The Sky is Falling: An Examination of Broiler Contract Design and Grower Revenues

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Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Denver, Colorado, July 1-4, 2004

Introduction

In the grow-out phase a broiler production, a processing firm, referred to as an integrator, contracts with growers to raise chickens to slaughter weight. The integrator supplies chicks, feed, medicines, and technical advice to growers. Growers provide facilities, labor, and the remaining inputs necessary for raising chickens. The contract between the grower and integrator specifies a formula that is used to measure the grower's efficiency of converting integrator supplied inputs into pounds of slaughter weight chickens. This measure is called the standard cost. The contract also specifies a method of determining the grower's compensation in terms of this standard cost.

Broiler growers are compensated almost universally according to a two-part piece rate tournament (Vukina). The essential features of such a tournament consist of a base payment per pound of live weight and a bonus payment determined by a grower's standard cost relative to others. Growers with relatively low (high) standard costs receive a positive (negative) bonus payment.[1] Tournament payment schemes are dominant in the grow-out phase of the broiler industry, more so than in the grow-out phases of other livestock and poultry industries (Knoeber; Tsoulouhas and Vukina). Knoeber describes how tournaments align incentives, reduce measurement costs, facilitate innovation, and lower the need for contract renegotiation in the presence of rapid technical change. Knoeber and Thurman (1995) show that basing compensation on relative performance shifts output price risk and common production risk from growers to integrators in a manner that improves incentives and lowers risk bearing costs. The predominance of tournaments in broiler grow-out has also been attributed to structural

[1] The term "tournament" is used more broadly than is sometimes found in the literature. Knoeber and Thurman (1994) distinguish between tournaments and linear relative performance evaluations. They use the former term for compensation schemes based on relative rankings and the latter for compensation schemes based off of the mean or other measure of the center of the distribution.

characteristics. In broiler grow-out, there are many more growers signed up with a particular integrator than is true of other livestock or poultry industries. This means that tournaments to do a better job of averaging out common production risk (Knoeber). Tsoulouhas and Vukina show that tournaments are less feasible when growers are concerned about integrator bankruptcy and argue that the predominance of tournaments is due to the large size of broiler processors and the price behavior of the broiler output market, both of which reduce bankruptcy concerns.

While there is much in the previous literature that suggests tournaments are well suited to the situation of broiler production, it is also apparent that the alignment of incentives and the efficiency of outcomes is influenced by more than the relative payment provisions of tournaments. For example, Lewin presents arguments suggesting a direct correlation between the relationship specificity of grower investments and strength of grower incentives, and Goodhue uses asymmetric information arguments to explain why integrators control key inputs for broiler grow-out. One need only look at broiler contracts themselves for alterations of the incentive structure of tournament payment schemes. It is not uncommon for contracts to specify allowances for fuel during winter months or to provide an increase in the base payment for growers with facilities that meet certain criteria. Such provisions acknowledge that the expected pay schedule under tournaments is not always sufficient to motivate the actions desired by the integrator, at least when it comes to capital improvements or optimal use of some grower supplied inputs.

Another aspect of the contractual relationship is the size and frequency of flock placements growers receive from the integrator. From an integrator cost minimization standpoint alone, it would not be surprising to see lower cost growers receive larger and/or more frequent placements. Goodhue, Rausser, and Simon use an agency theory model to develop hypothesized relationships regarding flock placements and grower ability. Their empirical results suggest that high ability growers do receive larger flocks. They find insignificant evidence that high ability growers receive more frequent flocks, but their results do suggest that higher ability growers face less variability in layout times between flocks. The size and frequency of placements can also be a source of grower risk. As found by Knoeber and Thurman broiler contracts shift output price risk from the grower to the integrator. However, growers may face risk in the form of size and frequency of placements as integrators change capacity utilization rates in response to changes in output price (Goodhue).

In what follows, we construct an example to illustrate how the size and frequency of flock placements can be used to differentiate grower incentives by grower abilities. We use a math program to model an integrator's problem of assigning growers into settlement pools. In making these pool assignments, the integrator is assumed to have some flexibility in the number of birds placed and the frequency of placements to growers of a given ability. The implications for grower incentives that result from the solution of our example reflect behavior under perfect information. Our intent is not to suggest that problems related to imperfect information are unimportant to the design and outcome of contractual relationships in the broiler industry. Studies mentioned above suggest otherwise. Rather the simplicity of a math programming framework allows us to hold constant key parameters of the model, arrive at some fairly straightforward relationships between placements and grower abilities, and examine how these relationships affect the incentive structure.

