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WORKING PAPER NO. 858, REV.

PROCESSOR PLACEMENTS AND PRODUCER INCENTIVES: ANALYZING BROILER CHICKEN PRODUCTION CONTRACTS

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Abstract

Recent theoretical work on agricultural contracts has utilized agency theory. Most of this work considers a moral hazard problem, and assumes that producers are homogeneous, so that there is no adverse selection problem. We utilize a sample of producer performance under a broiler production contract to confirm that heterogeneity exists. We model the principal's decision process and test predictions regarding how heterogeneity will affect the principal's decisions. We attempt to differentiate between symmetric and asymmetric information cases. We find some support for our hypotheses, including evidence that adverse selection may affect the processor's decisions.

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Recent theoretical work on agricultural contracts has utilized agency theory to examine the incentives underlying the design of these contracts. In a typical agency problem, the objective function of one player, the principal, is dependent on information known only to the other player (or players), the agent(s). In order to maximize his objective, the principal must induce the agent to reveal this information. The information may be actual information, such as the agent's ability, in which case the problem is referred to as an adverse selection problem, or it may be an action undertaken by the agent, which is a moral hazard problem. In some cases, both information problems may exist. Most of the existing work focusing on agricultural contracts addresses the implications of the existence of a moral hazard problem, and assumes that producers are homogeneous, so that there is no potential for an adverse selection problem. It has long been established, however, that producers are heterogeneous in ways that affect their production outcomes when they are independent producers. Accordingly, producer heterogeneity is likely to affect production outcomes under contact, regardless of whether there is an adverse selection problem or not.

In this paper, we utilize a sample of producer performance under a broiler production contract to confirm that heterogeneity exists. We model the principal's decision process and test predictions regarding how this heterogeneity will affect the principal's decisions. We also attempt to distinguish between symmetric and asymmetric information cases. We find some support for our hypotheses, including evidence that adverse selection may affect the processor's decisions.

Tsoulouhas and Vukina, Hueth and Ligon, and Goodhue (in press) utilize theoretical and numerical analysis to demonstrate that contract designs are consistent with agency theoretic predictions. Unfortunately, consistency is not a sufficient basis for designing recommendations for industry members and policymakers, since it is generally possible to formulate alternative theoretical explanations for contract provisions that result in empirically indistinguishable outcomes Goodhue (1999). We

address the possibility of observational equivalence using a two-step process: We present the simplest theoretical model with perfect information that results in our testable hypotheses, although these hypotheses may also be derived from an adverse selection model. We then test an additional hypothesis that will emerge only in the presence of adverse selection.

Due to the limited size of our sample, further testing of this relationship is desirable. If the importance of adverse selection considerations can be established, there are a number of insights from agency theory that we can use to understand these contracts. If asymmetric information influences contract design, this 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. If information is symmetric, then growers will be compensated in excess of their production costs and reservation utilities only to the extent that they have the bargaining power to do so. These observations in turn suggest 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. If asymmetric information is currently an important consideration, processors and other principals would increase their profits by reducing its importance. 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.

1. BROILER CONTRACTS: PREVIOUS LITERATURE

The broiler industry was one of the first agricultural sectors to widely employ production contracts. 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. Unfortunately, there is limited data available for doing so. The one notable exception is the data set collected and used by Charles Knoeber and Walter Thurman of North Carolina State University (Knoeber, Knoeber and Thurman (1994), Knoeber and Thurman (1995)). This analysis employs that data set as well.

A typical contract requires a broiler processor to provide chicks and feed to a grower, who provides the necessary labor and capital equipment. The primary component of this capital equipment is broiler houses. On average, a processor may contract with 100-200 growers for a single processing facility. Most contract growers are paid on a cents per pound delivered to the plant basis. Other pay bases reported for the industry include cents per square foot per week or month, dollars per 1,000 birds placed, dollars per 1,000 pounds raised, cents per bird delivered to the plant, dollars per 100 birds delivered to the plant. In most cases, the base payment is adjusted based on feed conversion rates and other processor costs, such as fuel and medication (Clouse). In many instances, these adjustments are based on a grower's relative performance. In other cases, a fixed performance standard is used.

