate rapidly over time, suggesting that tournament contracts offer more welfare than piece rates.

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I. Introduction

Tournaments or contests are labor contracts by which an individual's wage depends on his or her performance relative to others. The term "tournament" usually refers to a rank-order (ordinal) tournament such as that considered by Lazear and Rosen (1981). As in tennis or golf, it is only a player's rank that matters in the allocation of prizes, and rewards are intrinsically nonlinear. Although most of the literature regarding tournaments assumes contestants have equal abilities, virtually all real-world tournaments are contests among players with unequal abilities.[1] When players have different abilities, rank-order tournaments are known to exhibit some undesirable properties. For example, asymmetries in the knowledge of abilities entail inefficiencies because contestants do not self-sort into their own homogeneous leagues. Correcting this may result in entry credentials and bigger prize spreads in leagues, which target higher ability players. With full knowledge of abilities, rank-order tournaments with players of heterogeneous abilities still suffer from incentive problems. Handicapping and prize structures indexed by ability are possible consequences generated by a mixed tournament model in the presence of competition from segregated tournaments (see McLaughlin 1988).

Another type of tournament is the so-called payment by relative performance (Nalebuff and Stiglitz 1983), also known as the yardstick competition (Shleifer 1985) or the piece-rate tournament (Tsoulouhas and Vukina 1999). The term describes a tournament where the reward is a continuous function (typically linear) of the difference between an individual player's performance and the group average performance. These are the tournaments we study in this article.[2]

An important feature of payments by relative performance, which distinguishes them from rank-order tournaments, is that there are no efficiency losses associated with mixing players of uneven abilities. When rewards are linearly related to performance, better players have no incentive to stop exerting effort once they realize that they are going to win and worse players have no incentive to surrender once they realize that they are going to lose. Consequently, payments by relative performance do not provide incentives for organizers to handicap better players or sort them into homogeneous groups. Under these tournaments, the incremental reward for improved performance (penalty for worse per-

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[1] From our perspective in this article, the most relevant are models that deal with multiple contestants and multiple prizes; see Holmstrom (1982), Green and Stokey (1983), and Nalebuff and Stiglitz (1983).

[2] Although we do not deal with the rank-order tournaments, the nature of the problem that we identify and the results we develop are generally applicable to rank-order tournaments as well.

formance) at the margin is the same whether a player is more or less able (Knoeber and Thurman 1994).

The main tenet of this article is that mixing players of unequal abilities in tournaments creates a problem that has gone largely unnoticed in the literature on labor contracts. We call the phenomenon a "league composition effect" and define it as the change in the distribution of tournament payoffs, which results from an exogenous assignment of players to heterogeneous groups in which they compete. The phenomenon arises most clearly in sporting events such as the World Cup soccer tournament, the National Collegiate Athletic Association basketball tournament, and professional tennis tournaments but is also prevalent in many nonsport business environments. In settings where the league composition effect is present, we often see group assignments done by a seeding process to minimize this effect. A stylized example may serve to illustrate the phenomenon better.

The new format of World Cup soccer (like the 2002 tournament in Korea and Japan) consists of 32 teams divided into eight groups of four for a round-robin play. The top two teams from each league advance to a single-elimination bracket to determine the overall rankings. Suppose the outcome of any game is decided by a set of deterministic rankings, so a higher ranked team always beats a lower ranked team. Suppose further that teams are assigned randomly to leagues (no seeding) and consider the plight of the third-best team in the world. If the third-best team is placed in a league with none or only one of the higher ranked teams it will advance to the 16-team bracket. If the first- and second-best teams (which always advance) meet each other in the single elimination bracket before meeting the third-ranked team, the third-ranked team could reach the finals and place second. Alternatively, it could meet one of the higher ranked teams in the semifinals, round of eight, or round of 16 and finish tied for third, fifth, or ninth, respectively. If our team is placed in a league with both the first- and second-best teams, it will fail to advance altogether and finish tied for seventeenth. The variation of outcomes for the third-best team in our example is entirely because of the league composition effect.

An interesting case of the league composition effect is found in the contracts for the production of broiler chickens. The production of broilers in the United States is almost entirely organized via production contracts between processing companies (called integrators) and independent farmers (growers), with payments to the growers determined by a payment by relative performance. In this type of contract, a grower receives a payment per pound of live meat produced, which consists of a fixed-base payment and a variable payment based on the grower's relative performance. An important feature of the contract settlement through tournaments is the elimination of the common production uncertainty from the grower's payment. This is due to the fact that the individual performance of a grower is compared with the average performance of the group of growers whose flocks were harvested at approximately the same time, so that they are all exposed to the same influence of common stochastic factors such as weather. Since the league (group) composition changes from flock to flock at the integrator's discretion, an individual grower's payments can vary even if all else is constant. Many broiler growers are dissatisfied with the existing payment formula. "Under this system of determining grower payment, consecutive flocks grown by the same grower having similar production costs could receive substantially different payment amounts because of the results of other growers in the settlement group. Growers have expressed exasperation over this form of settlement because they have no way of estimating in advance how much to expect in payment" (GIPSA 1997, p. 5936).

A simple way to purge the effect of league composition on the grower's payment is to modify the tournament such that an individual grower's performance is no longer compared with the average performance of all growers but, rather, measured against some fixed standard. Such labor contracts, known as "fixed performance standards," are used in many livestock production contracts, such as turkeys and hogs, but rarely in the production of broiler chickens.[3] Under some simplifying assumptions discussed later, these contracts generally reduce to simple piece rates and are characterized by the fact that an individual grower's payment is independent of the performance of others; hence, the league composition effect is zero. However, a fixed performance standard exposes the player to common production shocks, which tournaments eliminate.

The first systematic account of the economic rationale behind the use of tournaments in the broiler industry appeared in Knoeber (1989), who described broiler tournaments as devices for risk sharing and rapid adaptation to technical change without the need for contract renegotiation. Subsequently, using data on the performance of broiler contract growers facing both rank-order tournaments and linear relative performance schemes, Knoeber and Thurman (1994) tested several predictions from the theory of tournaments and found some evidence that tournament organizers attempt to handicap players of unequal ability or to reduce mixing to avoid the disincentive effects of mixed tournaments. The only recognition of the league composition effect appears in Tsoulouhas and Vukina (2001), who analyze the welfare implications of proposed gov-

[3] One explanation of the differences in contracts across livestock industries is provided by Tsoulouhas and Vukina (1999), who showed that the danger of bankruptcy may hinder the principal's ability to offer payments based on the relative performance; the principal instead offers payments based on the fixed performance standards.

ernmental regulation of contracts in the broiler industry. They call it a "group composition risk" and say that it relates to the uncertainty regarding the average outcome when common production and idiosyncratic shocks are givens.[4]

The objective of this article is to define and characterize the league composition effect in a simple model of moral hazard and compare the welfare given by payments by relative performance and simple piece rates. We demonstrate that when agents have heterogeneous ability in a one-time tournament, the efficiency results hinge on the size of stochastic shocks. However, in a sufficiently long sequence of tournaments with fixed leagues, mixing players of unequal abilities renders tournaments contracts Pareto inferior to piece rates. Using contract production data for broiler chickens, we estimate a grower cost equation that enables us to measure the variance of growers' abilities as well as the magnitudes of common production risk and individual grower's (idiosyncratic) risk. The results show that growers are heterogeneous in their abilities and that common production shocks are significant. Since the variance of common shocks exceeds the variance of growers' abilities, it follows that payments to growers under a piece-rate tournament will have less variance than under a simple piece rate for all cases except when payments are made over a long-enough time horizon with fixed leagues. In this case, a simple piece-rate contract will offer less variance than any piece-rate tournament.

