# Understanding Production Contracts: Testing an Agency Theory Model

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**ABSTRACT:** We construct and test an agency-theoretic model of broiler production contracts. Our empirical results generally support our model, and provide insight into the incentives underlying the design of the contract and the sources of returns to broiler processors and growers.

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Production contracts between farmers and other stages of the agrofood chain have always been important in American agriculture. Relatively little is known, however, about the fundamental forces governing the adoption and design of these vertical coordination measures in the agricultural context. In order to gain insight into the incentives embedded in production contracts, we construct and test an agency-theoretic model of broiler production contracts. We then discuss the implications of our analysis for industry participants and government policy.

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 a 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. 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

[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).

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 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 is at least partially due to better growers owning more chicken houses, they argue that this is also consistent with better growers being handicapped with more densely housed flocks. Lower-performing growers tend to hold their flocks for longer periods; they speculate that this may be due to better growers 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.

We use agency theory to model these decisions. The theory generates testable hypotheses regarding flock placements and grower ability. Our work differs from previous work in two aspects. First, we utilize an explicit measure of grower ability, based on Varian's weak axiom of cost minimization, rather than using a grower-specific measure. 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. We confirm Knoeber and Thurman's 1994 result that better growers receive larger flocks. However, rather than confirming their hypothesis that better growers are handicapped by being assigned greater flock densities (a hypothesis they could not test directly), we find evidence suggesting that the processor in fact maximizes profits by assigning higher-ability growers to produce heavier birds. We also find that better growers receive flocks more consistently. This finding adds a new dimension to Knoeber and Thurman (1995)'s analysis of risk transfer due to broiler contracts: 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.

Model: Our empirical analysis is based on a principal-agent model with hidden information. The processor is modeled s the principal, and the growers as agents. 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. At the time growers initially sign a contract with the processor, their ability to produce broilers efficiently is private information for each grower. Appealing to the revelation principle, it is the processor's task to design a menu of contracts which will induce each grower to truthfully reveal his ability to raise broilers.[2] The risk-neutral processor maximizes profits subject to participation and incentive compatibility constraints for each ability type of risk-neutral utility-maximizing growers. The participation constraint requires that a grower must receive at least his reservation utility under the appropriate contract. The incentive compatibility constraint requires that each grower must receive at least as much utility from the contract intended for his type as he would from contracts intended for the other types.

We illustrate this theory with the following simple case. Agents may be one of two types: high ability or low ability. 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 the $U_i$ 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 $x_i$, i.e., $x_i = Q_i^{\rho} a_i^{1-\rho} t_i$, where $Q_i$ denotes a composite nonlabor input and $t_i$ is the type parameter. 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:

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

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

[2] 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. For more on this distinction, see Goodhue (1997).

where $a_{ij}$ is the effort that an agent of type $i$ must expend to produce the output specified in the contract for $j$. Since agents are utility maximizers, solving for $a_i$ is equivalent to solving for $W_i$. This theoretical formulation corresponds to the components of the processor-grower relationship. $W_i$ 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 labeled information rents. 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 will not be cost-minimizing. The fact that high ability growers must receive information rents increases the cost to the principal of effort exerted by the low ability growers and consequently the contractual input-effort ratio for the latter will be higher.[3] The solution to our example is presented below. Note that $a_h$ and $Q_h$ are at their first-best levels, while $a_l$ is distorted downward. On the other hand, the relationship between $Q_l$ and its first best level cannot be determined *a priori*.

$$a_h = \left(\frac{(1-\rho)t_h}{\phi}\right)^{\frac{1}{\phi-1}} \left(\frac{\rho t_h}{c}\right)^{\frac{\rho}{(1-\rho)(\phi-1)}} \tag{2}$$

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

$$a_l = \left(\frac{(1-\rho)t_l}{\phi}\right)^{\frac{1}{\phi-1}} \left(\frac{\rho t_l}{c}\right)^{\frac{\rho}{(1-\rho)(\phi-1)}} \left(\frac{1-p}{1-p\frac{t_l}{t_h}^{\theta}1-\rho}\right)^{\frac{1}{\theta-1}} \tag{4}$$

[3] For details and a formal development, see Goodhue (1998).

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

To implement this solution, the following lump sum transfers are needed:

$$t_h = a_h^{\phi} - W_h x_h + a_l^{\phi} - a_{hl}^{\phi} \tag{6}$$

$$t_l = a_l^{\phi} - W_l x_l \tag{7}$$

From (6) and (7), 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.

The model above yields several testable hypotheses. First, 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, and the processor will assign more of the composite input to higher ability growers (i.e., $Q_h$ in (3) above will exceed $Q_l$ in (5)). 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 production over a fixed period of time. Over a given time interval, the processor can increase composite input assignments to higher ability growers in one of two ways: he can either assign them larger flocks or assign them flocks more frequently. Accordingly, we test the following hypotheses:

**Hypothesis 1:** Contracts accepted by higher ability growers entail larger flocks assignments.

**Hypothesis 2:** Contracts accepted by higher ability growers entail more frequent flocks assignments.

An intuitive extension of these hypotheses is that the processor will seek to respond to output price variance by assigning flocks more consistently to higher ability growers, and varying the flocks assigned to lower ability growers as prices fluctuate. If growers are risk averse, this practice will reduce the cost of implementing the incentive compatibility constraints as well. Hence we have

**Hypothesis 3:** Contracts accepted by higher ability growers entail more consistent flock assignments from the processor.