In the sample analyzed here, 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. The precise formula for

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settlement cost in the sample is

$$SC = \frac{12 \times chicks + 6 \times kilocalories}{pounds} \tag{1}$$

where pounds refers to pounds of live chicken produced and the weights placed on the cost components reflect processor costs per unit. The settlement cost formula rewards growers with lower feed conversion rates, lower mortality rates, and increased liveweights. These provide incentives for better flock management by growers, since genetic and feed ration influences on these measures are generally viewed as common factors for growers in a given comparison group (Knoeber). On the other hand, variations in genetics and feed, plus mismeasurement of feed are common grower complaints (Clouse).

Knoeber credits the use of broiler contracts and relative compensation with encouraging productivity-improving innovation in the sector. Using a transaction cost analysis, he argues that using contract production reduced the disadvantages of using tournaments to compensate growers, while leaving the benefits of doing so largely intact. Further, the use of tournaments protected growers from common production shocks, so that they were more willing to experiment with innovations desired by the processor. Since the processor was better placed to absorb the risks of experimentation and had greater incentives to innovate than individual growers, this increased the rate of technical change in the sector. Knoeber follows Lazear and Rosen and observes that a relative compensation scheme can eliminate variance due to exogenous common shocks.

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 (1994) use grower performance records under a typical broiler contract with relative compensation, which they refer to as a LRPE (linear relative performance evaluation) contract, and under a rank-order tournament contract to test three predictions of tournament theory: 1.) changes in the level of prizes that leave prize differentials unchanged will not affect performance, 2.) in mixed tournaments, more able growers will choose less risky strategies than mless able growers will choose, and 3.) A processor will attempt to either handicap growers of unequal ability or homogenize tournaments by grower ability in order to mitigate the disincentives associated with a mixed tournament. They find evidence consistent with all three of their predictions.

They find some evidence that the processor grouped growers by ability. Allowing for grower-specific effects through grower dummy variables, 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. In their analysis, they control for the effect of the number of houses with grower dummy variables. Hence, their evidence suggests that better growers are handicapped with denser flocks per house. Knoeber and Thurman also find evidence that lower-performing growers tend to hold their flocks for longer periods; they speculate that better growers mày 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.

The comparison group we analyze here is not a true rank order tournament. As explained by Knoeber and Thurman (1994), the use of a linear relative performance evaluation preserves marginal incentives to a much greater degree, since winning the relative evaluation by a large amount results in a correspondingly larger prize. As they also note, the presence of a minimum payment clause will distort incentives for lower ability growers, who may choose to exert relatively little effort and receive the minimum level of compensation.

Goodhue (in press) constructs a theoretical model of broiler processors' flock placement decisions when growers are heterogeneous and their ability is unknown ex ante to the processor. This agency theoretic analysis generates a prediction that the processor assigns better ability growers fewer chicks per pound of chicken produced. This theoretical analysis also demonstrates that the processor's use of average grower cost to calculate relative compensation measures is not a sufficient statistic for the realization of common uncertainty when growers are heterogenous.

We generate testable hypotheses regarding flock placements and grower ability using a simple model of processor profit maximization. Our analytical framework differs from the current literature in two respects. First, we utilize an axiomatic measure of grower ability, which compares growers with each other using Varian's weak axiom of cost minimization. Knoeber and Thurman (1994), on the other hand, use grower-specific dummy variables, and so cannot treat "grower ability" as a single explanatory variable. Second, we focus on the processor's decisions regarding flock placement with heterogeneous growers and attempt to distinguish between symmetric and asymmetric information explanations for these placement decisions. 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 weak 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. The simultaneous existence of these two relationships suggests that adverse selection considerations may affect the broiler processor's flock placement decisions.