Approach

The integrator's problem is to minimize the costs of sourcing enough broilers each week to meet its slaughter capacity requirement. We assume that all growers are under a contract that contains the following payment provisions:

(1) a base payment rate of $0.04 per pound of live weight, net of condemned birds;

(2) a bonus payment calculated as the difference between the average standard cost of the settlement pool and the grower's standard cost; and

(3) a minimum payment of $0.03 per pound of live weight, regardless of grower standard cost.

In the model, differences in grower ability are represented by different grower types. We are assuming that the integrator can classify growers into types characterized by standard costs and that the integrator knows the grow-out capacity available from each grower type classification.

In a typical broiler grow-out situation, six weeks are required to grow chicks to slaughter weight. This is followed by a 1 to 3 week layout time before another flock is placed. For purposes of the model we allow the integrator to vary time between flock placements anywhere from 7 to 9 weeks. We also consider the possibility that the integrator may give short flocks – place a number of chicks with a grower that is smaller than 100 percent of grower's capacity. If the integrator provides a short flock, we assume that it is at least 80 percent of the grower's full capacity.

As a math program, the integrators problem assignment problem can be expressed as follows:

$$\text{minimize} \quad \text{cost} = w\sum_j \sum_i c_i z_{ij} + w\sum_j \sum_i p_{ij} z_{ij}$$

$$
\begin{array}{lll}
 & s.t. & \\
 & \text{C1.} & \mathbf{Gz}_i \le ?y_i \quad \forall\, i \\
 & \text{C2.} & \mathbf{Hz}_i \ge ?0.8 y_i \quad \forall\, i \\
(1) & \text{C3.} & \sum_i z_{ij} = x \quad \forall\ j \\
 & \text{C4.} & \frac{1}{x}\sum_i c_i z_{ij} = m_j \quad \forall\ j \\
 & \text{C5.} & 0.04 + m_j - c_i + b_{ij} \ge 0.03 \quad \forall\, i, j \\
 & \text{C6.} & 0.04 + m_j - c_i + b_{ij} = p_{ij} \quad \forall\, i, j \\
 & \text{C7.} & z_{ij}, b_{ij} \ge 0 \quad \forall\, i, j
\end{array}
$$

Where:

i = (1, 2, …, M) indexes the types of growers

j = (1, 2, … ,.N) indexes the settlement pools

i = a unit vector of dimension N×1

Endogenous variables in the model are

$\mathbf{z}_i$: an N×1 vector of intensity variables with elements (z_{ij}) representing amount of available grow-out capacity (in terms of number of birds) from the i^{th} type of grower used to fill the j^{th} pool.

m_j: the mean standard cost (per pound of. live weight) of growers used for the j^{th} pool

b_{ij}: an intermediate term used to enforce minimum payment provision of the broiler contract

p_{ij}: the payment (per pound of live weight), for the i^{th} type of grower used to fill the j^{th} settlement pool.

Exogenous coefficient in the model are:

w: Average weight per bird (assumed to be 5 pounds in this example and constant across growers and pools)

c_i: Standard cost of type i growers.

y_i: Available grow-out capacity (number of birds) of growers of type i

x: Number of birds per pool needed to meet the integrator's slaughter capacity.[2]

G and **H**: Coefficient matrices of dimension N×N used for the temporal flock placement constraints.

Explanations of the equations in the model are as follows.

- The objective function is the integrators cost of growing broilers over a given planning horizon and reflects both the cost of inputs provided by the integrator (the c_i) and payments to growers for their services (the p_{ij}).

- Constraints 1 and 2 are temporal flock placement constraints. Constraint 1 ensures that the capacity from type i growers used to fill pools in any 7 week period does not exceed the available capacity from type i growers. The coefficient matrix **G** in constraint 1 enforces this minimum time between flock placements. Table 1, depicts **G** as a coefficient tableau.

[2] Note that in the formulation above, the weekly capacity requirement is constant across weeks. This could easily be relaxed to accommodate differences in weekly capacities over the integrator's planning horizon.

- Constraint 2 requires that type i growers receive at least one flock every 9 weeks. In tableau form, the matrix **H** is similar to **G**, except row 1 would have the value of 1 in columns 1 through 9, row 2 would have the value of 1 in columns 2 through 10, etc. The formulation of constraint 2 allows for short flocks that are no smaller than 80 percent of a full flock.

- Constraint 3 requires that enough birds are assigned to each pool to meet the integrators weekly slaughter capacity requirements.

- Constraints 4-6 are used to compute payments for the different grower types. Specifically, constraint 4 is used to define the average standard cost of the j^{th} pool while constraints 5 and 6 enforce the minimum payment provision and define pay for the grower type, respectively.