The rest of the article is organized as follows: in Section II we present a general definition of the league composition effect together with a simple model of moral hazard and provide a framework for welfare comparison of piece-rate tournaments and simple piece-rate contracts. In Section III we discuss the basic features of production contracts for broiler chickens, describe the data set, and present the results of the econometric estimation of the grower performance equation. Section IV summarizes the results and concludes.

II. A Simple Model

Suppose that the output of agent i in time t is given by the following simple production function:

$$x_{it} = e_{it} + \mu_i + u_t + \epsilon_{it}, \tag{1}$$

where $e_{it} \geq 0$ is the effort exerted by agent i in period t, μ_i is the inherent ability of agent i, u_t is a common production shock occurring in period t independent across time, and ϵ_{it} is an idiosyncratic production shock

[4] Tsoulouhas and Vukina (2001) examine tournaments in which a grower's output is excluded from the group average against which she is compared. In the class of tournaments they study, their concept of group composition risk coincides with our definition.

independent across agents and time. Here we mean output in the general sense, that is, any dimension of performance that a principal may care about, such as quantity, quality, or cost efficiency. Both shocks are stochastic, realized at the end of the production cycle, with mean zero and finite variances, σ_u^2 and σ_ϵ^2, respectively. The production function (1) is a simple extension of the Lazear and Rosen (1981) output equation for agents with heterogeneous abilities.

Suppose further that agents contract their output with a single risk-neutral principal, and the output is sold in a perfectly competitive market. The principal observes the output but does not observe the level of effort; hence, there exists a "hidden action" moral hazard problem. All agents have the same utility function given by $U[y_{it} - C(e_{it})]$, where y_{it} represents a payment to the agent and $C(e_{it})$ is a strictly convex function of effort ($C', C'' > 0$) where $C(0) = C'(0) = 0$. We assume weak concavity of the utility function ($U' > 0, U'' \leq 0$) and set the reservation utility to zero. Both utility and costs are continuous and differentiable.

Finally, suppose that incentive contracts that a principal offers to his agents are based either on an independent scheme such as a simple piece rate,

$$y_{it}^P = B^P + K^P x_{it}, \tag{2}$$

where B^P denotes some level of base salary, or on a payment by relative performance,

$$y_{it}^R = B^R + K^R(x_{it} - \bar{x}_t), \tag{3}$$

where the cash payment is determined by comparing the individual contestant's performance to the group average performance: $\bar{x}_t = (1/n)\sum_{j=1}^{n} x_{jt}$.[5]

If offered a piece-rate contract with $B^P, K^P > 0$, the agent's problem is given by

$$\max_{e \in [0,\infty)} \int \int U[y - C(e)] f_u(u) f_\epsilon(\epsilon) du d\epsilon, \tag{4}$$

where f_u and f_ϵ are the density functions for the common production and

[5] Here we simply focus on payment mechanisms that we frequently observe without considering their optimality properties. For an explanation of the widespread use of linear compensation schemes in light of the fact that other contracts may be optimal, see, e.g., Holmstrom and Milgrom (1987) and Levy and Vukina (2002).

idiosyncratic shocks, respectively. This produces the resultant sufficient first-order condition:

$$\int\int U'[y - C(e)][K^P - C'(e)]f_u(u)f_\epsilon(\epsilon)du d\epsilon = 0, \quad (5)$$

which implies the unique solution:

$$K^P = C'(e^*). \quad (6)$$

When an agent is offered a linear contract based on a tournament against $(n - 1)$ other agents, the solution is similarly given by

$$K^R\left(\frac{n-1}{n}\right) = C'(e^*). \quad (7)$$

If we frame the agent's effort decision as a simultaneous-move, n-person game, then the choice of e^* in either case is a dominant strategy (see Levy and Vukina 2002). Notice that in the tournament case, effort is decreased slightly because of an agent's own contribution to the average given identical marginal payments.

Remark. When a simple piece-rate or a piece-rate tournament contract is offered, the effort chosen is the same for all agents although they have different abilities.[6]

In order to compare the welfare properties of piece-rate tournaments vis-à-vis simple piece rates, we need to introduce the concept of "league composition effect." We define the league composition effect as the variation from the expected outcome of a tournament resulting from the exogenous assignment of players to heterogeneous groups in which they compete. From the perspective of an individual contestant, the league composition risk can be measured as an effect on the distribution of payment caused by competing against a subset of the population of contestants instead of the entire population.[7]

Definition. Let y_{it}^{∞} be a stochastic payment received by agent i in tournament t when the tournament league consists of the entire population of contestants, and let y_{it}^{n} be a payment when the league consists of n contestants randomly drawn from the population. Then we say that the league composition effect is the random variable: $y_{it}^{n} - y_{it}^{\infty}$.

[6] This is, of course, completely because of the additive formula for ability in the production equation. If ability affects the marginal cost of effort or the marginal return of effort then agents of different ability would choose different levels of effort. Since our focus here is on the effects of league composition on welfare, we leave these other specifications for future research.

[7] In what follows, we assume the population is infinite; however, everything we do here can be easily applied to the case where the population is finite. We use an infinite population only because it makes the calculations more transparent.

In order to ease the exposition, from here on we will assume that the distributions of all random shocks are normal, which, given the fact that the tournaments and piece-rate contracts we study are linear schemes, will imply random variables y^{∞} and y^{n} are also normal and determined by their first two moments. Furthermore, since the ex ante means of those random variables are the same, our measure of the league composition effect reduces to the comparison of variances. Concretely, the effect of league composition can be computed by comparing the variance of a tournament payment with a finite number of players against the variance of a tournament payment with an infinite number of players.

A. League Composition in a Single Tournament

Suppose that prior to entering the contract the agent knows her own ability, but the abilities of her competitors are only known to be random draws from the normal distribution with mean zero and variance σ_{μ}^{2}. Under a tournament, the ex ante variance of payment to the agent is given by $\mathrm{Var}(y_{it}^{R}) = (K^{R})^{2}\{[(n-1)/n]\sigma_{\epsilon}^{2} + [(n-1)/n^{2}]\sigma_{\mu}^{2}\}$. Notice that tournaments eliminate common production uncertainty, but uncertainty still exists because of idiosyncratic shocks and uncertainty about abilities.[8] Applying the definition and fixing t, the league composition effect can be calculated as:

$$\begin{aligned}\mathrm{Var}(y^{n}) - \mathrm{Var}(y^{\infty}) &= \left(K^{R}\right)^{2}\left[\left(\frac{n-1}{n}\right)\sigma_{\epsilon}^{2} + \left(\frac{n-1}{n^{2}}\right)\sigma_{\mu}^{2}\right] \\ &\quad - \lim_{n\to\infty}\left(K^{R}\right)^{2}\left[\left(\frac{n-1}{n}\right)\sigma_{\epsilon}^{2} + \left(\frac{n-1}{n^{2}}\right)\sigma_{\mu}^{2}\right] \qquad (8) \\ &= \left(K^{R}\right)^{2}\left[\left(\frac{n-1}{n^{2}}\right)\sigma_{\mu}^{2} - \frac{1}{n}\sigma_{\epsilon}^{2}\right],\end{aligned}$$

which can be positive or negative depending on the relative magnitudes of two sources of risk. If the variation in abilities is larger than the idiosyncratic shock, for a large enough n, the league composition effect is positive, and players face more risk competing in leagues than all together. If on the other hand, the variance of idiosyncratic shocks exceeds the variance of abilities, the league composition effect is beneficial (risk reducing). The reason for this is that when growers compete in leagues, there is a beneficial correlation between a single grower's output and the