We find weak evidence suggesting that better growers have a lower variability of flock placements. Although the coefficient is not statistically significant in our 50 grower sample, it is economically important in magnitude. 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. Of course, the practical importance of contract risk properties is dependent on the relative risk aversion of the two parties, as well as considerations such as bankruptcy constraints (addressed in Tsoulouhas and Vukina). We remain agnostic about risk preferences, since risk aversion is not necessary to obtain our predictions.

2. THEORETICAL MODEL

We model in the simplest possible fashion the allocation decision of a processor allocating flocks among heterogeneous growers, and derive testable hypotheses regarding the mean and variance of flock placements as a function of grower ability. Following this derivation, we discuss the effects of asymmetric information on the processor's decision problem, and how an asymmetric information problem would manifest itself in the empirical analysis.

2.1. **Perfect Information.** Consider a risk-neutral, profit-maximizing processor who faces a stochastic, perfectly elastic demand curve. He observes the position of the demand curve before making his flock placement decisions.[1] The processor has the option of placing flocks with two growers. One grower is a high ability grower who can produce broilers more cheaply than the low ability grower can. Grower E can produce up to K_E broilers at a constant marginal cost of MC_E, and grower I can produce up to K_I broilers at a constant marginal cost of MC_I, where $MC_E < MC_I$. We make no assumption about the relative magnitude of K_E and K_I. For convenience, we assume that the processor has no additional production costs. The processor makes the following production decisions depending on the price of chicken, P: if $P < MC_E$, the processor chooses to not produce.

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[1] This assumption simplifies our analysis, but does not affect the general conclusions of our model regarding differences in flock placements across growers of different ability. We are not concerned with the processor's ability to forecast wholesale chicken prices, although that is an interesting question in its own right.

If $MC_E < P < MC_I$, the processor places K_E chickens with grower E. If $MC_I < P$, the processor places K_E chickens with grower E and places K_I chickens with grower I, for a total production level of $K_E + K_I$.

Consider a particularly simple distribution for the price of chicken: with probability 0.5 $MC_E < P < MC_I$, and with probability 0.5 $MC_I < P$. Each period the processor chooses whether or not to place a flock with each grower.[2] Over n periods, the processor will place n flocks with grower E, and (in expectation) $0.5n$ flocks with grower I. There will be no variance of placements for grower E, while grower I will face a placement variance of $0.25n$. Hence, we obtain the following testable hypotheses:

Hypothesis: High cost (low ability) growers will have less frequent flock placements than low cost (high ability) growers.

Hypothesis: High cost (low ability) growers will have a higher variance of flock placements than low cost (high ability) growers.

Now consider the decision facing growers who must decide how much to invest in capacity. The marginal cost of capital is assumed to increase at an increasing rate, and is identical for all growers, regardless of ability. Growers choose their capacity level knowing the processor's flock placement rule and the lifetime of the capacity units. Assume that growers receive the price of chicken (the processor makes zero profits), or their marginal cost per unit whenever the processor places a flock with them. Since high cost (low ability) growers have a lower expected return, they will invest in less capacity than will low cost (high ability) growers. Since the processor will place flocks to the grower's capacity limit, a low ability grower will receive smaller flocks. We summarize this as our third testable hypothesis:

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[2] We abstract from timing considerations; that is, if a processor places a flock with a grower in week 1, the grower will not be able to take another flock until week 8 or so. Instead, we consider the simpler case where each period the processor chooses whether or not to place a flock with each grower. This simplification can be viewed as representing the processor's choice among his available growers (those without flocks) at any point in time.

Hypothesis: High cost (low ability) growers will have lower capacity and smaller flock placements than low cost (high ability) growers.

2.2. **Effects of Asymmetric Information.** In the perfect information model described above, the processor knows each grower's ability and corresponding marginal cost. There are at least two alternative information regimes. The first is that the processor does not know growers' abilities, and must learn them over time. The second is that the processor does not know growers' abilities and designs his contracts with the growers in a fashion which induces growers to reveal their true abilities. We consider the second possibility in more detail. We do not consider the first, more complicated, possibility, since the data we use for our empirical analysis does not provide us with sufficient information to distinguish between these two explanations.