Data and assumptions

Data were collected that reflect 896 grower observations from 55 pools settled between 1997 and 2001. The data include growers contracted with three different integrators. Regardless of integrator, however, each grower observation provides the information necessary to compute standard costs according to an arbitrary contract specification. Four actual grower contracts were examined. Three of these were actual contracts used by growers in the dataset, and the fourth reflected an integrator complex located in the same geographic region but for which we had no grower data. Each contract specifies grower standard costs as [α(FEED USED)+β(HEAD PLACED)] ÷ (NET POUNDS), where NET POUNDS is total pounds of live weight net of condemned birds. The α and β terms differ among the contracts examined. We apply the fourth contract (which specified $\alpha = 0.10$ and $\beta = 0.138$) to all observations to obtain a series of standard costs.

Ideally, each observation on grower standard costs would reflect the same weather conditions and same quality of integrator supplied inputs such as chicks, feed, and support services. In this ideal situation, variations in standard costs could be attributed to differences in grower effort, quality of grower supplied inputs, and randomness. Because our data reflect potential differences in the quality of integrator supplied inputs and were generated under a variety of weather conditions, we construct a new series of grower standard costs after controlling, to the extent possible, for factors outside of the growers control.

To approximate a distribution of grower costs under identical grow-out conditions, we regress the computed standard cost on fixed pool effects, the number of chicks placed, and a squared term for the number of chicks placed. The rationale behind this regression model is as follows: All growers within a given pool are contracted with the same integrator (should face similar quality of integrator inputs) and would have been subject to similar weather conditions (because pools are comprised of flocks grown during the same time period). The number of chicks placed will be directly related to the number of houses a grower owns and can be used to control for the possibility of non-constant returns to scale in the grow-out phase of broiler production. We use the residuals from this regression to construct a new series of grower standard costs as:

(2) $$c_i = \bar{c} + e_i ,$$

where $\bar{c} = 0.232$ is the mean of the original standard cost series (or predicted cost at the mean of all regressors).

The R^2 value of the regression model just described was 0.347 and the adjusted R^2 value was 0.303. The coefficients on the head placed variables are of the expected sign but are small in magnitude and insignificant. The coefficient for head placed was -8.01447E-8 with a p value of 0.123. The coefficient for the squared term was 4.03821E-13 with a p value of 0.216. Figure 1 provides an empirical cumulative density function (CDF) for the new standard cost series created from regression residuals according to equation 2. This CDF is used to define grower types in terms of $0.005 differences in standard cost, with the lowest cost growers (type 1 growers) having standard costs of $0.21 per pound of live weight and the highest cost growers (type 11 growers) having standard costs of $0.26 per pound.

To implement the math program in equation 1, we assume that the integrator has a baseline processing capacity of x = 1.2 million birds per week (10 shifts per week at 120,000 birds per shift) and that, on average, growers receive a flock every 8 weeks. Thus the integrator must sign up enough growers to provide 9.6 million birds during any 8 week period. This 9.6 million bird grow-out capacity is divided among the different grower types according to table 2. Percentiles for the different grower types, reported in table 2, are from the empirical CDF in figure 1.

Once growers are signed up, we assume the integrator learns about grower ability and can classify growers according to standard costs. The integrator can use this classification to make pool assignments, lengthen or shorten placement times, and/or reduce the size of flocks placed with growers of a particular type. As described above, our model assumes that time between flock placements can vary between 7 and 9 weeks and that the integrator can reduce flock placements to 80 percent of a full flock. Thus, the available grow-out capacities reported in table 2 represent the maximum number of birds available from a given type of grower during any 7 week period. These grow-out capacities are used as values for the y_i parameters in the math program.

The model in equation 1 has a nonlinear objective function and is solved with the MINOS solver available through GAMS software. The dimensions of the model depend in large part on the 7 week minimum and 9 week maximum time requirements placed on flock placements. A full characterization of the integrator's problem requires that the model incorporate a 63 pools (N=63). We solve the model at the baseline integrator processing capacity of 1.2 million birds per week and for lower and higher capacity levels ranging from 0.95 million (79 percent of baseline capacity) to 1.3 million (108 percent of baseline capacity) in increments of 0.05 million.[3]

Results

The solution to the integrator's pool assignment problem can be used to determine flock placement rates, payments, and revenues for the different grower cost types. This information is summarized in Table 3 for the baseline integrator capacity of 1.2 million birds per week. To facilitate interpretation of the results, output from the programming model -- based on 63 pools -- is converted to an annual basis by the ratio 52/63. Values are also adjusted to have a per house interpretation assuming 18,000 birds per house and an average of 5 pounds per bird.