[8] Saying that the uncertainty emanates from playing against a randomly drawn subset of players whose abilities are known is the same as saying that the uncertainty comes from playing against a known subset of players whose abilities are unknown. This is a casual restatement of the Harsanyi doctrine. If, however, the player knows who her competitors are as well as their abilities, then the only risk that remains is the one about the realization of the idiosyncratic shock.

group average output through the idiosyncratic shock. A single grower competing against the entire population bears the entire risk of his idiosyncratic shock, but a grower competing in a league of size n bears only $(n-1)/n$ of the shock since the remainder is perfectly correlated with the group average.[9] By contrast, the effect of the variation in abilities on the group average output only raises the variance of payment.

Now consider a simple piece rate with the same expected payment as the tournament contract and marginal payment: $K^P = [(n-1)/n]K^R$. This guarantees that both contracts elicit the same effort and generate the same expected payment from the principal, and so the principal is indifferent between the two contracts. The variance of payment from a simple piece rate is given by $\mathrm{Var}(y_{it}^P) = (K^P)^2(\sigma_u^2 + \sigma_\epsilon^2)$. With a simple piece rate, the actions of other players have no impact on an individual player's payment; hence, the league composition effect is zero. However, a simple piece rate exposes the player to a common production shock that tournaments eliminate. Hence, choosing between these two contracts involves a trade-off between the common production risk and the league composition effect.

If we assume that agents' preferences over income are characterized by a constant absolute risk aversion (CARA) utility function, then an agent's welfare can be measured in terms of the mean and variance of payment: $U(y_i) = E(y_i) - (\lambda/2)\,\mathrm{Var}(y_i)$, where E denotes the expectations operator and $\lambda = -\{E[U''(y)]\}/\{E[U'(y)]\} > 0$ represents the Arrow-Pratt measure of absolute risk aversion. When the mean payments match for the piece-rate and tournament contracts, and both contracts elicit the same effort, the difference between the utility of a tournament and the utility of a simple piece rate is given by the difference in the respective variances of payments:

$$\begin{aligned} &U[y^R - C(e^*)] - U[y^P - C(e^*)] \\ &= -\frac{\lambda}{2}(K^R)^2\left[\left(\frac{n-1}{n}\right)\sigma_\epsilon^2 + \left(\frac{n-1}{n^2}\right)\sigma_\mu^2\right] + \frac{\lambda}{2}(K^P)^2(\sigma_u^2 + \sigma_\epsilon^2) \\ &= \frac{\lambda}{2}(K^R)^2\left(\frac{n-1}{n^2}\right)[(n-1)\sigma_u^2 - \sigma_\epsilon^2 - \sigma_\mu^2]. \end{aligned} \tag{9}$$

From the above expression, it is easy to see that as n increases the tournament is favored over the piece-rate contract for any values σ_ϵ^2, σ_μ^2, and σ_u^2. This is intuitive since as $n \to \infty$, the league composition effect disap-

[9] An extreme example helps to illustrate this point. When $n = 2$, we see that $\bar{x}_t = [\mu_1 + \mu_2 + 2(e^* + u_t) + \epsilon_{1t} + \epsilon_{2t}]/2$, and half of an individual's shock ϵ_{it} is absorbed into the average. In Tsoulouhas and Vukina (2001), the average for a particular agent does not include the contribution of that agent, and hence this effect vanishes. In this case, the league composition effect is the variance of the average because of the variation in abilities of the other competitors.

pears.[10] By contrast, for $n = 2$, an agent is better off with a simple piece rate if the sum of σ_ϵ^2 and σ_μ^2 is larger than σ_u^2. We can also see that a larger variance in individual abilities favors the piece rate as it increases the league composition effect. A larger variance in the common shock favors the tournament as it only affects piece-rate compensation. Finally, a larger variance in the idiosyncratic shock favors the piece rate because the marginal payment for a piece rate is smaller than for a tournament by a factor $(n - 1)/n$.

B. League Composition in a Sequence of Tournaments

Now we wish to extend the concept to analyzing agent welfare over a time horizon of T tournaments. Suppressing the cost of effort for a moment, let agents maximize an expected discounted utility function over T time periods given by $U(y_1, \dots, y_T) = \sum_{t=1}^{T} \delta^t V(y_t)$. In order to simplify the analysis, we will assume that $\delta = 1$ and agents can smooth consumption over the time horizon so that consumption in each period is given by the average payment $(1/T) \sum_{t=1}^{T} y_t$. As before, assuming a CARA utility function and normality of income, the utility function can be written in terms of the mean and the variance of the average payment. Hence, the expected utility is given by $E[(1/T) \sum_{t=1}^{T} y_t] - (\lambda/2) \operatorname{Var}[(1/T) \sum_{t=1}^{T} y_t]$.

We focus now on two benchmark cases. In the first case, the group of players in each of the tournaments is drawn at random from the population of players. In this situation our player is competing against a different pool of players in each consecutive tournament. We call this case a sequence of random leagues. In the second case, ex ante, the league is composed by randomly drawing players from the entire population, but then the composition of the league remains constant over T consecutive tournaments. This corresponds with the situation where our player is competing against the same group of players over and over again. We call this case a sequence of fixed leagues.

In the random-league case, when μ_i is known ex ante, the variance of the average payment from a tournament contract is $[(K^R)^2/T]\{[(n - 1)/n]\sigma_\epsilon^2 + [(n-1)/n^2]\sigma_\mu^2\}$, and the league composition effect lowers the risk because of idiosyncratic shocks by $(1/n)(\sigma_\epsilon^2/T)(K^R)^2$ and increases risk by $[(n-1)/n^2](\sigma_\mu^2/T)(K^R)^2$ by randomizing the benchmark. Alternatively, under the piece-rate contract, the variance of average payment is given by $[(K^R)^2/T](\sigma_\epsilon^2 + \sigma_u^2)$. In a large number of tournaments with randomly drawn leagues, both effects diminish, and the league composition effect gradually disappears. However, for any T, welfare comparisons between a tournament and a piece rate are exactly as in the one-

[10] Alternatively, if a finite population had been modeled, the league composition effect would vanish when n reaches the size of the population.

shot case, since random leagues are just independently and identically distributed repetitions of a single tournament.