The theoretical solution for the second possibility may be found by appealing to the revelation principle of agency theory. The solution will result in an outcome where low ability growers receive their reservation utility and high ability growers will receive in excess of their reservation utility. This additional utility is referred to as information rents. It is the cost to the processor of inducing growers to truthfully reveal their types. Goodhue (in press) establishes theoretically that the principal will distort his provision of an input to low ability agents, such as chicken flocks to high cost producers, in order to reduce his information costs. In particular, he will increase the input/output ratio for that input relative to its first best level for that output level. In the context of flock placements, information costs will increase flock sizes for low ability growers, other things being equal. In the next section, we discuss how we attempt to capture this effect econometrically.

Hypothesis: Information costs will distort flock sizes upward for low ability growers, other things being equal.

3. EMPIRICAL MODEL

In order to test our hypotheses, we construct a system of equations describing the production of a flock of broilers. First, the processor decides when to place a flock with a given grower. We hypothesize that the processor will place more flocks with higher ability growers over any given period of time. In practice, this means that we would expect to see a shorter time between flocks (on average) for higher ability growers. We refer to a grower's ability measure as his EFR. We define the time between flocks as the number of days between the time a flock is harvested and the time the next flock is placed with that grower. The time between flocks, HDIFF is likely to be affected by market conditions, so we include the wholesale price of chicken, WPRICE, which should reduce the time between flocks. The time between flocks, HDIFF is likely to be affected by market conditions, so we include the wholesale price of chicken, WPRICE, which should reduce the time between flocks. The time between flock placements may be affected by other production considerations. For example, if the processor places flocks with all growers along a given route at the same time, then the length of the production period for each flock, LENGTH, should determine the time between flocks, with a negative sign.[3] Accordingly, we test the following equation:

$$
\begin{aligned}
\text{HDIFF}_{ij} \;=\; \alpha \;&+\; \underset{(-)}{\beta_{\text{E}}\,\text{EFR}_i} \;+\; \underset{(-)}{\beta_{\text{WP}}\,\text{WPRICE}_{ij}} \;+\; \underset{(-)}{\beta_{\text{L}}\,\text{LENGTH}_{ij}} \\[6pt]
&+\; \beta_{\text{EFP}}\,\text{EFP}_{ij} \;+\; \beta_{\text{PRL}}\,\text{PRL}_{ij} \;+\; \beta_{\text{EFL}}\,\text{EFL}_{ij} \\[6pt]
&+\; \beta_{\text{E2}}\,\text{EFRSQ}_i \;+\; \beta_{\text{WPRICE2}}\,\text{WPRICE2}_{ij} \;+\; \beta_{\text{L2}}\,\text{LENGTHSQ}_{ij} \;+\; \epsilon_{ij}
\end{aligned}
$$

When placing a flock, the processor also decides how large a flock to place with a grower. We hypothesize that the processor will place larger flocks with higher ability growers. In addition, if asymmetric information is important, we anticipate an off-setting effect: other things being

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[3] This possibility was suggested by an anonymous referee.

equal, the processor will increase flock sizes for lower ability growers in order to reduce information rents. Once the flock is placed, the processor supplies feed to grow out the chicks. The total feed requirements depend on the number of chicks placed and the final carcass weight desired by the processor, as well as death rates for those chicks and grower management ability. Finally, the processor determines when to slaughter the flock. The final weight per chick placed depends on the length of the growout period, total feed consumed and death rates, which are a function of grower management ability as well as common factors across growers, such as chick health or genetic stock. The three dependent variables, flock size, feed and weight per chick, are interdependent, as indicated in the above discussion. In addition, if asymmetric information is important we anticipate an additional effect: other things being equal, the processor will increase flock sizes for lower ability growers for a given level of output in order to reduce information rents. We capture this effect by including the final weight per chick as an explanatory variable for flock size in our system of equations. If information rents exist, we predict that this variable will have a negative effect on flock size. In the absence of information rents, we would not expect this variable to have a significant effect on flock size, unless the processor was fully informed of chick health in advance and increased flock sizes when chicks were less healthy. If the processor did this, we would expect the final weight delivered to vary less than the number of chicks placed for any given grower. In order to separate these two explanations, we separately test the hypothesis that the coefficient of variation for flock size is larger than the coefficient of variation for final flock weight for all growers.

