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PERFORMANCE PAY AND PRODUCER INCENTIVES: ANALYZING BROILER CHICKEN PRODUCTION CONTRACTS

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Abstract

Modern contract theory is premised on the assumption that a principal has insufficient prior information to distinguish between high ability and low ability agents. The theory predicts that by offering agents an appropriate menu of contracts, the principal can mitigate the effects of this information asymmetry, and will maximize profits subject to information constraints by differentially assigning inputs to agents with different abilities. This paper tests this prediction in the context of broiler production. Over 90% of broilers are produced under contracts in which processors provide growers with essential inputs. We test the hypothesis that processors will utilize higher ability growers more intensively, and will provide them with fewer chicksfor producing a given amount of total output. While the first prediction would also emerge in a standard production model without hidden information, the second prediction is a direct consequence of the information rents obtained by high ability growers in the presence of hidden information. Our results provide strong but qualified support for this hypothesis. We identify a significant positive relationship between flock size and grower ability, that emerges only after controlling for the fact that processors assign higher ability growers fewer chicks per pound of chicken produced. This second effect would not be significant in a perfect information situation, indicating that hidden information does affect processor decisions. Furthermore, while we find no evidence that higher ability growers are assigned flocks more frequently, there is strong evidence that they are assigned flocks more consistently. Since the profitability of broiler production varies with relative prices, this last finding suggests that processors respond to price variability in a profit-increasing manner by differentiating their flock placements according to grower ability.

Contents

1. Introduction

Modern contract theory is premised on the assumption that a principal has insufficient prior information to distinguish between high ability and low ability agents. The theory predicts that by offering agents an appropriate menu of contracts, the principal can mitigate the effects of this information asymmetry, and will maximize profits subject to information constraints by differentially assigning inputs to agents with different abilities. This paper tests this prediction in the context of broiler production. In particular, we test the hypothesis that processors will utilize higher ability growers more intensively. This hypothesis would also hold in a perfect information setting, where the principal knows the ability of each agent. When growers have private information about their types, however, agency theory predicts that input-output ratios will be distorted relative to their neoclassical levels due to information rent considerations. Our analysis shows that such a distortion exists and is significant.

An agricultural production contract is a contract between a farmer (or grower) and a processor, shipper, or other principal that specifies one or more of the production practices used by the farmer. Production contracts between farmers and other stages of the agrofood chain have always been important in American agriculture. As a classic example of a principal-agent relationship, this kind of contract is of interest to economists for two reasons: First, contracts that include production specifications are becoming increasingly sophisticated, and the fundamental incentives underlying their design remain largely unexamined. If in practice such contracts correspond to the predictions of agency theory, there is a large body of theoretical literature which will aid the evaluation of the impact of these contracts on the welfare of industry members—in particular, the allocation of aggregate producer surplus among them—and overall industry performance. Second, production contracts provide an opportunity to test agency theory predictions against actual empirical observations. (Cf. the analysis of executive compensation contracts in such papers as Jensen and

Murphy (1990) and Gibbons and Murphy (1992) and the analysis of franchising arrangements in such papers as Lafontaine (1992) and Kaufmann and LaFontaine (1994)).

The broiler industry was one of the first agricultural sectors to widely employ production contracts.[1] Over 90% of broiler production is contracted, with the remainder primarily raised at processor-owned facilities. Due to the importance of contracting in the broiler industry, it is an ideal candidate for examining the incentives underlying contract design.

A typical contract design requires a broiler processor to provide chicks and feed to a grower, who provides the necessary labor and capital equipment. On average, a processor may contract with 100-200 growers for a single processing facility. In a typical contract, growers are paid on a per-pound basis. The base price per pound of chicken produced is adjusted for each grower depending on his "settlement cost" relative to the average settlement cost of the group of growers slaughtering flocks within a one- to two-week comparison window. A grower's settlement cost measures how efficiently he converts the processor-provided chicks and feed to final product. Growers with lower settlement costs receive a higher price per pound.[2] Thus, broiler production contracts commonly have a relative compensation element.

Other researchers have investigated broiler contracts. Knoeber (1989) credits the use of broiler contracts and relative compensation with encouraging productivity-improving innovation in the sector. Knoeber and Thurman (1995) compare the price, common production and idiosyncratic risk borne by growers and processors on a per-flock basis under existing contracts, counterfactual contracts without relative compensation, and a counterfactual spot market. They find that growers transfer most of their per flock risk to processors, relative to a spot market. Knoeber and Thurman

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[1] The fruit and vegetable industry has been another sector which has intensively utilized contracting. Elsewhere, we discuss contracts in the fresh and processed tomato industries (Goodhue and Rausser 1998, Goodhue 1997).

[2] The precise formula for settlement cost is

$$\mathsf{SC} = \frac{a \times chicks + b \times kilocalories}{pounds} \tag{1}$$

where pounds refers to pounds of live chicken produced and a and b are weights placed on the cost components that reflect processor costs per unit. Typically, a and b are fixed values for costs per chick and costs per feed calorie. In the sample used in this study, $a = 12$ and $b = 6$.

(1994) use grower performance records under a typical broiler contract and under a rank-order tournament contract to test predictions of tournament theory. They find some evidence that the processor grouped growers by ability. Allowing for grower-specific effects, they find evidence that better growers receive more chickens, and that these effects are larger under the rank-order tournament contract. While they note that this correlation can be at least partially explained by the fact that better growers own more chicken houses, they argue that it is is also consistent with the possibility that better growers are assigned more chickens per house. These two explanations have strikingly different implications: if the former is true, then better growers are being favored by producers while if the latter is true, they are being handicapped. Knoeber and Thurman also find evidence that lower-performing growers tend to hold their flocks for longer periods; they speculate that better growers may be being rewarded with more frequent flocks. An alternative, more intuitive explanation is that it may simply take longer for less capable growers to grow chickens of the desired weight.