The integrator's solution involves maximizing the use of grow-out capacity from the lowest cost growers and minimizing the use of capacity from the high cost growers. For grower types 1 through 5, those with costs of $0.23 and below, constraint 1 is binding for each of the 63

[3] Starting values for the model variables did affect the local optima returned by the MINOS solver. Among the starting strategies we considered, that which provided the smallest locally optimal solution was to use the solution to a linear version of the model to get a feasible starting point for the z_{ij}. The linear version excluded constraints 4 through 6 and the second term in the objective function. Although solutions are sensitive to starting values, differences in the objective function at local optima were small, the ratio of smallest to largest objective function values ranged from 0.999 to 0.992 over the various levels of integrator processing capacity.

pools. The integrator places a full flock with these growers at 7 week intervals for 7.43 full flocks per year. For grower types 7 through 11, those with costs of 0.24 and above, constraint 2 is binding for each of 63 pools. These growers receive a short flock that is 80 percent of a full flock once every 9 weeks. This is equivalent to 4.62 full flocks per year. For grower type 6 with a standard cost of 0.235, constraint 1 was binding in 42 of the 63 pools, and constraint 2 was never binding. Growers of this type receive the equivalent of 7.07 full flocks per year with an occasional short flock or delayed placement. These results are intuitive. The standard cost represents chicks and feed supplied by an integrator and constitutes the largest part of the integrator's cost of sourcing broilers. Naturally an integrator would favor growers with low standard costs and seek to use low-cost growers to the greatest extent possible.

What is probably more interesting is the potential for variation in placements to complement the incentive structure of the grower tournament. Figure 2 presents (1) grower payment curves, (2) grower revenue curves, and (3) change in grower revenue curves resulting from ½ cent cost reductions. The grower payment curve is read off the left axis. The revenue and change in revenue curves are read of the right axis. The solid curves are calculated from the solution to our model and reflect the possibility of delayed placements and short flocks. The dashed curves in the figure are calculated under the assumption that the integrator gives each grower 1 full flock every 8 weeks and is used to illustrate the payment and incentive structure of the tournament in the absence of variable placements.[4]

The payment curve from the constant 8-week placement schedule can be summarized as follows. Growers with costs of \$0.245 and higher receive the minimum payment of \$0.03 per pound. For growers with costs below \$0.245 per pound, payments increase at a constant rate as

[4]Recall that the integrator signs up just enough growers to meet the weekly capacity of 1.2 million birds. If we impose the 8 week placement schedule for all growers, the model is just feasible and the integrator uses 1/8 of the capacity from each grower type for each pool.

costs are reduced. The payment curve under the model solution is similar. Again, growers with costs of $0.245 and above receive the minimum payment or something very close to the minimum.[5] At costs below 0.245, payments follow a pattern similar to that shown for the 8 week placement schedule. However, there is more variation in the rate of payment increases, and the payment curve calculated from the model solution is usually below the payment curve calculated under the assumption of 8 week placements. This can be attributed the fact that in the model solution, low cost growers are used more intensely than high cost growers resulting in an excess of grow-out capacity that allows pools to be formed that lower bonus payments.

The payment structure of the tournament has implications for grower incentives. It is useful to highlight these before moving on to a discussion about the revenue and change in revenue curves. One implication is that the tournament provides little, if any, incentive for incremental improvements by highest cost growers. In the present example, if a $0.255 grower were to improve and become a $0.250 grower, he still gets the minimum payment and there is no reward for the additional effort or expenditures that were necessary to make the ½ cent improvement. While the highest cost growers face little incentive for incremental improvements, all other growers face roughly the same incentive under the tournament payment curve. For example, the change in payment that results when one improves from a $0.24 grower to a $0.235 grower is about the same as that which could be expected by a $0.215 grower that improves to a $0.210 grower.

Let us consider the payment structure from the integrator's perspective. First of all, would an integrator want an incentive structure that is essentially flat for high cost growers? An intuitive answer would be no, but there are arguments that the flat portion of the payment curve

[5] Constraint 5 always holds with equality for high cost growers, those with costs of 0.25 and above (grower types 9-11). These growers receive the minimum payment of $0.03 per pound each time they participate in a pool. Constraint 5 is binding the vast majority of the time for growers with costs of $0.245 (type 8 growers).

might not be very problematic in practice. Note from the frequency distribution of grower types (table 3) that the highest cost growers, those with no incentives for small improvements, constitute a small portion of the total grow-out capacity available to the integrator. In fact, less than 7 percent of the grower capacity faces no increase in payment as a result of a ½ cent cost reduction. Second, it could be that at highest cost levels, improvements are only possible through substantial capital expenditures to upgrade grow-out facilities. If this were true, the payment structure does provide incentives for the large improvements that could result from such expenditures. In other words, incentives for incremental improvements may be of less importance at the highest standard cost levels. A third argument is that the flat portion of the payment curve is an artifact of our model and the assumptions behind it. If this is true, the solution to our model does not reflect all of the incentives that high cost growers face in the real world. For example, growers that consistently receive the minimum payment are probably at the most risk of termination by the integrator. This is a potentially large incentive for improvement that is not reflected in the payment structure and would not otherwise be reflected in the results of our model.