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The remaining three equations in our system are the following:

$$CHICKS_{ij} = \alpha_{CHICKS} + \underset{(+)}{\beta_E} EFR_i + \underset{(-)}{\beta_{WTPER}} WTPER + \underset{(+)}{\beta_{WP}} WPRICE_{ij} \qquad (2)$$

$$+ \beta_{EP} EFP + \beta_{\P 2} WPRICE2_{ij} + \beta_{E2} EFRSQ_i + \epsilon_{ij}$$

$$WTPER_{ij} = \alpha_{WTPER} + \underset{(+)}{\beta_E} EFR_i + \underset{(-)}{\beta_{CHICKS}} CHICKS_{ij} + \underset{(+)}{\beta_{KCAL}} KCAL_{ij} + \underset{(+)}{\beta_L} LENGTH_{ij}$$

$$\qquad (3)$$

$$+ \beta_{EFL} EFL_{ij} + \beta_{E2} EFRSQ_i + \beta_{L2} LENGTHSQ_{ij} + \epsilon_{ij}$$

$$KCAL_{ij} = \alpha_{KCAL} + \underset{(+)}{\beta_E} EFR_i + \underset{(+)}{\beta_{CHICKS}} CHICKS_{ij} + \underset{(+)}{\beta_{WTPER}} WTPER + \underset{(+)}{\beta_L} LENGTH_{ij}$$

$$\qquad (4)$$

$$+ \beta_{EFL} EFL_{ij} + \beta_{E2} EFRSQ_i + \beta_{L2} LENGTHSQ_{ij} + \epsilon_{ij}$$

The remaining testable hypothesis from our theoretical model is that lower ability growers will have a higher variability of flock placements. Again, we examine this prediction by looking at the time between flocks. We consider the variance of flock placements over the sample period, VHDIFF, and estimate the following equation using ordinary least squares:

$$VHDIFF_i = \alpha + \underset{(-)}{\beta_{EFR}} EFR_i + \underset{(+)}{\beta_{MHDIFF}} MHDIFF_i + \beta_{EFD} EFDIFF_i + \beta_{E2} EFRSQ_i + \epsilon_i$$

The error term ϵ_i is assumed to be an independent, identically-distributed random variable across growers. Since there is a minimum time between flocks required for cleaning and disinfecting the facilities, it is likely that a longer average time between flocks will be more variable, apart from the direct effects of ability. This is reflected in the predicted sign on MHDIFF, the average time between flocks for each grower during the sample period.

4. Data

Charles Knoeber and Walter Thurman of North Carolina State University graciously provided the data used in this analysis. 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 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, 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.

5. 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 derived above.

5.1. 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 Figure 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. The hypothesis that mean performance across growers is equal is strongly rejected, with an F statistic of 2.53. (See Table 1.) This provides statistical confirmation of 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.

5.2. **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 which the integrator can measure or infer in some way. In this paper we refer to this attribute as ability. From the processor's point of view, grower ability is the grower's ability to efficiently use the inputs provided by the processor. That is, the processor wishes to obtain as many pounds of chicken as possible, given the number of chicks and pounds of feed he has supplied to the grower. Equivalently, he equates higher grower ability with lower unit production costs.

Our measure of grower ability is based on the weak axiom of cost minimization (Varian).[4] 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. This limits its effectiveness as a measure of efficiency in a stochastic context. We use a variation of the weak axiom of cost minimization that attempts to correct for this difficulty. Following Hermalin and Wallace, 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 Figure 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 higher ability growers will build more capacity and 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 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.