We turn now to the more interesting case of fixed leagues. When μ_i is known ex ante, the variance of the average payment is given by $\mathrm{Var}\,[(1/T)\sum_{t=1}^{T} Y_{it}] = (K^R)^2\{[(n-1)/n][(\sigma_\epsilon^2)/T] + [(n-1)/n^2]\sigma_\mu^2\}$, and the league composition effect becomes $(K^R)^2\{[(n-1)/n^2]\sigma_\mu^2 - (1/n)(\sigma_\epsilon^2/T)\}$. As before, the effect of league composition is twofold: it increases the risk resulting from the variation in abilities by $(K^R)^2[(n-1)/n^2]\sigma_\mu^2$, and it lowers the risk resulting from idiosyncratic shocks by $(K^R)^2(1/n)(\sigma_\epsilon^2/T)$. Notice that, importantly, here the first term is independent of T, while the second term vanishes as $T \to \infty$.

Now consider the simple piece-rate contract as in equation (2) played T times. The welfare comparison between piece-rate tournaments and simple piece rates is given by the difference in the variances of average payments; hence,

$$V\left[\frac{1}{T}\sum_{t=1}^{T} y_t^R - C(e^*)\right] - V\left[\frac{1}{T}\sum_{t=1}^{T} y_t^P - C(e^*)\right]$$
$$= \frac{\lambda}{2}(K^R)^2\left[\left(\frac{n-1}{n}\right)^2\frac{\sigma_u^2}{T} - \left(\frac{n-1}{n^2}\right)\frac{\sigma_\epsilon^2}{T} - \left(\frac{n-1}{n^2}\right)\sigma_\mu^2\right]. \qquad (10)$$

From equation (10), we see that a piece-rate contract will eventually dominate a tournament as the time horizon grows longer because of the persistent influence of the variance of abilities. The critical time horizon for which piece-rate contracts start to welfare dominate tournaments increases in n and σ_u^2, while it decreases in the heterogeneity of the players σ_μ^2 and σ_ϵ^2. This result can be summarized as:

Proposition 1. For a sequence of fixed leagues and fixed n, σ_ϵ^2, σ_u^2, σ_μ^2, all finite, and $(n-1)\sigma_u^2 > \sigma_\epsilon^2$, $V[(1/T)\sum_{t=1}^{T} y_t^P - C(e^*)] - V[(1/T)\sum_{t=1}^{T} y_t^R - C(e^*)] > 0$ if and only if $T > [(n-1)\sigma_u^2 - \sigma_\epsilon^2]/\sigma_\mu^2$. If $(n-1)\sigma_u^2 \leq \sigma_\epsilon^2$, then $V[(1/T)\sum_{t=1}^{T} y_t^P - C(e^*)] - V[(1/T)\sum_{t=1}^{T} y_t^R - C(e^*)] \geq 0$ for any T.

Proposition 1 shows that over time, the effect of league composition is the decisive factor in comparing welfare between tournaments and piece rates. Unlike common production shocks and idiosyncratic shocks, the risk from a random benchmark is never averaged away as T grows. If agents compete in fixed leagues, tournaments lower welfare compared with simple piece-rate contracts. In Section III we empirically examine the validity of the fixed-league hypothesis in the broiler industry setting.

III. Empirical Evidence

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 finally processing plants. A large proportion of the industry value added comes from the processing stage, which explains why the processors became the coordinators of the industry. The finishing stage of production is organized almost entirely through contracts between integrators and independent growers.[11] The empirical analysis in this study is carried out using the grower performance and payroll data from five different finishing contracts. The observations in the data set are the individual growers' production costs and compensation rates for multiple flocks grown under different conditions. Our objective is to measure the size of the league composition effect, to compare it to the magnitudes of other relevant types of risks in the production of broiler chickens, and to compare the welfare of two frequently observed linear payment schemes, a simple piece rate and a piece-rate tournament.

A. Broiler Contracts

The contracting of broiler production started in the late 1940s with so-called open account contracts where growers were provided with loans from a bank, a production credit association, or a feed mill in return for interest payments. Facing increased competition for growers, some integrators started offering an open account–no loss contracts, which carried a clause ensuring that any deficit incurred by the grower after broilers had been marketed was absorbed by the contractor. In the 1950s and 1960s, the industry was using the guaranteed price contracts, which were quite similar to those of their predecessors except for an additional clause guaranteeing the grower a certain price per bird delivered. The guaranteed price contracts were followed by the flat fee contracts under which growers were compensated for their husbandry and inputs by payment per pound, per bird, or per week. The integrator retained ownership of birds; provided feed, medicine, and chicks; and coordinated production and marketing decisions. The next generation in the evolution of broiler contracts emerged as the integrators tried to mitigate the agency problems. To stimulate growers to reduce costs, the broiler companies started including feed conversion bonuses in their flat-fee contracts as well as profit sharing. Share contracts stipulated proportions according to which profits were shared between the integrator and the grower with the responsibilities of the two parties remaining as in the flat-fee contract. A basic feed conversion contract compensated growers according to a specified schedule of feed conversion (pounds of feed divided by pounds of live weight). Such contracts were often used together with a flat-fee payment,

[11] The finishing stage refers to the final stage of the production process where 1-day-old chicks are brought to the farm and then grown to market weight and slaughtered.

which made those contracts very similar to the contracts we observe today (Martin 1994).

Modern broiler production contracts are agreements between an integrator company and growers that bind farmers to tend for a company's chickens until they reach market weight by strictly following specific production practices in exchange for monetary compensation. Broiler contracts have two main components: one is the division of responsibility for providing inputs, and the other is the method used to determine grower compensation. The grower provides land and housing facilities, utilities (electricity and water), and labor. Operating expenses such as repairs and maintenance, cleanup, and manure and mortality disposal costs are also the responsibility of the grower. The company provides chicks, feed, medication, and the services of field men. Items like fuel or litter can be the responsibility of either the integrator or the grower, or they can be shared. Most integrators nowadays require that houses be built according to strict specifications regarding construction and equipment. New houses are typically well-insulated units, with highly automated feeders, drinkers, and heating and cooling devices. Given that the useful life of a chicken house is about 25 years, the vintages of houses under contract differ from grower to grower. Although we might expect that growers with newer facilities would routinely outperform growers with older units, company production managers frequently argue that grower skills and management attention are decisive in keeping production costs under control.[12]

Most of the modern broiler contracts are settled using a two-part, piece-rate tournament consisting of a fixed base payment per pound of live meat produced and a variable bonus payment based on the grower's relative performance. The bonus payment is determined as a percentage of the difference between group average settlement costs and the producer's individual settlement costs. Settlement costs are obtained by adding chicks, feed, medication, and other customary flock costs divided by total pounds of live poultry produced. The calculation of the group average performance includes growers whose flocks were harvested within the same week. For the below-average settlement costs (above-average performance), the grower receives a bonus, and for the above-average settlement costs, he receives a penalty.[13]

[12] Unfortunately, the data set at our disposal includes neither the age of the facilities under contract nor the type of equipment that is installed, so we cannot test this proposition empirically.