Moving on to the second question, would an integrator want a payment curve that is relatively constant for all growers below a certain cost threshold? Here the answer must be no. To see why refer once again to the frequency of grower types. Suppose that the integrator could choose between a marginal improvement by the $0.235 growers and a marginal improvement by the $0.215 growers. The integrator would naturally prefer the improvement in the $0.235 growers for the simple reason that there is a lot more of them. After all, $0.235 growers comprise close to 28 percent of grower capacity, while $0.215 growers comprise less than 2 percent. If the $0.235 growers can be convinced that they need to lower costs by ½ cent the integrator stands to save a great deal more money than would result from convincing the $0.215 growers to do the same. If this is in fact what the integrator would prefer, then the incentive for improvement should not be constant and $0.235 growers should face a more powerful incentive for improvement.

The solution to our model suggests that variable placements play a role in differentiating incentives by grower cost type. Note that under the assumption of constant 8-week placements, the revenue curve follows the same general pattern as the payment curve and all growers below a certain cost level can expect the same change in revenue to result from an incremental improvement in standard costs. The curves based on the model solution differ in that the revenue curve becomes steep over the $0.240 to $0.230 cost range and marginal revenue is relatively large. It is over this cost range where the integrator transitions growers from the 9 week placement schedule with short flocks to the 7 week placement schedule with full flocks. In the model solution, growers with costs of $0.240 have the largest incentive for improvement, followed by growers with costs of $0.235. Together, these growers account for 44 percent of the integrator's grow-out capacity. In our example, the carrot (or stick) of placement frequency provides a relatively large incentive to a substantial portion of the integrators growers.

The importance of placements to these incentives is illustrated in table 3. If a grower with a given number of pounds (Q) and receiving a corresponding payment (P) changes his performance, then the corresponding change in revenue can be decomposed as follows:

$$\Delta R = \Delta P \times Q + \Delta Q \times P + \Delta P \times \Delta Q. \quad (4)$$

For discussion purposes, we will refer to the first term as the payment effect, the second term as the placement effect, and third term as the interaction affect. All growers with costs of $0.250 and below would expect a payment effect in return for ½ cent improvement. When improvements bring the potential for larger and more frequent flocks, the placement effect can be large and important. In our example, the placement effect provides a large incentive for the $0.240 growers. In fact, the revenue curve suggests a 62 percent increase for a ½ cent improvement in performance.

The notion of a placement effect explains differences in revenue possibilities that would occur if the integrator changes slaughter capacity, say, in response to changes demand for the final product. Figure 3, depicts the revenue curve at the baseline capacity of 1.2 million birds per week along with spreads around that baseline for capacities of 0.95 million birds to 1.3 million birds in increments of 0.05 million. Regardless of capacity level, the highest cost growers, those with costs of $0.245 and above receive 9 week placements, 80 percent flocks, and per pound payments that are at or near minimum. Consequently, revenues for these growers are largely unaffected by changes in slaughter capacity. This conclusion assumes, of course, that the integrator does not terminate high cost growers when slaughter volume is cut back. Conversely, the integrator places as many birds as she can with the lowest cost growers, those with costs of 0.220 and below. At each capacity level, these growers get full flocks on a 7 week placement schedule.[6] The spread in revenue possibilities for these low cost growers is due solely to differences in optimal pool composition at the different capacity levels. Growers in the middle, those with costs of $0.240, $0.235, and $0.230, have revenue outcomes that can change dramatically in response to a change in slaughter capacity. This is shown by the wide spread in revenue possibilities relative to either the low cost or high cost growers. Again, revenue fluctuations are due in part to differences in pool composition at different capacity levels that

[6] Except at the lowest 0.95 million slaughter capacity, $0.225 growers were also assigned full flocks and 7-week placements.

affect bonus payments. However, the relatively wide spread in revenue outcomes results from these growers being subject to changes in the size and/or frequency of placements.

The important point here is that variable placements can provide an incentive in the form of narrowing the spread of revenue possibilities. To illustrate, consider a $0.230 grower. At the baseline capacity of 1.2 million birds the revenue curve would indicate that a ½ cent improvement would increase revenue per house by 4.4 percent, from $29,551 to $30,859. Under the baseline, this incentive is small relative to other growers. Our $0.230 grower is already receiving full flocks on a 7 week schedule so there is no placement effect that amplifies his payment incentive under the tournament. However, the ½ cent improvement would greatly narrow the spread of revenue possibilities and this may be an important augmentation to the payment incentive. In short, the improvement would all but insure the continuation of full flocks in the event of a capacity decline.