Of course, there is also the potential for a dynamic bias in the use of this estimator. Given that the data used to compute the ability measure encompassed a time period of thirty months and included growers dealing with a single processing plant, this bias is unlikely to be significant. Further, we are

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

essentially concerned with grower ability relative to other growers in the sample. For a dynamic bias to be an important concern any technical progress must have an asymmetric effect across growers. Given the nature of the weak axiom of cost minimization, this asymmetric effect must also be large relative to the stochastic shocks. This is particularly unlikely in such a short time period.

We have a third and final concern regarding our ability measure. We utilize grower outcomes under a rank order tournament regime to estimate grower ability. We then use these ability measures to examine outcomes under a RLPE regime. As noted by Lazear and Rosen, under a rank order tournament lower ability growers are likely to choose risker strategies and higher ability growers are likely to choose less risky strategies than they would in the absence of the tournament incentives. While in expectation average grower performance (and our ability measure) should remain unaffected, our small sample size implies that our ability estimates could be distorted upward or downward for low ability growers.

5.3. **Results.** We utilized three stage least squares to estimate flock size and time between flocks in conjunction with final weight per chick and total kilocalories supplied. Our estimation results are reported in Table 2. We report standard errors that are corrected for the presence of a stochastic regressor, assuming that errors in the regressor are uncorrelated with errors in the dependent variable. Our results generally support our hypotheses. Results for the feed consumption (kilocalories) and final weight per chick equations generally followed our predictions. Grower ability and kilocalories had positive and significant effects on final weight per chick. The square of grower ability had a significant negative effect, but the net effect of ability is positive. Flock size had a negative and significant effect, as predicted. No other variables were significant. Grower ability, flock size and final weight per chick all had a positive and significant effect on total kilocalories, as predicted. The ability-length interaction variable and the square of grower ability had negative and significant effects, and the net effect of grower ability is indeterminate.

In the time between flocks equation, the only statistically significant variables were the intercept, which was negative and significant, price, which was positive and significant, and the squared values of price and grow out period length, which were both negative. (All significances are reported for the 5% level.) The sign on the price coefficient is the opposite of the predicted value, and dominates the negative coefficient on the square of price. Ability is not significant. Length of the grow out period is not significant. Although its square is significant, the coefficient is extremely small, so that the economic effect is not important. Overall, the results for this equation do not support our predictions. We suspect, as did an anonymous referee, that the lack of significance may be due to the relatively small number of growers and observations per grower in our sample.

The flock size component of the estimation supported our predictions. Ability had a positive and statistically significant effect on flock size. The square of ability had a negative and statistically significant effect on flock size. The net effect of the two measures is positive. The final weight per chick had a negative and significant coefficient, as predicted. As mentioned in our discussion of our emprical model, this effect could be due to the presence of asymmetric information. Alternatively, it could be a result of the processor increasing flock size when chicks are sickly. If the latter explanation was correct, we anticipate that the processor would place bigger flocks when he anticipated a higher death rate, in order to obtain roughly the same final output. If this were the case, we predict that the number of chicks placed would vary more than the total final flock weight delivered for a grower. We compare the covariances of these two measures for each grower. In contrast to our prediction, flock size varies less than final flock weight for 62 of the 63 growers. This suggests that the effect is due to the effects of asymmetric information.

We regressed the coefficient of variation of the time between flocks on grower ability and average time between flocks in a separate ordinary least squares regression. Grower ability was negative, as predicted, but was not statistically significant. It was economically important in magnitude. Average time between flocks had a negative and highly significant effect on the variance, which

was opposite of the predicted sign. This may be partially explained by the positive and highly significant coefficient for the ability- average time between flocks interaction variable. Given the range of values for the ability variable in the sample, the net effect will be small and positive for most growers.

6. CONCLUSION

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.

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 statistically 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. We also found weak evidence that higher ability growers had a lower variance of flock placements. These findings suggest that models that rely on the assumption of grower homogeneity may result in distorted theoretical conclusions and policy recommendations. While our analysis clearly indicates the importance of grower heterogeneity to contract outcomes, it is less clear regarding whether information on grower ability is symmetric or asymmetric. The relationship between initial flock size and output varied according to grower ability in precisely the manner predicted by agency theory, but is not statistically significant. However, it was economically important in magnitude. 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.