[13] One of the recent developments in some broiler contracts has been the introduction of the market price clause defined as the percentage (typically 5%) of the positive difference between the market price for broilers and the integrator's average variable cost of producing them. The market price clause makes the base payment dependent on time, thus introducing an additional source of risk into

The total payment y_{it} to grower i in tournament t is the sum of the base payment and the bonus factor multiplied by the live pounds of poultry moved from the grower's farm:

$$y_{it} = \left[A + K\left(\frac{1}{n}\sum_{j=1}^{n}\frac{c_{jt}}{q_{jt}} - \frac{c_{it}}{q_{it}}\right)\right]q_{it}, \tag{11}$$

where c_{it} is the cost generated by grower i in time t, q_{it} is the quantity produced, A is the base payment (e.g., 3.5¢–4.5¢ per pound), c_{it}/q_{it} is an individual grower's settlement cost, and K is the marginal bonus payment expressed as a percentage (50%–100%) of the production cost savings that the grower retains.

An alternative type of remuneration mechanism, advocated by broiler growers yet rarely used by broiler companies, is a combination of a base payment and a production cost bonus paid per pound of chicken meat produced. Under one such scheme, known as a fixed performance standard, growers are paid a floor payment corrected by a feed conversion bonus, which is calculated by comparing individual growers' feed conversion to a predetermined benchmark s:

$$y_{it} = \left[A + K\left(s - \frac{c_{it}}{q_{it}}\right)\right]q_{it}. \tag{12}$$

Notice that in calculating c_{it}/q_{it} in equation (12), production inputs such as chicks, medication, and so on, are ignored, and the bonus payment is determined solely by focusing on feed utilization. As it turns out, the difference between a simple feed conversion ratio and total settlement costs is not that important because prices used to convert physical units of production inputs into costs are not market prices but, rather, fixed weights (for an illustration, see Knoeber and Thurman [1994, p. 163]). The only important difference between a tournament and a fixed standard lies in the computation of the benchmark against which the performance of an individual grower is compared. Whereas in the first case the benchmark is determined by the contest among growers, in the second case it represents a predetermined technological constant.

Different companies, or different profit centers within the same company, typically specialize in the production of a particular size (weight) of birds and offer their own contracts to their growers. The contracts for growing different-sized birds usually differ only with respect to the base payment (parameter A in eq. [11]) in that farmers growing heavier birds typically receive larger base payments than those growing smaller birds. The technology used for growing different sizes of birds is highly malleable. The grower can easily adjust the housing unit from growing one

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the grower's payment. We ignore this detail because the analysis would become considerably more complicated, yet it would not qualitatively affect the results.

type of bird to growing another type if requested to do so by the integrator.

An interesting feature of the broiler contracts is that they are short-term, that is, they cover one flock at a time. In most instances, after one flock is harvested, the contract gets tacitly renewed and the grower receives a new batch. The cases of grower terminations are extremely rare and are typically caused by a major violation of the contract stipulations (e.g., gross negligence or theft of feed or birds), by the closure of a profit center, or by the bankruptcy of the entire integrator company. Contracts generally do not guarantee the growers any particular number of flocks per year; hence, the decision about the volume of production (the rotation of flocks on a given farm) is determined solely by the integrator. This flexibility is important to the integrators because by delaying the delivery of new flocks to growers they can manipulate their total supplies in response to the market signals.

B. A Simple Econometric Model

In order to develop an econometric model to estimate the size and the significance of the league composition effect in broiler tournaments, we follow Knoeber and Thurman (1994) and Tsoulouhas and Vukina (1999) and assume a fixed flock size and a common mortality rate for all growers.[14] Given that the integrator sets the target weight of marketable broilers, the output expressed in pounds of live broilers is similar across all growers. Hence, the differences in individual growers' performances are adequately captured by the differences in the production (settlement) costs. The competition in broiler tournaments is not about who can produce more output but, rather, who can produce a targeted level of output with the smallest possible cost. As shown in the appendix, the tournament mechanism from equation (11) reduces to a payment by relative performance from equation (3), where $x_{it} = -c_{it}/q_{it}$ is the grower's settlement cost measured as a negative number (hence, higher values are better), and the grower payment per pound of live broilers delivered, y_{it}^R, is the sum of the base salary B^R and the bonus payment determined by comparing the individual grower's settlement costs x_{it} to the group average settlement cost: $\bar{x}_t = (1/n)\sum_{j=1}^{n} x_{jt}$. Similarly, the fixed performance standard in equation (12) becomes a simple piece rate from equation (2) where the parameters have been chosen such that $B^P = A + K^P s$.

[14] The assumption of fixed flock size is not overly restrictive since most chicken houses come in standard sizes, and optimizing the density of birds tends to reduce the variation in flock size across growers. Mortality rates are largely driven by the quality of 1-day-old chicks delivered to growers and, hence, tend to be quite similar across growers within the settlement group. Therefore, most of the variation in output is caused by the scale of operation, i.e., by the differences in the number of chicken houses.

In order to assess the risk associated with the production of broilers under various contracts, we estimated the following cost equation separately for each one of the five contracts for which we have data:

$$x_{it} = \alpha + \sum_{k=2}^{n} \mu_k d_{it}^k + \sum_{k=2}^{T} u_k g_{it}^k + \epsilon_{it}, \tag{13}$$

where x_{it} denotes the individual settlement cost of farmer i in tournament t, μ_k is the ability of farmer k, u_k is the common production shock realized by all farmers in tournament t, and $d_{it}^k = 1$ if $i = k$ and 0 otherwise, while $g_{it}^k = 1$ if $t = k$ and 0 otherwise. Finally, ϵ_{it} is an idiosyncratic production shock faced by farmer i in tournament t. Equation (13) is essentially an unbalanced two-way, fixed-effects model. Given estimates of the parameters in equation (13), we can decompose the components of the payment variance to the grower. The sample variance of the estimated fixed effects can be calculated as $\hat{\sigma}_\mu^2 = (1/n)\sum_{j=1}^{n}(\hat{\mu}_i - \bar{\mu})^2$, where $\bar{\mu} = (1/n)\sum_{j=1}^{n}\hat{\mu}_i$ is the sample mean. Similarly, the sample variance of the common production shocks can be calculated as $\hat{\sigma}_u^2 = (1/T)\sum_{t=1}^{T}(\hat{u}_t - \bar{u})^2$, where $\bar{u} = (1/T)\sum_{t=1}^{T}\hat{u}_t$ is the sample mean. The variance of the idiosyncratic shock is given from the sum of squared errors of the regression.

C. Estimation Results

The basic structure of all five contracts used in this study is the same and corresponds with the above description, with the payment mechanisms determined by equation (11). However, there are smaller modifications in each one of the contracts that are mainly determined by the grow-out technology used and the size of the birds grown under a particular contract.[15] Namely, two of our contracts are for the production of roasters with female fillers (RFF1 and RFF2), one is for roasters with straight run (RSR), one is for large broilers (LB), and one is for the production of regular size broilers (RB). For three contracts, the settlement dates range from July 1995 to July 1997, for the total of 104 tournaments each. The time span of the remaining two contracts is somewhat shorter. The number of growers in each of the profit center varies from 202 in RFF2 to 356 in LB. The average size of the league varies from

[15] According to their live weight at harvest, the industry distinguishes broilers (4–5 lb. birds) from roasters (5–6.5 lb. birds). The technology for growing roasters (single sex, 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 with both sexes (straight run). After about 7 weeks when fillers are harvested, the barrier is removed so that roasters can use the entire space for another couple of weeks to grow to their market weight.