Discussion

The example suggests that differentiating the size and frequency of placements by grower cost types can impact grower incentives in a way that gives some growers greater incentives for incremental improvement than others. Provided there is some degree of excess grow-out capacity, this conclusion arises out of cost minimizing behavior on part of the integrator. In our example, the integrator used a constant 8-week placement schedule and recruited enough growers to meet weekly capacity. Once growers are signed up, the integrator can differentiate growers according to standard costs, and the solution to the integrator's sourcing problem leads to excess grow-out capacity because the integrator uses the capacity of low cost growers more intensively than that of the high cost growers. The differentiation of incentives occurs because some growers receive a placement incentive in addition to a higher in bonus payment under the tournament. The results of our example indicate that these placement incentives can be large.

It is important to emphasize that the amount of excess grow-out capacity will affect the incentive structure. Other things equal, a greater degree of excess capacity will shift the placement incentives to lower cost growers and a lesser degree of excess capacity will shift the placement incentives to the higher cost growers. One argument made above is that if the integrator faces a grower cost distribution that is similar to that used in this example, she might target grow-out capacity levels so that mid-range growers receive the placement incentives. The point being that there are lots of mid-range growers and giving them the placement incentives maximizes the percentage of growers that receive the strongest incentives for improvement.

Another consideration in determining which growers should receive the placement incentive relates to situations where the tournament pay schedule is insufficient to motivate desired actions. For example, it is common for broiler contracts specify an increase in the base payment to growers that have houses or equipment meeting certain criteria. In essence, the integrator recognizes that a potential increase in bonus payments alone may not be sufficient to motivate the desired capital upgrades. Placement incentives, not included specifically in the contract but centered on growers in need of a capital upgrade, could have the same effect.

Solutions at different levels of integrator slaughter capacity suggest there can be a risk lowering component to the placement incentive. Top growers had a considerably narrower band of revenue possibilities over different levels of integrator capacity than did the mid-range growers. This was attributed to the fact that changes in integrator capacity jeopardize the size and frequency of placements the mid-range growers while revenue differences among the top growers were affected only by the optimal pool compositions. One possibility is to extend the programming framework of this study to address integrator profit maximization and examine the extent to which variation in final product price passes through as placement risk for the different grower types. The major difficulty with a profit maximization model is that integrator capacity would be endogenous. This would require a nonlinear constraint, and make it more difficult to find solutions to the model with available solvers.

We contend that our model and assumptions behind it are a reasonable approximation of a typical grow-out situation; however, as with any model it represents an abstraction from reality. Many broiler contracts stipulate bonus payments in terms of a median standard cost or an adjusted average computed after eliminating extraordinarily high and low cost flocks. Our decision to compute bonus payments from a simple average is due to practical considerations in formulating a math program but still reflects the essential feature of actual broiler tournaments. We might provide a better approximation of the real world by estimating different average bird weights by grower type and using these in the model. For example, low cost growers, those with better feed conversion rates, would have heavier birds at settlement time than high cost growers. By using a constant average weight, the revenue curve is likely biased upwards for high cost growers and downwards for low cost growers. The basic features of the incentive structure would be the same. We also recognize that the number of grower type classifications is somewhat arbitrary, but a larger or smaller number of grower types does not alter the main conclusion that variable placements can differentiate incentives by grower cost type. This conclusion would be largely unaffected if different assumptions were made about minimum and maximum placement times, the base payment, etc.

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Table 1. Coefficient Tableau for Minimum Flock Placement Constraints

j/j	1	2	3	4	5	6	7	8	9	10	11		N-2	N-1	N
1	1	1	1	1	1	1	1	0	0	0	0	…	0	0	0
2	0	1	1	1	1	1	1	1	0	0	0	…	0	0	0
3	0	0	1	1	1	1	1	1	1	0	0	…	0	0	0
4	0	0	0	1	1	1	1	1	1	1	0	…	0	0	0
⋮															
N-1	1	1	1	1	1	0	0	0	0	0	0	…	0	1	1
N	1	1	1	1	1	1	0	0	0	0	0	…	0	0	1

Table 2. Grower costs and capacity by type

Grower type	Standard cost ($ per lb. live weight)	Percent	Grow-out capacity (# of birds)
1	0.210	1.67	160,320
2	0.215	1.68	161,280
3	0.220	4.80	460,800
4	0.225	10.60	1,017,600
5	0.230	24.00	2,304,000
6	0.235	27.67	2,656,320
7	0.240	15.96	1,532,160
8	0.245	7.15	686,400
9	0.250	2.45	235,200
10	0.255	2.01	192,960
11	0.260	2.01	192,960
Totals		100.00	9,600,000