Agency theory provides us with a framework for modeling these decisions. The theory generates testable hypotheses regarding flock placements and grower ability. Our work differs from previous work in two respects. First, we utilize an axiomatic measure of grower ability, which compares growers with each other using Varian (1984)'s weak axiom of cost minimization. Knoeber and Thurman (1994), on the other hand, use a grower-specific measure, and so cannot treat "grower ability" as a single explanatory variable. Second, we focus on the processor's decisions regarding flock placement. Reflecting actual broiler industry practices, we model the processor as controlling the size and timing of flocks placed with growers. Our first result confirms Knoeber and Thurman's 1994 finding that better growers receive larger flocks. However, rather than confirming their hypothesis that better growers are being assigned denser flocks (a hypothesis they could not test directly), we find evidence suggesting that, to the contrary, the processor is in fact assigning lower ability growers more chicks per pound of final product produced than higher ability growers. Our

analysis identifies a significant positive relationship between flock size and grower ability, once we control for this input effect. The simultaneous existence of these two relationships is due to incentive compatibility considerations (see the discussion of equations (4) and (6) on page 8 below). We also find that better growers receive flocks more consistently. This finding adds a new dimension to the analysis of risk transfer due to broiler contracts in Knoeber and Thurman (1995): while growers transfer price risk and some production risk to the processor on a per-flock basis, they exchange this risk for flock placement risk, since the processor determines the timing and size of flock placements. Further, the importance of this placement risk varies according to grower ability.

2. Model

Our empirical analysis is based on a principal-agent model with hidden information. The processor is modeled as the principal, and the growers as agents. All agents are assumed to be risk-neutral utility maximizers. At the time a grower initially signs a contract with the processor, he has private information about his ability to produce broilers efficiently. Appealing to the revelation principle, we formulate the processor's problem as the task of designing a menu of contracts that will induce each grower to truthfully reveal his ability to raise broilers.[3] We assume that the processor maximizes profits subject to a participation and incentive compatibility constraint for each ability type of growers. The participation constraint stipulates that any proposed contract must yield the grower at least his reservation utility. The incentive compatibility constraint requires that no grower can increase his utility by selecting a contract other than the one that the processor intends him to select.

We test a static revelation model in which growers' types are instantaneously revealed to the processor. An alternative approach would be to assume that the processor learns about growers'

[3] This contract menu consists of *implicit* contracts regarding total production quantities, marginal prices, and transfers between the grower and processor, such as the grower's investment in capital equipment. This menu is not the same as the explicit legal contract signed between the parties. Most importantly, the use of relative compensation for growers results in different *expected* wages for growers of different abilities, so that their marginal returns are ability-dependent (provided, of course, that comparison groups are not perfectly segregated by ability). For more on this distinction, see Goodhue (1997).

abilities over time.[4] Since only six to eight weeks are required to raise a single flock, a learning model might seem to be a more accurate representation of reality. On the other hand, there is a significant one-shot component to these relationships. As mentioned above, growers must invest in capital equipment to initiate a relationship with the processor. Broiler houses have a useful life of approximately ten years, and they are the primary determinant of growing capacity, i.e., the maximum size of a flock that can be placed with a given grower. By appropriately designing his contract menu, a processor can induce growers to reveal their types by their capacity decisions. That is, in equilibrium, each agent will build the capacity level, or number of broiler houses, required to fulfill the contract he has selected.

We illustrate this theory with the following simple case. Output $x_i = Q_i^{\rho} a_i^{1-\rho} t_i$, where Q_i denotes a composite nonlabor input, consisting of chicks and feed in fixed proportions. While the fixed proportions assumption is a simplification, it appears to be a reasonable one for two reasons: first, the processor provides the chicks for all growers, generally from a common genetic pool, and determines the amount and composition of the feed used for each flock. Second, growers are rewarded for incremental improvements in output relative to their use of the two inputs in fixed proportion. a_i denotes agent effort and t_i is the agent's type. Agents may be one of two types: high ability (h) or low ability (l), with $t_l > t_h$. We assume that the number of broilers produced is a fixed proportion of the number of chicks input, so that increased effort results in an increase in the output weight per chick. Note that with this interpretation, high ability agents can produce any amount of total output more cheaply than low ability agents can.

Agent i is risk-neutral and maximizes his utility, U_i, which is a function of income, y_i, and effort a_i, i.e., $U_i = y_i - d(a_i)$. We assume that additional units of effort are increasingly costly, i.e., $d(a_i) = a_i^{\phi}$, with $\phi > 1$. This implies that U_i is strictly concave in effort (or output). We restrict attention to affine compensation functions ($y_i = x_i W_i + T_i$) which are increasing in output.

[4] Murphy (1986) tests these two alternatives in the context of executive compensation.

We assume that the price of output is 1 and that each agent's reservation utility is zero. Letting p denote the probability that an agent's ability is high, the processor maximizes the following expression:

$$\max_{W_h, W_l, T_h, T_l, Q_h, Q_l} p\Big[x_h - W_h x_h - T_h - cQ_h\Big] + (1-p)\Big[x_l - W_l x_l - T_l - cQ_l\Big] \tag{2}$$

$$\text{s.t.} \quad y_i - d(a_i) \geq 0, i \in \{h, l\}$$

$$y_i - d(a_i) \geq y_j - d(a_{ij})$$

where a_{ij} is the effort that an agent of type i must expend to produce the output specified in the contract earmarked for j. Since agents are utility maximizers, solving for a_i is equivalent to solving for W_i. The components of this theoretical formulation correspond closely to the components of the actual processor-grower relationship. In theory, the principal makes a take it or leave it offer to the agents; in practice, the processor prepares the contracts which are offered to growers. W_i is the per-pound payment to growers. Under the settlement cost-based relative compensation system, when growers of both types are in a comparison group, high ability agents will receive a higher per-pound rate than will low ability growers. The lump-sum transfers correspond to growers' investment in the necessary capital equipment. Q_i corresponds to the chicks and feed provided by the processor. x_i is the pounds of chicken produced. a_i is labor expended by growers.