Table 1
OLS Estimates of the Farmer Cost Equation

Contract	Estimation and Testing Results
Contract RB	$y_{it} = \alpha + \sum_{i=2}^{217} \mu_i d_{it} + \sum_{t=2}^{49} u_t g_t + \epsilon_{it}$
	Adjusted $R^2 = .8510$
	$\hat{\sigma}_\epsilon^2 = .6461, \hat{\sigma}_u^2 = 3.305, \hat{\sigma}_\mu^2 = .5360$
	Tests: H_0: $\sigma_\mu^2 = 0$, $F = 2.732$; H_0: $\sigma_u^2 = 0$, $F = 85.31$
Contract LB	$y_{it} = \alpha + \sum_{i=2}^{356} \mu_i d_{it} + \sum_{t=2}^{104} u_t g_t + \epsilon_{it}$
	Adjusted $R^2 = .9309$
	$\hat{\sigma}_\epsilon^2 = .7156$, $\hat{\sigma}_u^2 = 9.301$, $\hat{\sigma}_\mu^2 = 2.678$
	Tests: H_0: $\sigma_\mu^2 = 0$, $F = 4.552$; H_0: $\sigma_u^2 = 0$, $F = 393.7$
Contract RFF2	$y_{it} = \alpha + \sum_{i=2}^{202} \mu_i d_{it} + \sum_{t=2}^{76} u_t g_t + \epsilon_{it}$
	Adjusted $R^2 = .9419$
	$\hat{\sigma}_\epsilon^2 = .4390$, $\hat{\sigma}_u^2 = 6.785$, $\hat{\sigma}_\mu^2 = .4362$
	Tests: H_0: $\sigma_\mu^2 = 0$, $F = 2.22$; H_0: $\sigma_u^2 = 0$, $F = 192.6$
Contract RFF1	$y_{it} = \alpha + \sum_{i=2}^{311} \mu_i d_{it} + \sum_{t=2}^{104} u_t g_t + \epsilon_{it}$
	Adjusted $R^2 = .9455$
	$\hat{\sigma}_\epsilon^2 = .6005$, $\hat{\sigma}_u^2 = 9.511$, $\hat{\sigma}_\mu^2 = 8.017$
	Tests: H_0: $\sigma_\mu^2 = 0$, $F = 8.042$; H_0: $\sigma_u^2 = 0$, $F = 226.8$
Contract RSR	$y_{it} = \alpha + \sum_{i=2}^{298} \mu_i d_{it} + \sum_{t=2}^{104} u_t g_t + \epsilon_{it}$
	Adjusted $R^2 = .9093$
	$\hat{\sigma}_\epsilon^2 = 1.014$, $\hat{\sigma}_u^2 = 10.22$, $\hat{\sigma}_\mu^2 = 3.499$
	Tests: H_0: $\sigma_\mu^2 = 0$, $F = 1.749$; H_0: $\sigma_u^2 = 0$, $F = 62.97$

NOTE.—OLS = ordinary least squares. Estimates of fixed effects have been suppressed for brevity. Estimates of the intercepts have been suppressed for confidentiality. All tests shown reject at .01%.

nine growers in RSR to 31 growers in LB. The total number of usable observations is 7,566 flocks.

The estimated parameters of equation (13) are given in table 1 along with the estimates of the variance of grower heterogeneity and the variance of the common production shock. Immediately evident from the results is the strong evidence of the heterogeneity of growers and the existence of common production shocks. In all contracts, the hypotheses of equal ability and no common time effects are strongly rejected. In table 2, we present the estimates of the model parameters from the pooled sample, which give qualitatively similar results. The estimates of grower ability are given in figure 1 for each of the five contracts. The differing dispersions across contracts reflect the variances estimated in table 1. None of the histograms appear severely skewed.

Common production shocks based on the individual contract estimates from table 1 are plotted in figure 2. The graph clearly indicates that during

Table 2
Pooled OLS Estimates of the Farmer Cost Equation

$$y_{it} = \alpha - .0482\text{RFF1} - .8473\text{LB} - .0329\text{RSR} - .0934\text{RFF2}$$
$$\qquad (.0723) \qquad (.0735) \qquad (.0734) \qquad (.0443)$$
$$+ \sum_{i=2}^{1062} \mu_i d_{it} + \sum_{t=2}^{104} u_t g_t + \epsilon_{it}$$

Adjusted $R^2 = .9151$
$\hat{\sigma}_\epsilon^2 = .855$, $\hat{\sigma}_u^2 = 9.406$, $\hat{\sigma}_\mu^2 = 4.637$
Test of grower heterogeneity:
H_0: $\mu_1 = \mu_2 = \ldots = \mu_{1062}$
Calculated $F = 3.981$ (p-value < .0001)
Test of no common shocks:
H_0: $u_1 = u_2 = \ldots = u_{104}$
Calculated $F = 29.031$ (p-value < .0001)

NOTE.—OLS = ordinary least squares. Estimates of fixed effects have been suppressed for brevity. Estimate of the intercept has been suppressed for confidentiality.

the period covered by the data, no large discontinuities from catastrophic events or sudden technological advances occurred. The shocks appear to be relatively smooth, indicating that they are most likely dominated by evolving influences such as weather (temperature and humidity), feed mixes, and genetic strains of birds. The degree of similarity among five contracts is remarkable. This is not completely surprising given the fact that all contracts originate from the same climate zone.

Given these estimates for the variance of ability and the variances of idiosyncratic and common shocks, we can assess the welfare differences between tournaments and simple piece-rate contracts. Since the variance of common shocks exceeds the sum of the variance of grower ability and the variance of the idiosyncratic shock, we have that payments to growers for a single tournament will have less variance than would exist under a simple piece rate. Moreover, this carries over to the case of random leagues over any time horizon. However, from proposition 1, we know that if leagues are fixed, a piece rate will offer less variance than any tournament of size n given a long enough time horizon T. Using the variance estimates from the pooled regression in table 2, table 3 shows the longest time horizon for which tournaments offer less variance of average payment than a fixed performance contract for various tournament sizes. Hence, when the time horizon is smaller than indicated, a tournament offers less risk, but when the horizon is longer, a simple piece rate offers less risk.

From our earlier analysis, we know that the crucial factor in comparing the welfare of tournaments to piece rates is the validity of the fixed-league assumption. In figure 3 we present the dissipation of settlement groups for all tournaments associated with contract RSR (others are similar). The heights correspond with the proportion of the original league in subsequent tournaments. If leagues were fixed, then the heights would be one at intervals of about 7 or 8 weeks, and the graph would look like a series of fences parallel to the diagonal. However, we see that this is not the case. The graph clearly indicates that the original groups disintegrate rapidly, with typically less than half of the original group remaining intact for the very next tournament. After about four tournaments the leagues have largely turned over, and subsequent tournaments more closely resemble the random case than the fixed case. Since the average league size is over 20 growers, given table 3 we expect grower welfare to be higher with a tournament than with a piece-rate contract. The smooth dispersion of leagues over time suggests that changes in leagues' composition are likely because of differences in the time individual growers need to grow birds to market weight and to clean and prepare the chicken houses for new flocks, and also because of the integrator's idiosyncracies in scheduling the delivery of new chicks. The dissipation of leagues also provides an indirect support for the conclusion that principals have no incentive to sort agents into homogeneous groups according to their abilities.