Table 3. Grower revenues and payments at baseline integrator capacity of 1.2 million birds/week

Grower type	Grower type pct. of total	Standard cost	Pmt. per lb. (P)	Annual full flocks	Annual revenue per house	MR of \$0.005 cost reduction	Pct. MR of \$0.005 cost reduction	ΔP×Q	ΔQ×P	ΔP×ΔQ
1	1.67	\$ 0.210	\$ 0.0600	7.43	\$ 40,114					
2	1.68	0.215	0.0578	7.43	38,629	1,486	3.85	1,486	-	-
3	4.80	0.220	0.0508	7.43	33,949	4,680	13.79	4,680	-	-
4	10.60	0.225	0.0462	7.43	30,859	3,090	10.01	3,090	-	-
5	24.00	0.230	0.0442	7.43	29,551	1,308	4.43	1,308	-	-
6	27.67	0.235	0.0368	7.07	23,414	6,137	26.21	4,721	1,178	238
7	15.96	0.240	0.0346	4.62	14,397	9,017	62.63	904	7,633	479
8	7.15	0.245	0.0302	4.62	12,557	1,840	14.66	1,840	-	-
9	2.45	0.250	0.0300	4.62	12,480	77	0.62	77	-	-
10	2.01	0.255	0.0300	4.62	12,480	-	-	-	-	-
11	2.01	0.260	0.0300	4.62	12,480	-	-	-	-	-

Figure 1. Distribution of Grower Standard Costs and Grower Type Approximations.