Under standard technical assumptions, the solution to the principal's problem has the following properties. Under the optimal contract menu, the high-ability agent will produce his first-best output level, i.e., the level the principal would require him to produce in the absence of private information. He will produce this level using the combination of effort and processor-supplied inputs that minimizes his production cost. He will receive utility in excess of his reservation level; the difference is referred to as his *information rent.* In contrast, the low ability agent will receive exactly his reservation utility but will not produce his first-best level of output. Instead, his output

will be distorted downward. Moreover, his mix of inputs and effort conditional on that output level will not be production cost-minimizing. Because high ability growers obtain information rents, the cost to the principal of effort exerted by low ability growers exceeds the perfect information cost of this effort. Consequently the contractual input-effort ratio for the latter will be higher than the first-best ratio for that type and (distorted) output level.[5] The effort and input allocations for our example are presented below. Note that a_h and Q_h are at their first-best levels, while a_l and Q_l are distorted. Further, the ratio of the nonlabor input to output, $\frac{Q_l}{x_l}$, will be higher for low ability growers than for high ability growers when each are producing their contractually-specified output levels, due to this informational distortion.

$$a_h = \left(\frac{1-\rho}{\phi}\right)^{\frac{1}{\phi-1}} \left(\frac{\rho}{c}\right)^{\frac{\rho}{(1-\rho)(\phi-1)}} t_h^{\frac{1}{(1-\rho)(\phi-1)}} \tag{3}$$

$$Q_h = \left(\frac{1-\rho}{\phi}\right)^{\frac{1}{\phi-1}} \left(\frac{\rho}{c}\right)^{\frac{\phi+\rho-1}{(1-\rho)(\phi-1)}} t_h^{\frac{\phi}{(1-\rho)(\phi-1)}} \tag{4}$$

$$a_l = \left(\frac{(1-\rho)(1-p)}{\phi}\right)^{\frac{1}{\phi-1}} \left(\frac{\rho(1-2p(\frac{t_l}{t_h})^{\frac{\phi}{1-\rho}})}{c}\right)^{\frac{\rho}{(1-\rho)(\phi-1)}} \left(\frac{t_l}{1-p(\frac{t_l}{t_h})^{\frac{\phi}{1-\rho}}}\right)^{\frac{1}{(1-\rho)(\phi-1)}} \tag{5}$$

$$Q_l = \left(\frac{(1-\rho)(1-p)}{\phi}\right)^{\frac{1}{\phi-1}} \left(\frac{\rho(1-2p(\frac{t_l}{t_h})^{\frac{\phi}{1-\rho}})}{c}\right)^{\frac{\rho+\phi-1}{(1-\rho)(\phi-1)}} \left(\frac{t_l}{1-p(\frac{t_l}{t_h})^{\frac{\phi}{1-\rho}}}\right)^{\frac{\phi}{(1-\rho)(\phi-1)}} \tag{6}$$

To implement this allocation, the principal chooses the following wages and lump sum transfers:

$$W_i = \frac{\phi a_i^{\rho+\phi-1}}{(1-\rho)t_i Q_i^{\rho}} \tag{7}$$

$$T_h = a_h^{\phi} - W_h x_h + a_l^{\phi} - a_{hl}^{\phi} \tag{8}$$

$$T_l = a_l^{\phi} - W_l x_l \tag{9}$$

[5] For details and a formal development, see Goodhue (1997).

(7) is determined by the utility-maximization problem facing the agents. From (8) and (9), the information rents received by the high-ability grower are $a_l^\phi - a_{hl}^\phi = a_l^\phi(1 - (\frac{t_l}{t_h})^{\frac{\phi}{1-\rho}})$. Clearly, these rents increase with the effort exerted by the low-ability grower and with the Cobb-Douglas weight $(1-\rho)$ on agent effort, and decrease with $\frac{t_l}{t_h}$ and the convexity of the function d relating effort and utility.

2.1. **Hypotheses.** The model above yields several testable hypotheses. The first of these is that higher ability growers will select contracts from the optimal contract menu which require them to raise more broilers than lower ability growers. Under reasonable parameter specifications, this output effect will dominate the input substitution effect discussed above, so that the processor will assign more of the composite input to higher ability growers (i.e., Q_h in (4) above will exceed Q_l in (6)). What "more input" means in practice, however, is not straightforward. The theoretical model ignores the time dimension of broiler production; it merely makes a static prediction about the relative size of Q_l and Q_h. For the purposes of empirical testing, we treat this as a prediction about relative input assignments over a fixed period of time. Empirically, the theoretical prediction would be supported if higher-ability growers received larger flocks, or more flocks during the sample period, or both. Evidence of the former would support the idea that higher-ability growers construct more broiler houses as part of their long-term *implicit* contract with the processor. While growers can vary flock density within a single house, their ability to do so is relatively limited, compared to the observed differences in average flock size across growers. Formally, in this section we test the following hypothesis:

Hypothesis 1. Contracts accepted by high-ability growers entail larger chicken assignments during the sample period than do contracts accepted by low ability growers. This may occur through

- Larger flocks.
- More frequent flock receipt.

2.1.1. *Flock size.* According to the above hypothesis, flock size should be positively related to grower ability. The size of a flock placed with a particular grower on a particular date is affected by demand conditions and production considerations other than grower ability. Higher wholesale prices for chicken should be associated with larger flock placements. Chicken demand tends to be seasonal, with the most demand occurring during the summer months, and relatively little demand in the winter. We capture these seasonal effects with monthly dummy variables.

A further complicating factor is that when the processor is deciding how many chicks to place with a grower, he must consider the information costs of his flock placements. For the incentive compatibility reasons discussed above (page 8), total production per given flock size should be larger on average for better growers, so the coefficient on the ability-total weight interaction variable should be negative. This will reduce the size of high ability growers' initial flock placements relative to those of low ability growers.

Errors are assumed to be independent across flocks, with identical distributions. The estimated equation, with predicted signs in parentheses, is the following, where CHICKS is flock size, α is the intercept, EFR is the measure of grower ability, WPRICE is the wholesale price of chicken, WEIGHT is the total ending weight of the flock, EFGAP is the ability-weight per chick interaction variable, d^k is the dummy variable for month k ($d^k_{ij} = 1$ if the slaughter date for flock j was in month k and $d^k_{ij} = 0$ otherwise), and ϵ_{ij} is an independent identically distributed error term for each flock:

$$\begin{aligned} \mathsf{CHICKS}_{ij} = \alpha &+ \underset{+}{\beta_{\mathsf{E}}}\,\mathsf{EFR}_i + \underset{+}{\beta_{\mathsf{WP}}}\,\mathsf{WPRICE}_{ij} + \underset{+}{\beta_{\mathsf{WT}}}\,\mathsf{WEIGHT}_{ij} \\ &+ \underset{-}{\beta_{\mathsf{EG}}}\,\mathsf{EFGAP} + \beta^k d^k_{ij} + \epsilon_{ij} \end{aligned} \tag{10}$$

2.1.2. *Time between flocks.* If better growers receive flocks more frequently, then the time between flocks should be negatively related to grower ability. The time between flocks is defined as the

number of days between the time a flock is harvested and the time the next flock is placed with that grower. The wholesale chicken price variable WPRICE should have a negative effect on the time between flock placements: that is, if the processor accurately predicts the wholesale price at the time of slaughter when placing flocks, the time between flocks will be reduced when higher prices are anticipated.