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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	65.609	0.951	2.53	0.0001
Error	408	153.417	0.376		
Corrected Total	477	219.026			

R-Square	C.V.	Root MSE	SC Mean
0.300	2.928	0.613	20.95

TABLE 2. Size and Frequency of Flock Placements

Three-Stage Least Squares Estimation
System Weighted MSE: 30.396 (1427 D.F.)   System Weighted R-Square: 0.652
Cross Model Covariance

Sigma	CHICKS	HDIFF	WTPER	KCAL
CHICKS	130572840.25	2895.813	2735.032	21333924.834
HDIFF	2895.813	12.190	0.056	912.561
WTPER	2735.032	0.056	0.064	-991.991
KCAL	21333924.834	912.561	-991.991	410625567.3

Parameter Estimates
Dependent variable: CHICKS

Variable	Parameter Estimate	Standard Error
INTERCEPT (α)	-679120	742693
EFR*	2435721	426774
CGAP*	-24764	4581
WPRICE	-4736	23594
EFP	478.2	5083
P2	42.14	216.7
EFR2*	-1536548	181590

Dependent variable: HDIFF

INTERCEPT (α)*	-531.469	231.8
EFR	186.752	133.2
WPRICE*	18.372	7.365
LENGTH	0.625	3.828
EFP	-1.258	1.587
PRL	0.077	0.067
EFL	-2.465	1.702
P2*	-0.205	0.068
L2*	-0.034	0.008
EFR2	-4.470	56.69

Dependent variable: WTPER

INTERCEPT (α)	-3.257	14.69
EFR*	31.941	8.440
CHICKS*	-0.0000620	0.00000637
KCAL*	0.00000416	0.000000613
EFL	0.196	0.108
LENGTH	-0.162	0.243
L2	-0.000358	0.000522
EFR2*	-25.429	3.591

Dependent variable: KCAL

INTERCEPT (α)*	-2957529	1339323
EFR*	3402284	769615
CHICKS*	10.413	0.605
CGAP*	133190	8260
LENGTH	41867	22116
L2	70.355	47.57
EFL*	-48762	9829
EFR2*	-762606	327468

* significant at 5% level

TABLE 3. Variance of Flock Placements

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	51199560.525	12799890.131	134.655	0.0001
Error	46	4372618.619	95056.927		
Corrected Total	50	55572179.144			

R-Square	Adj. R-Square	Root MSE	VHDIFF Mean	C.V.
0.921	0.915	308.313	233.556	132.008