IV. Conclusions

An important feature of linear relative performance schemes (piece-rate tournaments) is that there are no efficiency losses associated with mixing players of uneven abilities. However, mixing players of unequal abilities creates a league composition effect that has gone largely unnoticed in the literature on tournaments and contracts. We define the phenomenon as the change in the distribution of tournament payoffs, which results from an exogenous assignment of players to heterogeneous groups in which they compete.

In this article we characterize the league composition effect in a simple moral hazard model and compare tournaments and simple piece-rate contracts in both the one-shot and dynamic settings. We demonstrate that in the environment with heterogeneous agents and a one-time tournament, the efficiency results hinge on the relative sizes of stochastic shocks. In a sequence of tournaments, however, mixing players of uneven abilities creates a significant league composition effect, which makes piece rates more attractive when leagues are fixed. These results highlight the essential need to mix players in a tournament setting not only ex ante but contemporaneously as well.

We study an interesting case of the league composition effect in the contracts for the production of broiler chickens. Using contract production performance and payroll data, we estimate the grower cost equation, which enables us to measure the variance of growers' abilities as well as the magnitudes of common production risk and an individual grower's

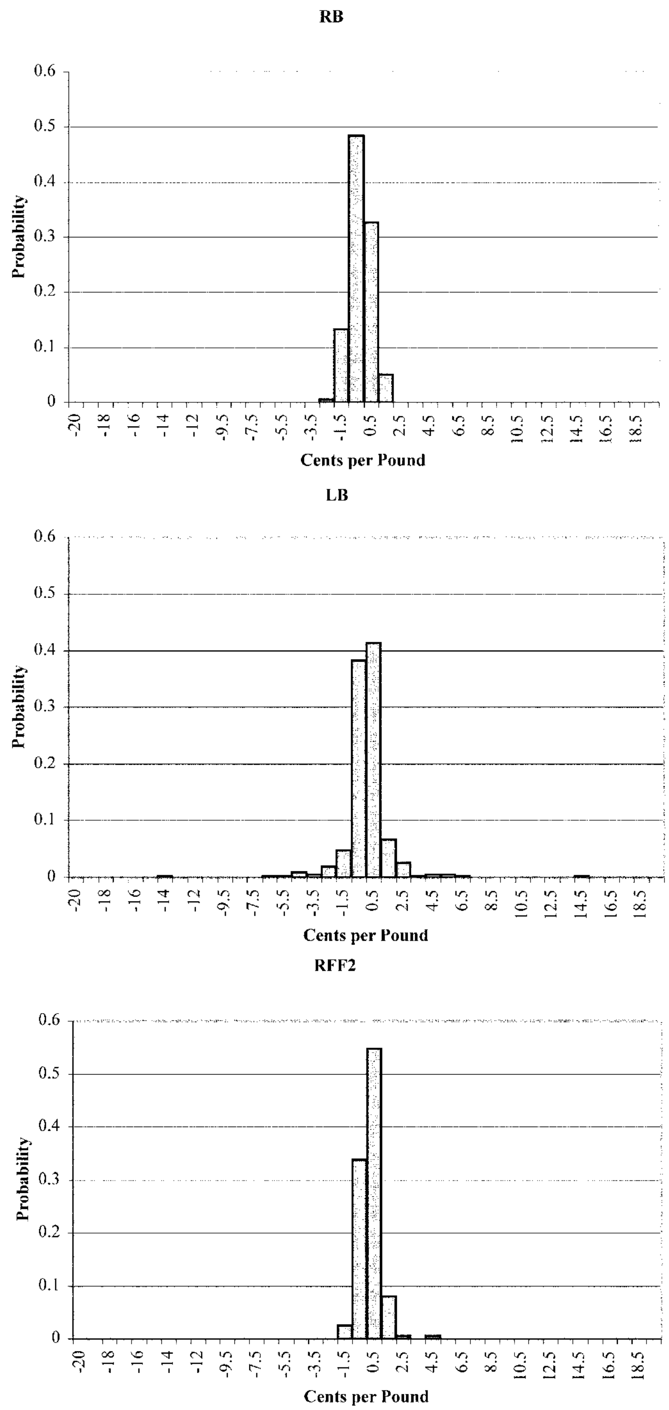

FIG. 1.—Distribution of grower abilities

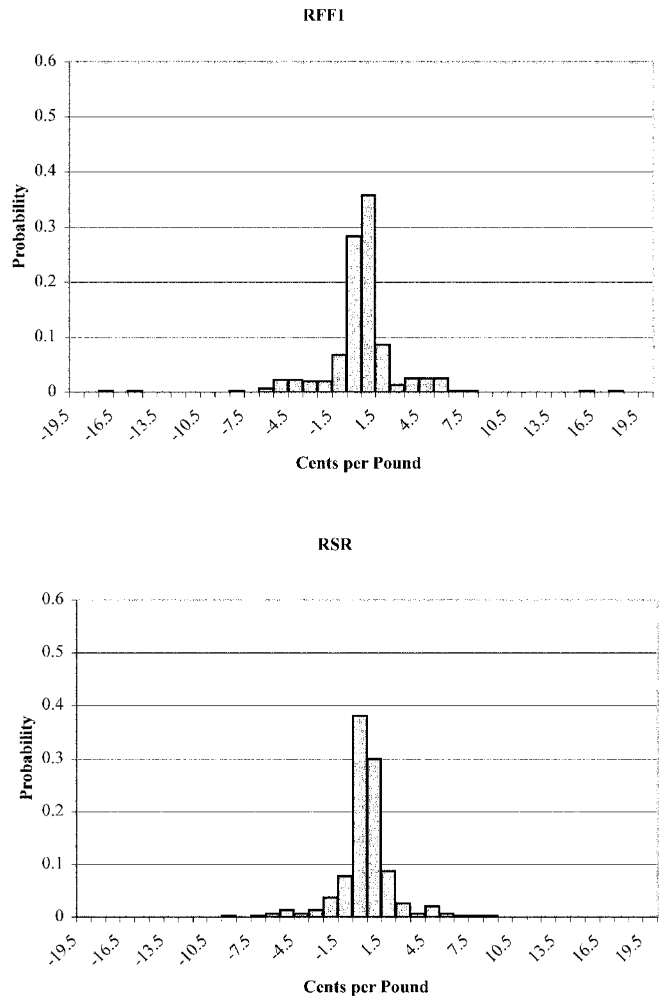

FIG. 1 (*Continued*)

idiosyncratic risk. The evidence shows that growers are heterogeneous in their abilities and that common production shocks are significant. Since the estimated variance of common shocks exceeds the variance of the grower's idiosyncratic shocks, it follows that payments to growers under a tournament will have less variance than under a simple piece-rate contract for a single flock and for multiple tournaments when leagues are random. However, when payments are made over a time horizon with fixed leagues, a simple piece-rate contract will offer less variance than any tournament given a long enough time horizon.