In addition, the time between flocks (HDIFF) is affected by capacity (MCHICKS), the length of the grow-out period (LENGTH), interaction variables, and monthly dummies (d_{ij}^k). If ability and capacity interact, the interaction variable (EFCAP) should negatively affect the time between flocks. Apart from its association with ability, the effect of an increase in capacity on the time between flocks is indeterminate. If bigger growers are more efficient, then we would expect them to receive flocks more frequently. If, however, the processor is concerned with issues such as smoothing weekly production, or managing the supply to respond to prices, then this may affect the time between flocks as well. Since larger flocks have more of an effect on these goals, they might be spaced further apart than smaller flocks. That is, the processor may schedule larger flocks on more fixed schedule than smaller flocks. The smaller flocks, used for a flexible response, might then show a shorter average time between flocks. For similar reasons, the sign on the coefficient of the length of the grow-out period can not be predicted a priori.

Price and the length of the grow-out period may interact to affect the time between flocks, although the sign of this effect (PRL) is indeterminate ex ante: the processor may slaughter flocks more quickly when prices are high, or may lengthen the grow-out period in order to sell heavier broilers. The ability-length interaction variable (EFL) captures the negative effect of grower ability on the length of the grow-out period, other factors being equal.

Errors are assumed to be independent, identically distributed random variables for each flock, denoted ϵ_{ij}. The equation for the time between flocks, including predicted signs for independent variables, is the following:

$$\begin{aligned}\mathsf{HDIFF}_{ij} &= \alpha + \underset{-}{\beta_{\mathsf{E}}}\,\mathsf{EFR}_i + \underset{-}{\beta_{\mathsf{WP}}}\,\mathsf{WPRICE}_{ij} + \underset{indet}{\beta_{\mathsf{MC}}}\,\mathsf{MCHICKS}_i \\ &+ \underset{indet}{\beta_{\mathsf{L}}}\,\mathsf{LENGTH}_{ij} + \underset{indet}{\beta_{\mathsf{PRL}}}\,\mathsf{PRL}_{ij} + \underset{indet}{\beta_{\mathsf{EFL}}}\,\mathsf{EFL}_{ij} \\ &+ \underset{indet}{\beta_{\mathsf{EFCAP}}}\,\mathsf{EFCAP}_{ij} + \beta^k d^k_{ij} + \epsilon_{ij}\end{aligned} \tag{11}$$

2.1.3. *Variance of flock placements.* A processor must consider fluctuations in chicken demand when making flock placement decisions. Knoeber and Thurman (1994) find significant variance across growers in the number of flocks produced over a given time period. If growers are heterogeneous in their production abilities, the processor is likely to utilize this heterogeneity when adapting to demand fluctuations, which would explain the observed variance. A processor might consistently place chickens with high ability growers to the degree allowed by demand conditions, and use the capacity of low ability growers to adapt to the remaining fluctuations in demand. If growers are risk-averse, then reducing the variability of placements will increase their utility.[6] Thus, by rewarding higher-ability growers with lower throughput variance, the processor may be able to reduce the cost of satisfying his incentive compatibility constraints, while at the same time managing his own risk more effectively. Accordingly, the variability of flock placements and flock sizes is hypothesized to depend negatively on grower ability.

Hypothesis 2. The processor more consistently utilizes the capacity of the high-ability growers, so that high ability growers have a lower variance of flock placements.

Other variables may affect the variance of the time between flocks. The mean time between flocks for a grower (MHDIFF) should increase the variance of the time between flocks. An increase in the average grow-out period (MLENGTH) should increase the variance of the time between

[6] Knoeber and Thurman (1995) examined how contract terms affect the distribution of risk across the processor and growers on a *per flock* basis; risk due to differences across flocks, or differences in the time between flocks was not considered.

flocks, since it will increase the variance of the length of the grow-out period.[7] An increase in capacity (MCHICKS) is likely to reduce the variance of flock placements. These variables are also likely to interact with each other in ways that affect the variance of the time between flocks. EFCAP denotes the ability-capacity interaction variable. EFDIFF denotes the ability-average time between flocks interaction variable. EFL denotes the ability-average length of the grow-out period interaction variable. LDIFF denotes the average length of the grow-out period-average time between flocks interaction variable. CAPDIFF denotes the capacity-average time between flocks interaction variable. LCAP denotes the average length of the grow-out period-capacity interaction variable. The error term ϵ_i is assumed to be an independent, identically-distributed random variable for each grower.

$$\begin{aligned} \mathsf{VHDIFF}_i = \alpha \quad & + \underset{-}{\beta_{\mathsf{A}}}\,\mathsf{EFR}_i + \underset{-}{\beta_{\mathsf{MC}}}\,\mathsf{MCHICKS}_i \quad + \underset{+}{\beta_{\mathsf{MH}}}\,\mathsf{MHDIFF}_i \\ & + \underset{+}{\beta_{\mathsf{ML}}}\,\mathsf{MLENGTH}_i \quad + \beta_{\mathsf{EFC}}\,\mathsf{EFCAP}_i \quad + \beta_{\mathsf{EFD}}\,\mathsf{EFDIFF}_i \quad + \beta_{\mathsf{EFL}}\,\mathsf{EFL}_i \\ & + \beta_{\mathsf{LD}}\,\mathsf{LDIFF}_i \quad + \beta_{\mathsf{CD}}\,\mathsf{CAPDIFF}_i \quad + \beta_{\mathsf{LC}}\,\mathsf{LCAP}_i \quad + \epsilon_i \end{aligned} \tag{12}$$

3. Data

A total of 478 usable observations of flocks grown by 70 different growers were obtained from the data set. Each observation included the number of chicks delivered to the grower, the number and pounds of live broilers produced, the pounds of feed delivered, the date the chicks were delivered and the date the broilers were shipped to the processing plant. Flocks placed between June 8, 1984, and November 8, 1984, were compensated at a base rate of \$0.032, with a minimum guaranteed payment of \$0.026 per pound. From November 9, 1984 through December 1985 the base payment

[7] This would of course not be the case if the processor was following a rule that dictates a fixed time between flocks for each grower. Under this scenario, however, the processor would not have any flexibility to respond to demand conditions.

was \$0.034, with a corresponding increase in the guaranteed minimum payment to \$0.028. The average settlement cost for each grower was calculated as the average cost for a comparison group of all the flocks slaughtered in an approximately two-week period. Growers with extremely low or high settlement costs outside a \$0.015 band around the average were excluded from the calculation of the average. (Information regarding contract parameters obtained from Knoeber (1989), Knoeber and Thurman (1994) and Knoeber and Thurman (1995).) The data set also included information on flocks reared under a tournament contract between November, 1981 and June, 1984. This portion of the data set was used to obtain measures of grower ability and capacity, as discussed below. The wholesale chicken price for the month in which each flock was slaughtered was obtained from United States Department of Agriculture Livestock and Poultry Situation and Outlook Reports.