Parameter Estimates

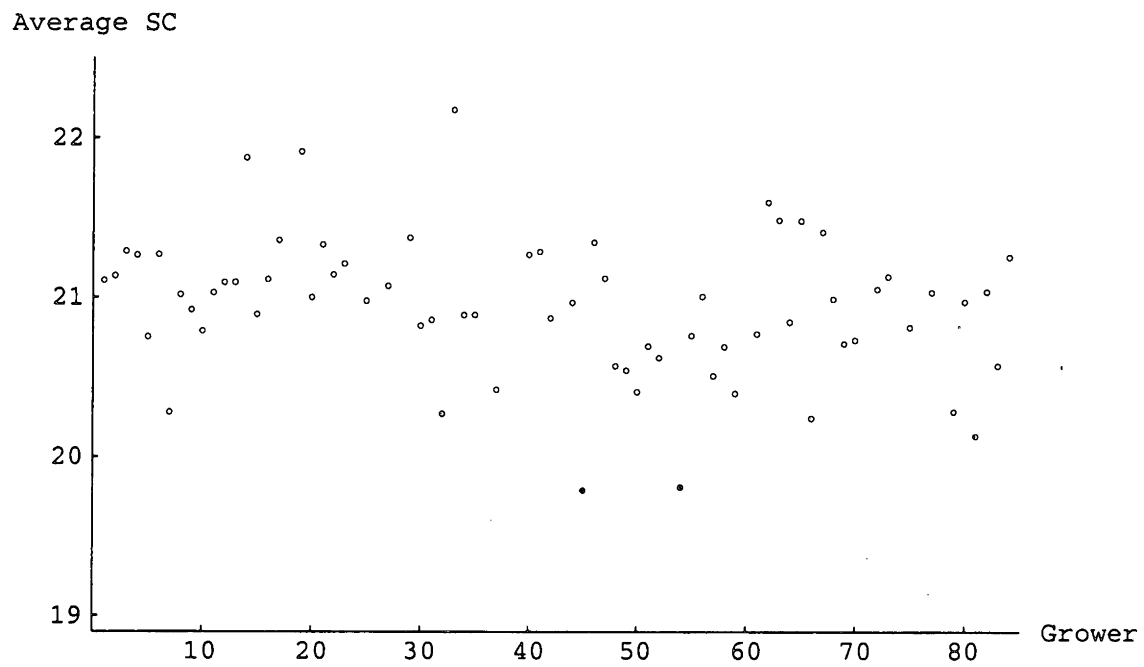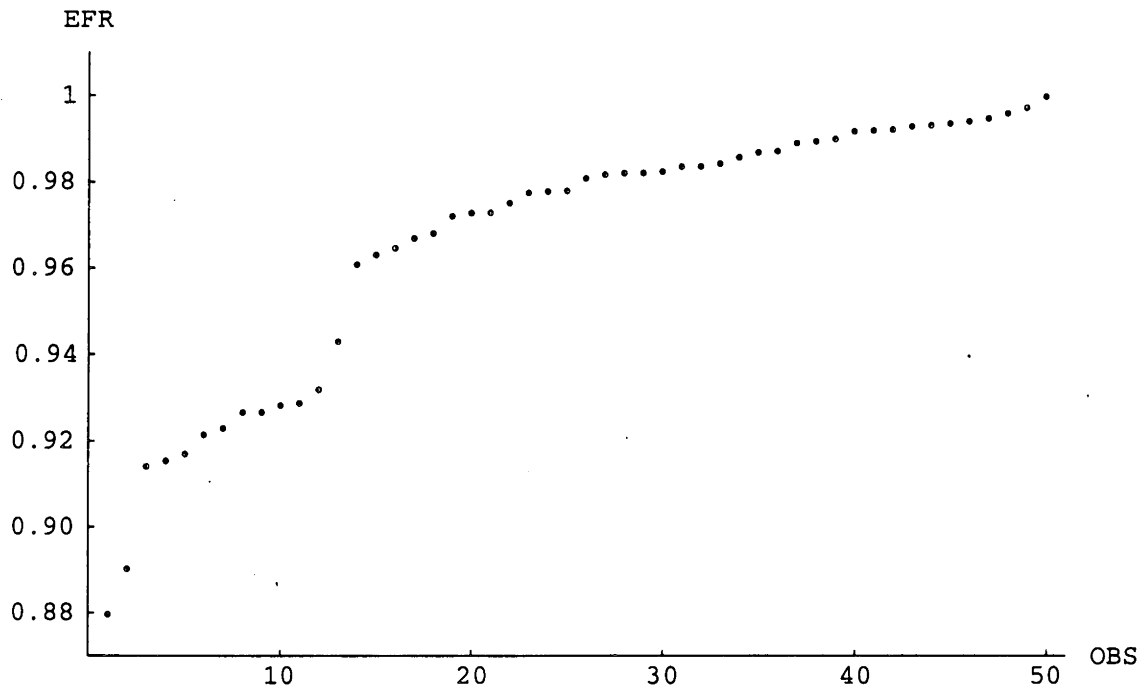| Variable	Estimate	Error
INTERCEPT (α)*	21961	9663.872
EFR	-24215	19773.063
MHDIFF*	-1535.362	363.293
EFDIFF*	1719.668	368.158
EFR2	-409.732	11035.266

* significant at 5% level

FIGURE 1. Average Settlement Cost by Grower

FIGURE 2. EFR Ability Measure