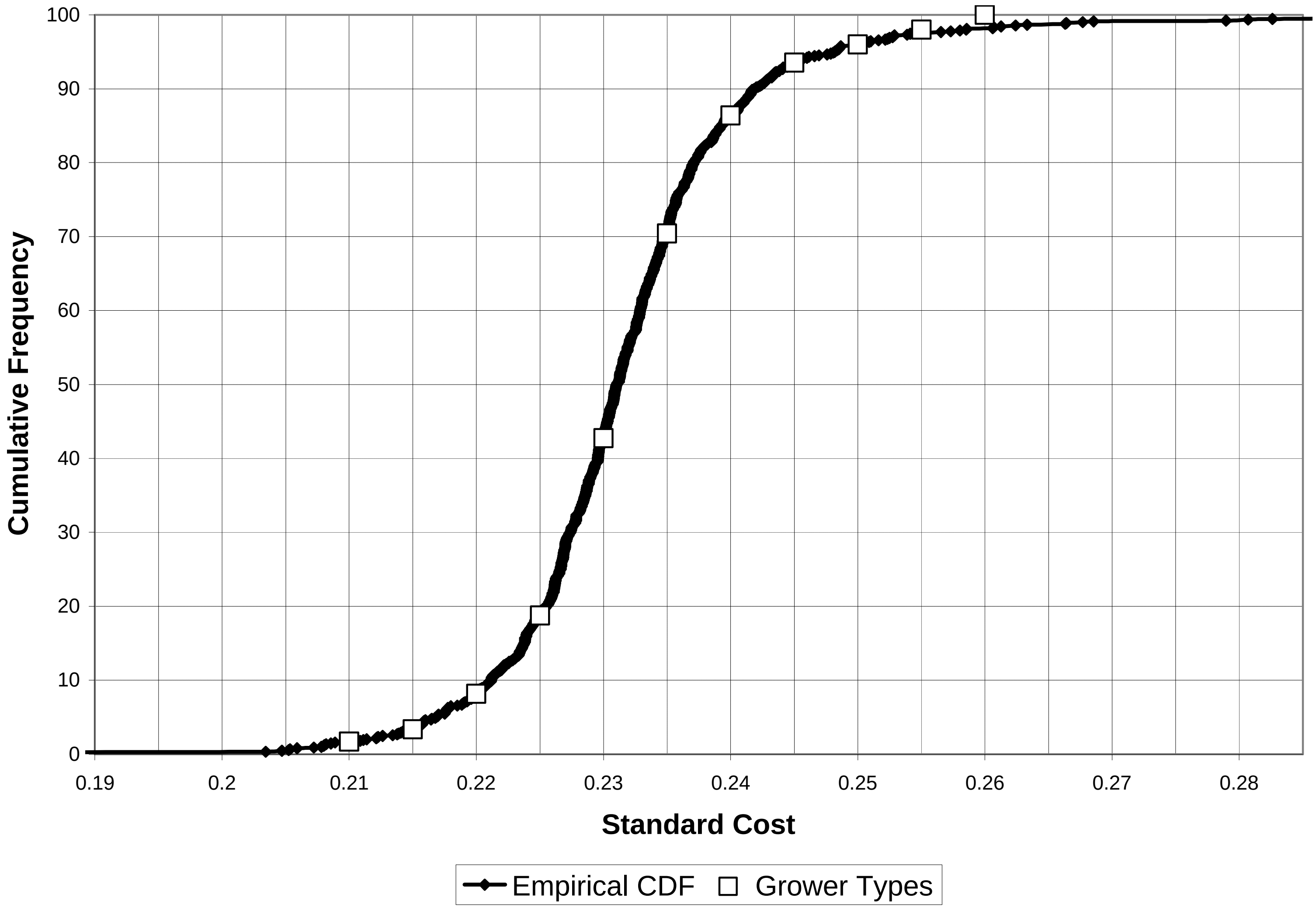

Figure 2. Grower revenues and payments at baseline integrator capacity of 1.2 million birds/week

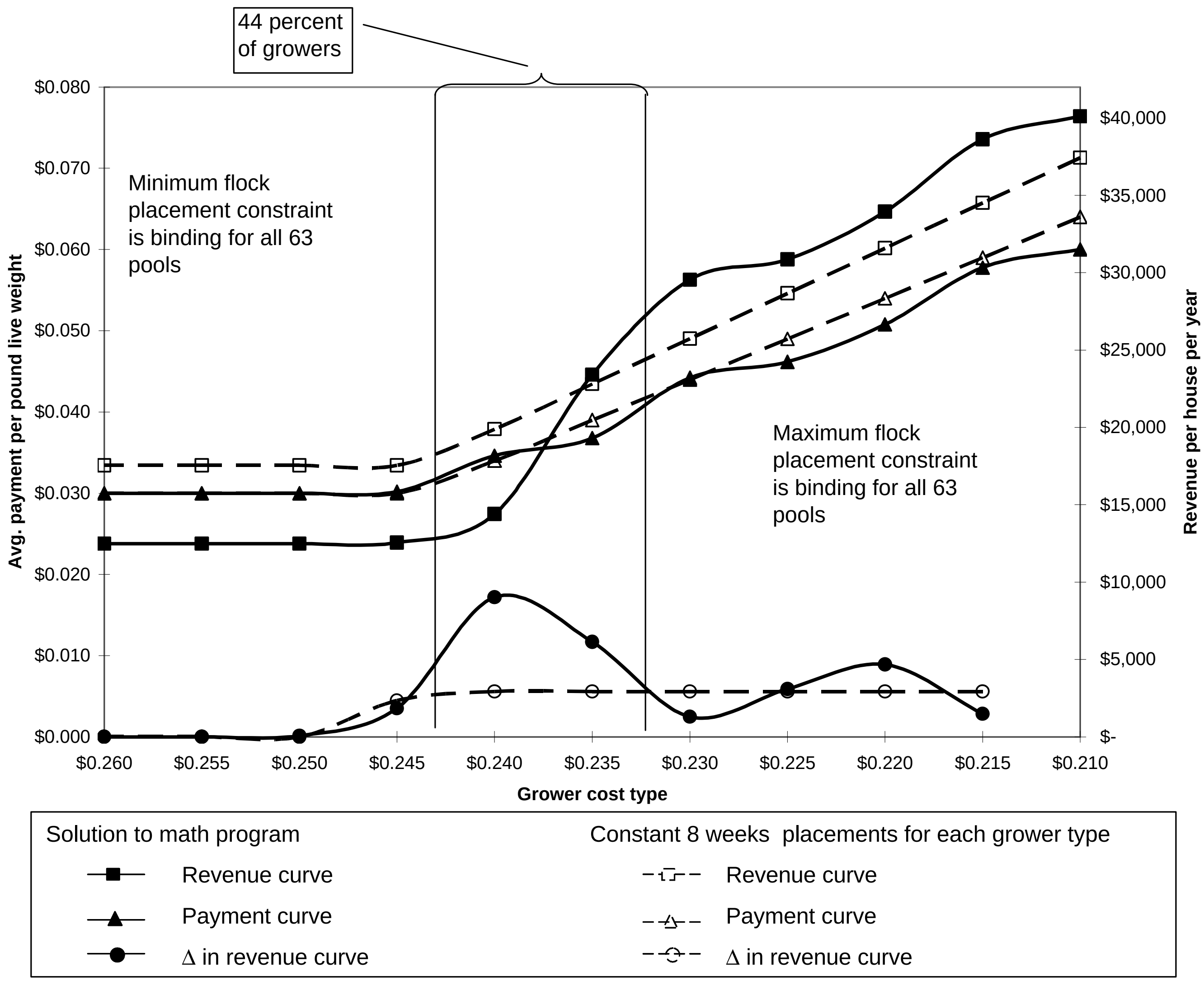

Figure 3. Range of grower revenues at for baseline capacity and capacities above and below baseline