4. Data Analysis

The contract data described above is used to test that grower performance is heterogeneous and that this heterogeneity affects processor decisions in a manner consistent with the predictions of an agency theoretic framework.

4.1. **Grower heterogeneity.** In order to consider sources of variance in grower performance, grower performances must vary significantly in the sample. Settlement cost is the measure of grower performance used by the processor. Essentially, settlement cost measures effectively the grower uses chicks and feed, the processor-provided inputs, to produce pounds of chicken.

The average settlement cost for the sample as a whole is 20.946 cents, with a variance of 0.46 cents. Examining Fig. 1, there appears to be a substantial amount of variation in growers' average settlement costs. This visual examination is confirmed by performing an analysis of variance on average settlement costs, using the GLM procedure in SAS. The hypothesis that mean performance across growers is equal is strongly rejected. (See Tbl. 1.) This provides statistical confirmation of

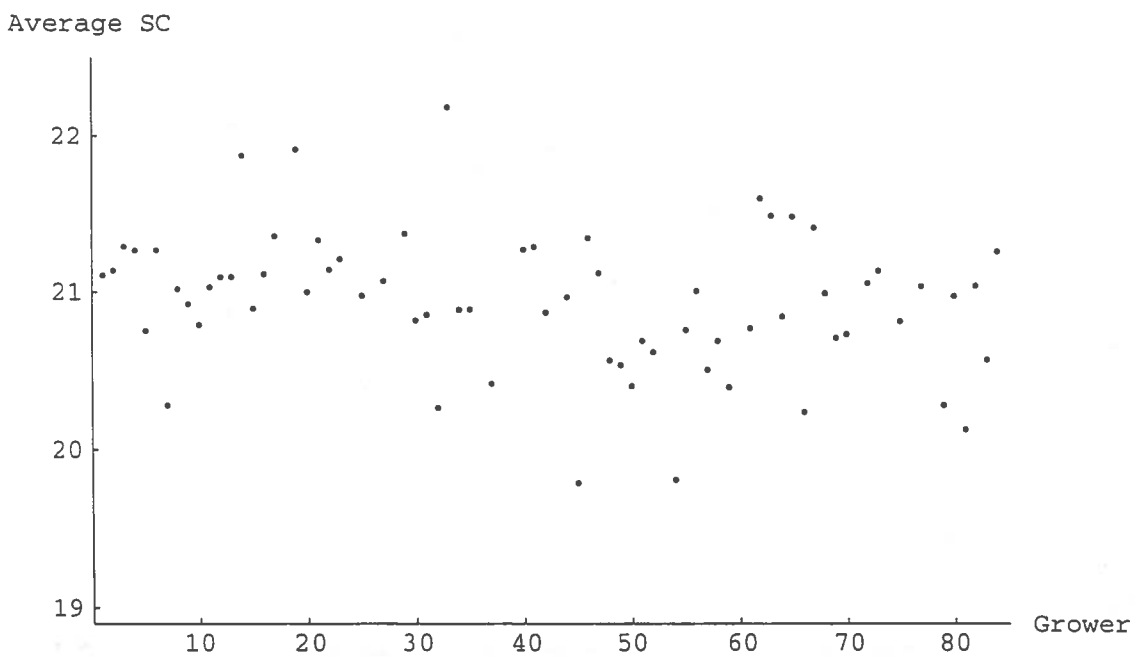

FIGURE 1. Average Settlement Cost by Grower

TABLE 1. Variation in Grower Settlement Costs

Dependent Variable: Settlement Cost (SC)					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	69	65.608669	0.950850	2.53	0.0001
Error	408	153.416941	0.376022		
Corrected Total	477	219.025610			
	R-Square	C.V.	Root MSE	SC Mean	
	0.299548	2.927503	0.6132	20.946	

the observations in the broiler industry and other agricultural products that there are consistent performance differences across growers.

In our econometric analysis, we restrict our sample to growers with at least three flocks during the sample period (due to variance evaluations), for whom data is available during the tournament period for computing ability measures. These restrictions result in a sample of fifty growers and 365 observations. The hypothesis that the growers in this subsample are homogeneous in performance is also strongly rejected.

4.2. **Grower ability measures.** Even if performance differences between growers exist, they cannot affect the integrator's decisions unless they are systematically related to some grower attribute