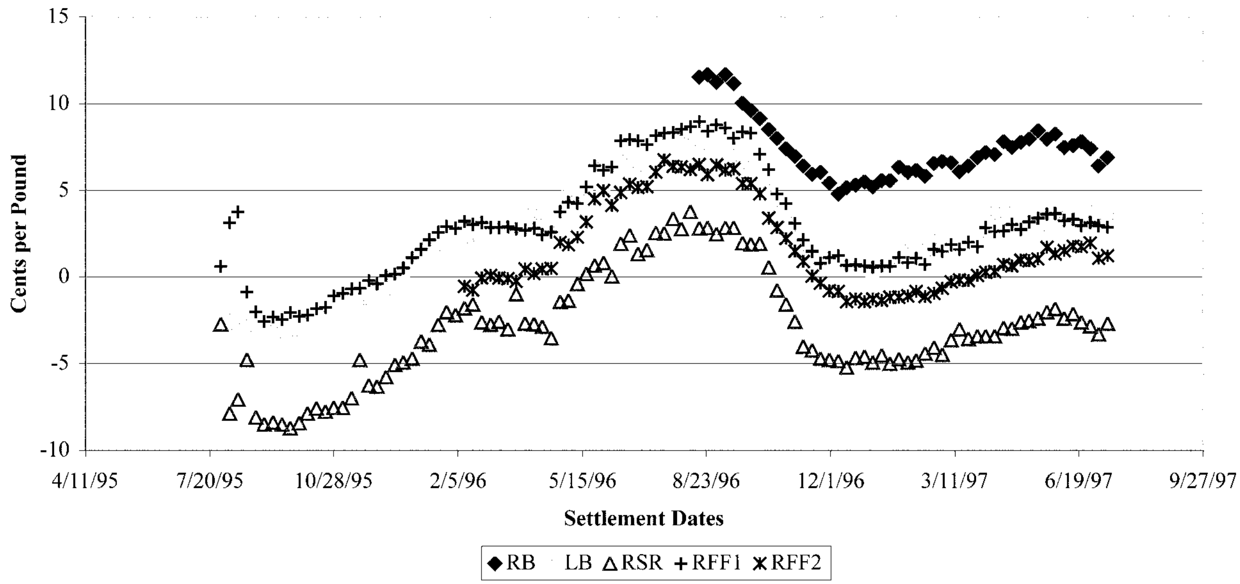

FIG. 2.—Common production shocks

Table 3
Longest Time Horizon Where Fixed Tournaments Offer Less Risk

Tournament Size	No. of Tournaments
25	49
10	19
5	8

These results show that broiler growers' dissatisfaction with settlement schemes based on tournaments is substantive in the sense that the league composition effect is statistically significant. The evidence also suggests that the logistics of the delivery of flocks to growers leads to a rapid dissipation of leagues over time. We found that organization of leagues in broiler tournaments can be approximated by the random league hypothesis after about five subsequent tournaments. Hence, the welfare importance of the league composition effect seems to be small for the production of broiler chickens. This suggests that the observed broiler tournament contracts offer higher welfare to growers than do piece-rate contracts.

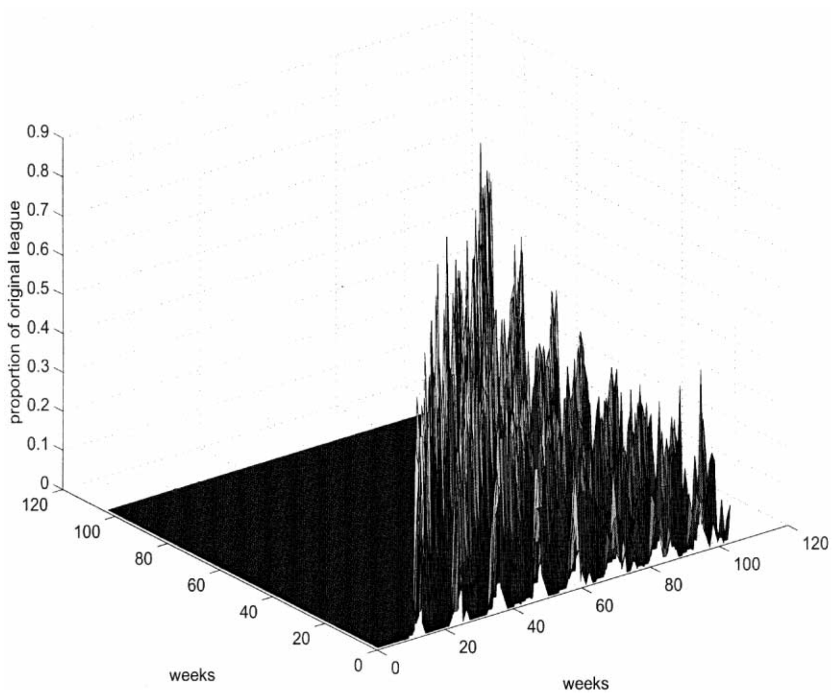

Fig. 3.—Dissipation of leagues in subsequent tournaments: contract RSR

Finally, the estimated league composition effect in our data is relatively small compared with the magnitude of common shock, which is precisely what we expect to be the case in an industry that would use relative performance compensation schemes. It is interesting to note that two other livestock industries, namely, turkeys and swine, which also contract the grow-out of animals with independent farmers, rarely (turkeys) or almost never (swine) use payments by relative performance schedules (Tsoulouhas and Vukina 1999). The fact that the profit centers in those industries typically contract with fewer growers than broiler profit centers and that the production cycle for turkeys and especially for hogs is longer than for broilers suggests that these industries may be less suitable for tournaments because their leagues would necessarily be more stable over time. Examining whether the league composition effect is the deciding factor for the prevalence of piece-rate contracts in those industries would be an interesting topic for further research.

Appendix

Here we provide the formal link between the theoretical model of Section II (eqq. [2]–[3]) and the contracts observed in the broiler industry described in Section III.A (eqq. [11]–[12]). Let the quantity of output be given by

$$q_{it} = \eta(1 - \theta_{it})z_{it},$$

where η is the target market weight of a broiler chicken, θ_{it} is the broiler mortality rate obtained by grower i at time t, and z_{it} is the number of baby chicks received. Let $x_{it} = -c_{it}/q_{it}$ be the negative of the individual grower's settlement cost; then equation (11) becomes

$$\begin{aligned} y_{it} &= Aq_{it} + Kq_{it}\left(\frac{1}{n}\sum_{j=1}^{n} x_{it} - x_{jt}\right) \\ &= [A\eta(1 - \theta_{it})z_{it}] + [K\eta(1 - \theta_{it})z_{it}](x_{it} - \bar{x}_t). \end{aligned}$$

Assuming that all growers have the same chicken house capacity, which is fixed over time, and consequently receive the same number of baby chicks and that the mortality rate is constant, the above equation reduces to equation (3).

Similarly, equation (12) becomes

$$\begin{aligned} y_{it} &= Aq_{it} + Kq_{it}(s + x_{it}) \\ &= [A\eta(1 - \theta_{it})z_{it}] + [K\eta(1 - \theta_{it})z_{it}](s + x_{it}) \\ &= [(A + sK)\eta(1 - \theta_{it})z_{it}] + [K\eta(1 - \theta_{it})z_{it}]x_{it}, \end{aligned}$$

which under the same set of assumptions reduces to equation (2).

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