Data: The analyzed data set was supplied by Walter Thurman of North Carolina State University. 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. 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. The data set also included information on flocks reared under an earlier tournament contract. This portion of the data set was used to obtain a measure of grower ability and capacity. 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.

Our measure of grower ability is based on the weak axiom of cost minimization (Varian 1984).[4] 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. 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

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

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 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.

RESULTS — HYPOTHESIS I: 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 predict that better growers will receive larger flocks, so that the coefficient on ability should be positive. Higher product prices should lead to larger flock placements, if processors correctly anticipate prices, so this coefficient should be positive as well. We include the interaction term (EFGAP) for two reasons. First, as noted above, incentive compatibility considerations decrease the value of the final weight per chick placed with lower ability growers, and increase their flock placements, relative to their first-best levels, so the interaction term should be negative. Second, if the processor has higher ability growers grow heavier birds, then the interaction term for ability and weight per chick should be negative. Here the predictions of our model contrast sharply with Knoeber and Thurman (1994), who suggests that better growers are assigned denser flocks. If this were the case, the interaction variable coefficient would be *positive*.

TABLE 1. 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 ($\alpha$) | 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

Regression results are reported in Tbl. 1. The monthly dummies were insignificant. Except for the wholesale price variable, all remaining coefficients are significant at the 1% level. The significant coefficients all had the predicted sign. 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. There is some evidence of heteroskedasticity and autocorrelation; we are in the process of evaluating different estimation methodologies that will address these features.

<u>RESULTS — HYPOTHESIS II</u>: 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 a flock's slaughter date and the placement date for 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 is affected by grower capacity, the length of the grow-out period, interaction variables, and monthly dummies that capture seasonal effects. If ability and capacity interact, the interaction variable should be negatively related to the time between flocks. Apart from its association with ability, the effect of an increase in capacity on the time between flocks cannot be predicted. (We use average flock size during the tournament (non-sample) period as a proxy for capacity.) If bigger growers are more efficient, we would expect them to receive flocks more frequently. But the time between flock assignments may also be affected by other processor concerns, such as smoothing weekly production and managing supply in response to fluctuating prices. For similar reasons, the effect 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: the processor may slaughter flocks more rapidly when prices are high, or may lengthen the grow-out period in order to sell heavier broilers. The slaughter weight per chicken decision may cause the length of the grow-out period to interact with grower ability in a similarly indeterminate way. The ability-length interaction variable captures this effect. It will also capture a second effect: grower ability should have a negative effect on the length of the grow-out period, ther factors being equal. Errors are assumed to be independent, identically distributed random variables for each flock.

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. 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

TABLE 2. 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 ($\alpha$) | 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

as to grow flocks only during certain seasons, so we eliminate observations with over a two and a half month gap between flocks 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. 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 flocks for the sample as a whole is 3.79 days. If better growers receive flocks more frequently, as predicted, then the ability measure will affect the time between flocks negatively.

As shown in Tbl. 2, the ability measure did not have a significant effect on the time between flocks. The only significant coefficients were the wholesale price, with its predicted negative effect, and the wholesale price-grow-out length (PRL) coefficient, which was 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.

TABLE 3. 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* ($\alpha$) | 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

RESULTS — HYPOTHESIS III: We hypothesize that the variability of flock placements and flock sizes depends negatively on grower ability, so that an increase in ability should decrease variability. Indeed, the processor may utilize better growers more consistently by spacing their flocks farther apart on average. This would suggest a negative relationship between flock variability and the mean time between flocks. To test these relationships, we regress the variance of time between flocks for each grower 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. 3, ability and the mean time between flocks have the predicted negative and significant effects on the variance of flock placements. Capacity and the mean grow-out time are insignificant. 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 these contracts. While they 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 processor. Our regresssion result indicates that the importance of this risk depends significantly upon grower ability.

Concluding Remarks: Our agency-theoretic model is based on the hypothesis that the relationship between growers and the processor will be designed to maximize the gains to the latter. The model predicts that when agents are heterogeneous, high-ability agents will capture some returns (information rents) above their reservation utility level, but low ability agents will be held to their reservation utility level in equilibrium. In practice, however, the manner in which processors offer preferential treatment to higher ability agents is by no means obvious. Our empirical results provide general support for our agency-theoretic model and in addition shed some light on the issue just raised. Our first regression supported the hypothesis that higher ability agents receive larger flocks. Our second did not support the conjecture that they also receive flocks more frequently. Our final regression introduced a third dimension along which processors can distinguish between growers with different abilities. By providing higher ability growers with more consistent placements, and thereby shielding them to a greater extent than other growers from throughput risk, processors can transfer rents in the form of reduced risk, while serving their own need to maximize flexilibility in the face of fluctuating prices.

The paper also 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.

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