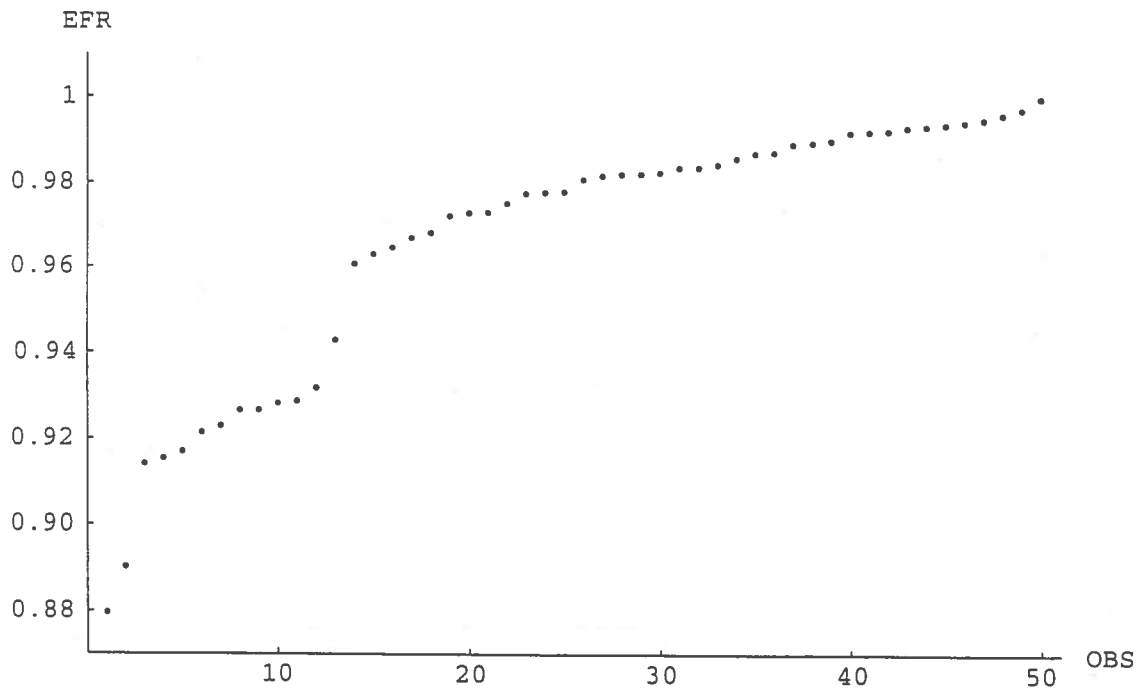

FIGURE 2. EFR Ability Measure

which the integrator can measure or infer in some way. In this paper we refer to this attribute as ability. Our measure of grower ability is based on the weak axiom of cost minimization (Varian 1984).[8] The weak axiom of cost minimization states that a grower can not be minimizing production costs if his costs are greater than those of any other grower producing at least as much output. In its original formulation, a flock will fail the axiom's test if it fails a single comparison. Following Hermalin and Wallace (1994), we construct an efficiency ratio for each grower i (EFR_i), which summarizes the number of times he passes Varian's cost-minimization test for all his flocks as a share of all eligible pairwise comparisons. This measure is shown for all growers in Fig. 2. In the current context, the cost minimization test may result in a downward bias in the scores obtained by higher ability growers, for the following reason. Our theoretical model predicts that better-ability growers will build more capacity and will tend to have larger flocks. If production outcomes are dependent upon a stochastic process, then a high ability grower with a large flock may realize a particularly

[8] This flexible approach has been applied in other agricultural contexts (Ray and Bhadra 1993, Tauer 1995, Tiffin and Renwick 1996).

good outcome. Other high-ability growers with similarly-sized flocks will fail the two-way comparison. Low-ability growers with sufficiently smaller flocks will still have smaller total costs than the extremely efficient large grower, so they will pass the two-way comparison. As a result of this asymmetry, if these shocks are evenly distributed by flock size (or by grower ability), large growers will fail a larger share of their two-way comparisons than small growers in expectation, regardless of their actual ability. Thus, this measure of grower ability may understate the relative ability of large flock (high capacity) growers. The effect of this bias is that our hypotheses are *less* likely to be validated empirically.

4.3. **Results: grower ability and flock placements.** In this section, we test for evidence that grower heterogeneity affects processor flock placement decisions.

4.3.1. *Flock size.* To test whether higher-ability growers receive larger flocks, we regress flock size on the following explanatory variables: grower ability; the wholesale price of chicken in the month the flock was slaughtered; the final weight of the flock; monthly dummies to capture seasonal effects; and a term measuring the interaction between grower ability and the final weight per chick placed. We found evidence of autocorrelation in our initial OLS analysis, although the hypothesis of homoskedasticity can not be rejected. Regression results controlling for autocorrelation are reported in Tbl. 2.

The monthly dummies were insignificant. With the exception of the wholesale price variable, all remaining coefficients are significant at the 1% level and have the predicted signs. Grower ability and the ability-weight per chick interaction variable account for an economically important share of overall variation in the data; other things equal, a 10% increase in a grower's efficiency ratio would lead to a flock that was 4,000 chicks larger, which is approximately 8% of the mean flock size for the sample as a whole. The interaction variable has a coefficient with a magnitude roughly a third of the ability measure. Note that the coefficient on the interaction variable EFGAP is negative. This relationship is predicted by our agency theory model: the negative sign indicates that lower ability

TABLE 2. Testing Effect of Ability on Flock Size

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	175886284651	11725752310	7584.372	0.0001
Error	349	539568390.22	1546041.2327		
Corrected Total	364	176425853041			

R-Square	Adj. R-Square	Root MSE	CHICKS Mean	C.V.
0.9969	0.9968	1243.39906	49625.47945	2.50557

White test	DF 63	ChiSq value	70.9872	Pr > ChiSq	0.2289

Asymptotic test for autocorrelation: 1.6430

	Parameter Estimates	Standard Errors
INTERCEPT (α)	6217.767842	8984.7030174
EFR* (ability)	40303	4322.6629571
WPRICE (wholesale price of chicken)	88.761910	165.81148739
WEIGHT* (total production)	0.264618	0.00143988
EFGAP* (EFR * weight per chick)	-13518	366.19244310

Coefficients for monthly dummies not reported.
* significant at 1% level

growers are assigned more chicks for each pound of chicken that they produce. On the other hand, if better growers were handicapped with denser flocks, as Knoeber and Thurman (1994) argue, we would expect the sign of EFGAP to be the opposite of the sign we obtain. Further, in a perfect information neoclassical world this interaction variable would not be significant, because the ratio of the composite nonlabor input to output would be invariant with respect to grower type. Thus, the sign and significance of the variable EFGAP indicate that information asymmetries affect the processor's production decisions in the manner predicted by agency theory.

To highlight the role played by WEIGHT and EFGAP in the regression, we plot flock size against the ability measure in Fig. 3. Clearly, the plotted relationship is negative. Given the results of the regression, we can infer that the simple correlation between ability and flock size is overwhelmed by the relationship between flock size and total output.

4.3.2. *Time between flocks.* In order to see whether or not better growers receive flocks more frequently, a variable HDIFF is constructed to measure the time between flocks. This variable is defined

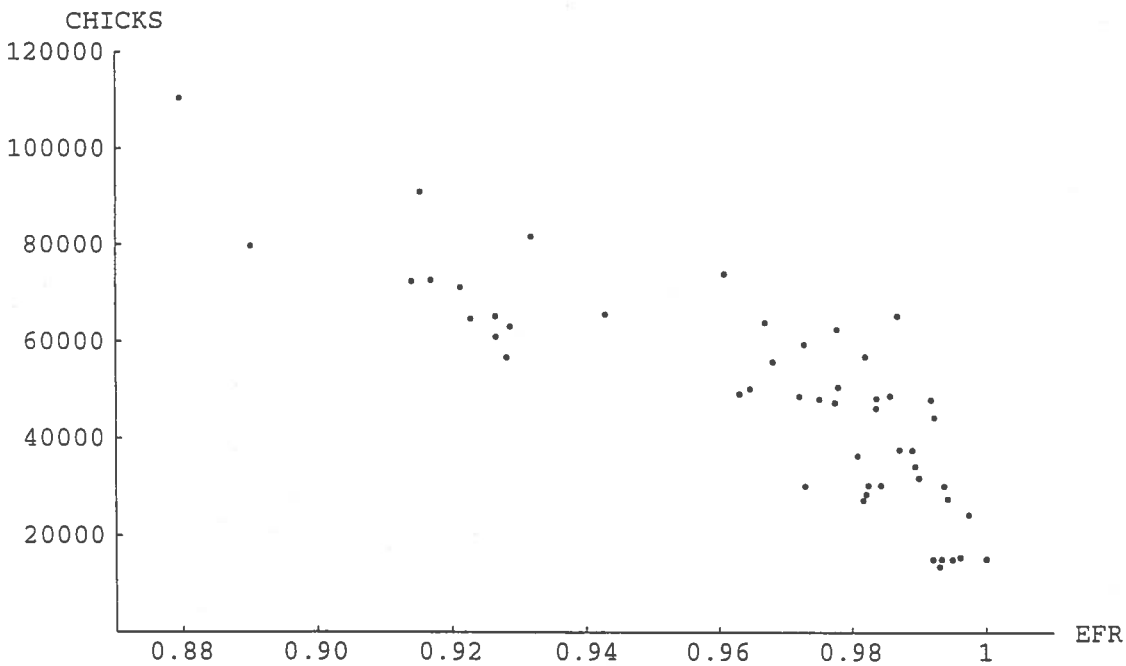

FIGURE 3. Average Flock Size by EFR Ability Measure

as the number of days between the time a flock is harvested and the next flock is placed with that grower. The mean time between flocks is 15.85 days, just over two weeks. The number of days between flocks varies considerably, however, with a minimum value of 7 days and a maximum value of 201 days. Since the underlying conditions determining the excessively long intervals between flocks are unknown, observations with over a two and a half month gap between flocks were eliminated from the analysis. Two and a half months is slightly above the average time between placements; any period at least this long between flocks meant that the grower missed an entire cycle of growing a flock and preparing the facilities for another flock. The data set does not provide any information about whether these extremely long intervals were due to the processor's flock placement decision, or to decisions made by the grower, such as to grow flocks only during certain seasons. Since these intervals are longer than an average production cycle and we do not know who determined their length, they are not considered for analyzing the factors affecting the processor's flock placement decisions. After removing these extremely long intervals, the maximum time between flocks is 46 days, and the mean time between flocks is 14.43 days. The standard deviation of the time between

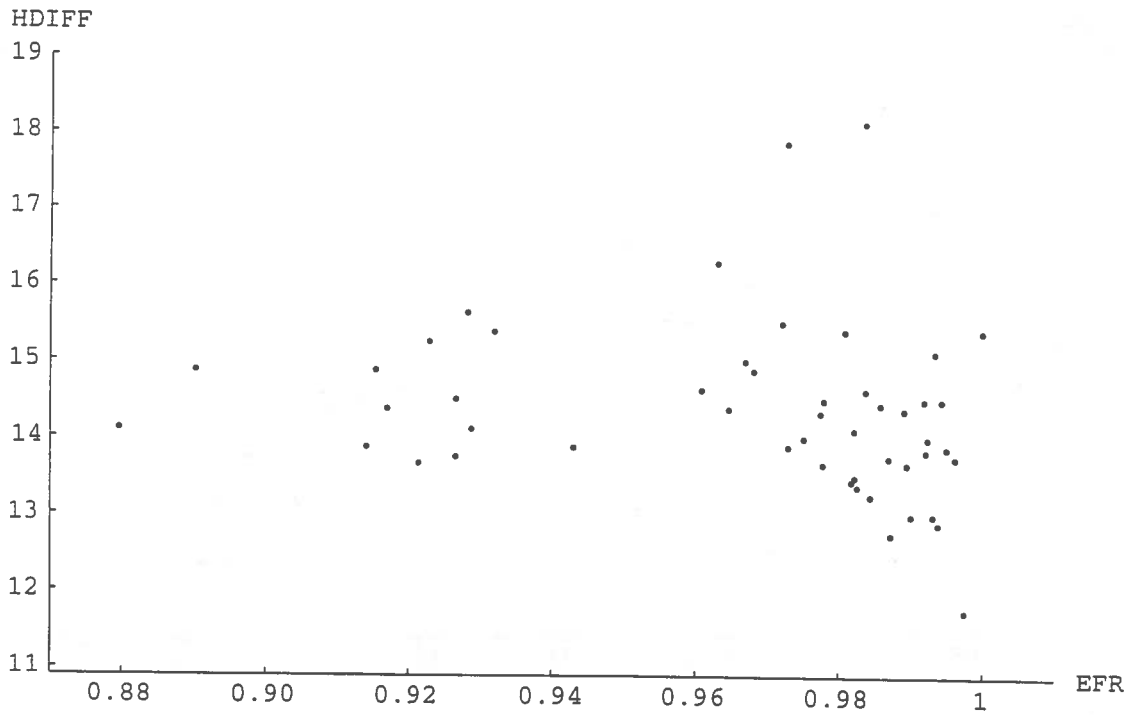

FIGURE 4. Average Time between Flocks by EFR Ability Measure

flocks for the sample as a whole is 3.79 days. If better growers receive flocks more frequently, as predicted, then there will be a negative effect of the ability measure on the time between flocks.

Fig. 4 plots the relationship between grower ability and the grower's average time between flocks. Consistent with the figure, Tbl. 3 shows that the ability measure did not have a significant effect on the time between flocks. The only significant coefficient at the 5% level was the wholesale price, with its predicted negative effect. The wholesale price-grow-out length (PRL) coefficient was weakly significant and positive. Of the monthly dummies, which are not reported in the table, March, April, August, September and October were negative and significant at the 1% level, relative to the December base.

4.3.3. *Variance of flock placements.* We hypothesized that the variability of flock placements and flock sizes depends negatively on grower ability, so that an increase in ability should decrease variability. To test this relationship, we regress the variance of time between flocks for each grower

TABLE 3. Testing Effect of Ability on Time between Flocks: EFR

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	18	2144.18005	119.12111	13.471	0.0001
Error	346	3059.51858	8.84254		
Corrected Total	364	5203.69863			

R-Square	Adj. R-Square	Root MSE	HDIFF Mean	C.V.
0.4120	0.3815	2.97364	14.35616	20.71334

White test	DF 106	ChiSq value	61.9897	Pr > ChiSq	0.9998

Asymptotic test for autocorrelation: 1.624

	Parameter Estimates	Standard Errors
INTERCEPT (α)	271.682840	158.16338889
EFR (ability)	25.244261	128.72932703
WPRICE* (wholesale price of chicken)	-5.286315	2.22785412
MCHICKS (grower capacity)	-0.000235	0.00022227
LENGTH (length of growing period)	-4.493428	3.39098115
PRL* (WPRICE * LENGTH)	0.101839	0.04847578
EFL (EFR * LENGTH)	-0.968128	2.71361764
EFCAP (EFR * MCHICKS)	0.000246	0.00022724

Coefficients for monthly dummies not reported.
* significant at 5% level

on ability, capacity, each grower's average time between flocks, each grower's average grow-out time, and interaction variables accounting for how these variables influence each other.

As shown in Tbl. 4, both ability and the mean time between flocks have the predicted negative and significant effects on the variance of flock placements. Both capacity and the mean grow-out time have insignificant effects. Coefficients on the variables accounting for interactions between the mean time between flocks and the other regressors were all significant except for the average grow-out period interaction variable coefficient. The remaining interaction variable coefficients were insignificant.

The observed relationship between ability and flock variability highlights a risk property of broiler production contracts. While these contracts may transfer much *per flock* price and production risk from growers to the processor (Knoeber and Thurman 1995), growers exchange this risk for throughput risk; that is, the size and the timing of the flocks they raise is determined by the

TABLE 4. Testing Effect of Ability on Variance of Time between Flocks

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	53034621.656	5303462.1656	83.599	0.0001
Error	40	2537557.4881	63438.937203		
Corrected Total	50	55572179.144			

R-Square	Adj. R-Square	Root MSE	VHDIFF Mean	C.V.
0.9543	0.9429	251.87087	233.55552	107.84197

White test	DF 43	ChiSq value	36.6354	Pr > ChiSq	0.7423

Asymptotic test for autocorrelation: -0.1928

	Parameter Estimates	Standard Errors
INTERCEPT* (α)	379151	155617.96471
EFR* (ability)	-376103	153606.06911
MCHICKS (capacity)	-0.372127	0.22712598
MHDIFF** (average time between flocks)	-10340	1667.7065867
MLENGTH (average growing period)	-5051.312547	3175.8976311
EFCAP (EFR * MCHICKS)	0.059138	0.09369903
EFDIFF* (EFR * MHDIFF)	10028	1894.4057520
EFL (EFR * MLENGTH)	4980.710559	3099.1026778
LDIFF (MLENGTH * MHDIFF)	6.949598	13.84820780
CAPDIFF** (MCHICKS * MHDIFF)	0.008505	0.00170353
LCAP (MLENGTH * MCHICKS)	0.004207	0.00547018

** significant at 1% level, * significant at 5% level

processor. Our regression result indicates that the importance of this risk depends significantly upon grower ability.

5. CONCLUSION

5.1. **Results.** Econometric examination of producer performance under broiler contracts confirmed that heterogeneity among producers exists, and that it affects processor decisions regarding flock placements. Growers demonstrated significant differences in their settlement costs during the sample period. These differences were significantly affected by grower ability. Higher-ability growers tended to receive larger flocks, and to receive flocks more consistently. Further, the relationship between initial flock size and output varied according to grower ability in precisely the manner predicted by agency theory. The ability-based distortion is due to the effect of input assignments on the information rents received by high ability agents. By distorting the input-output ratio up

from its neoclassical production cost minimizing level for low-ability agents, the processor increases total profits. In the absence of hidden information, this effect would not exist.

Our results highlight some of the forces that determine the design of agricultural production contracts. Anecdotally, differences in growers' production abilities are widely recognized by integrators in the broiler industry and for other agricultural products such as strawberries, lettuce, and fresh and processed tomatoes. Here, these ability differences were shown to affect a broiler processor's flock placements.

5.2. **Lessons.** Our empirical results support agency theory predictions. This consistency implies that economic theory can offer insights into agricultural vertical coordination relationships. Agency theory predicts that these relationships will be designed to maximize the gains to the principal. With heterogeneous agents, high-ability agents capture some returns above their reservation utility level, but low ability agents are held to their reservation utility level in equilibrium.

This theoretical result has a direct lesson for participants in such contracts. If a grower can imitate another grower's output at a lower production cost due to better abilities or other factors, then the integrator must pay him the production cost difference, in addition to the actual costs and his reservation utility. If a grower is unable to imitate another, then he will be compensated only for his production costs and reservation utility. The variance of the time between flocks is another source of income variance for growers which has been underemphasized in past analyses. In other words, the returns and risks borne by growers may depend upon their abilities relative to other growers.

5.3. **Implications.** This observation in turn suggests a potential role for the government in such non-market relationships. If growers are unsure of their relative abilities, it will be more difficult to estimate their returns from contracting. If the government collected information on contract terms and contract outcomes, this would aid producers in evaluating their options.

Agency theory can provide further predictions regarding the likely evolution of the design of agricultural production contracts. Principals, such as broiler processors, can reduce the information rents they must pay to high ability agents by limiting the role of ability or skill in the production process. They can also limit such information rents by collecting information regarding growers' abilities *prior* to offering a contract menu. In some products, principals require farmers to share financial and production records from earlier years with them before a contract is signed. Agency theory would predict that such measures will be increasingly utilized.

Agricultural production contracts offer a potentially important venue for testing the predictions of agency theory. Here, we tested and confirmed some basic theoretical predictions using broiler contract data. As these production contracts become increasingly sophisticated in design, they will provide additional opportunities for testing agency theory.

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