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Production Contracts, Risk Shifting, and Relative Performance Payments in the Pork Industry

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ABSTRACT

Actual performance records of production contract farmers are used to assess the extent to which contract production reduces the risk borne by pork producers. Comparisons of contracting relative to independent market production reveal that farmers who enter into production contracts based on absolute performance measures reduce risks associated with variable income. Weak evidence is found that relative performance contracts, similar to those used in the broiler chicken industry, further reduce income variability. The effectiveness of such relative performance contracts will rely on several factors; among these are increased contract production and a more uniform pork production and processing system.

Key Words: absolute performance payment, income variability, pork industry, production contracts, relative performance payment, risk shifting.

Improvements in disease control and genetics facilitated the development of large-scale, confined livestock and poultry operations. Beyond altering size, technological advancements led to the reorganization of production and marketing in these industries. The most conspicuous changes occurred in the broiler chicken industry, which is essentially entirely vertically coordinated either via production contracts or company-owned farms. The pork industry appears to be following a similar course as it moves toward a more vertically coordinated organizational design.

Contract hog production is an important part of the emerging system of vertical coordination. Nearly 17% of the hogs slaughtered in 1994 were finished on contract (Grimes and Rhodes). Contract farming is even more widely used in nontraditional pork producing areas. Industry experts suggest as much as 80% of total production in North Carolina is contract finished. Production contracts differ from other forms of vertical coordination in that they specify marketing *and* production practices. Coordination itself is done by the contractor or "integrator." This individual or firm owns the animals and provides inputs ranging from feeder pigs and feed to veterinary services. The farmer's major contributions include labor and housing, a substantial capital investment. Farmer compensation is at a rate (typically based on the number of hogs and the rate of gain) predetermined in the contract. This contractual rate of pay does not rely on the market price of hogs or of inputs (feed).

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Since a contract farmer's pay is not subject to fluctuations in major input or output prices, the risk associated with variability in his or her income should be less than that of an independent producer. In fact, the primary reason given by producers for choosing contract farming is the combination of less market risk and a less variable income (Rhodes and Grimes). Previous research on pork production contracts has focused mainly on descriptive analysis and profitability issues (Johnson and Foster; Kliebenstein and Hillburn; McDaniel et al.; Zering and Beals). The current study attempts to assess the extent to which contract production reduces the risk borne by pork producers.[1] To do this, the actual performance records of 123 contract growers are used to address three issues. First, the extent of risk shifting provided by the absolute performance contracts currently used in the industry is measured. Second, the potential for additional risk shifting if *relative* performance contracts (similar to those used in the broiler chicken industry) replaced current absolute performance contracts is evaluated. Finally, sources of income variability and their relative importance in pork production are estimated.

Hog Production Contracts

Production contracts exist in several categories: sow farrowing arrangements, specialized nursery units, feeder pig enterprises, finishing operations, and farrow-to-finish farms. Grimes and Rhodes estimate that nationally, finishing contracts occur twice as often as either farrowing or farrow-to-finish contracts. The popularity of nursery contracts is more difficult to assess since this type of agreement has emerged relatively recently with the introduction of segregated early weaning practices. Finishing contracts are the focus of this study.

Finishing contracts may be as simple as a farmer contracting with a neighbor to finish a current excess of feeder pigs. More often, these contracts are multiperiod agreements between a large firm and a farmer which require the farmer to meet specific production standards. To capture economies of scale in production, many farmers own multiple houses. The cost of a 1,000-head finishing house ranges from $80,000 to $150,000, depending upon building design and geographic location. A contract farmer in the Southeast may borrow from $200,000 to $1 million to construct several of these facilities (Warrick and Stith). Such large-scale coordinated production has enabled farmers in states outside the traditional hog belt to quickly expand production.

Grower Income Variability Under Absolute and Relative Performance

Production contracts may tie compensation to performance in one of two ways. The first uses an absolute measure of performance and the second uses a relative measure of performance. In the first, a farmer is evaluated against an absolute standard and earns a specified piece-rate payment. In the second, a farmer is evaluated against similar growers. A relative performance (RP) contract may take one of two forms: compensation may be based on a grower's performance rank (x cents per pound for first place, y cents per pound for second place, and so on), or linearly upon his or her performance relative to the average of other growers.

Relative performance contracts are the primary form used in the broiler industry, but almost all hog integrators currently use only absolute performance contracts.[2] Which contract best reduces income variability depends upon the type of shock to which a farmer is subject. To see this, consider the following

[1] As pointed out by anonymous reviewers, a substantial amount of literature exists on the transactions costs explanation for vertical coordination or integration (e.g., Coase; Williamson; and others). Although significant reductions in transactions costs may occur from contracting, this study focuses on the risk-shifting aspects of contract production that arise from production and price shocks associated with pork production. Likewise, although a potentially important factor, risk associated with an integrator's ability and willingness to continuously fill the grower's house to capacity with healthy pigs is not addressed.

[2] One major North Carolina integrator began offering a relative performance contract around 1993.

typical absolute performance contract that determines grower payment by

$$(1) \qquad Y_{it}^{AP} = XG_{it} + b(\widetilde{FC} - FC_{it})HD_{it},$$

where Y_{it}^{AP} = absolute performance contract payment, X = fixed piece rate per pound gained, G_{it} = pounds gained, b = incentive coefficient used in calculating per head bonus, $\widetilde{FC}$ = standard feed conversion ratio, FC_{it} = actual feed conversion ratio, HD_{it} = head shipped to market, i = grower ($i = 1, \ldots, k$), and t = herd (i.e., "turn"; $t = 1, \ldots, n$).

Under this contract, the grower receives a fixed piece rate, X, per pound of gain with a bonus paid per head.[3] The size of the bonus is based on the difference between the grower's feed conversion ratio (pounds of feed/pounds of gain) and a standard feed conversion ratio. The standard ratio lies below the support of the feed conversion ratio probability distribution. With this contract, the variability of a farmer's income[4] is

$$(2) \qquad \mathrm{Var}(Y^{AP}) = X^2\sigma^2_{G_i} + (bHD)^2\sigma^2_{FC_i} - 2(XbHD)\mathrm{Cov}_{(G_i,FC_i)}.$$

Now consider a possible relative performance contract. Farmers who finish hogs during a set time interval are grouped together in a single "round" and each receives a payment:

$$(3) \qquad Y_{itr}^{RP} = XG_{itr} + b(\overline{FC}_r - FC_{itr})HD_{itr},$$

where Y_{itr}^{RP} = relative performance payment, $\overline{FC}_r$ = head-weighted mean feed conversion ratio for the round, $\{i = 1, \ldots, k\}$ indicates growers, $\{t = 1, \ldots, n\}$ indicates herds, and $\{r = 1, \ldots, m\}$ indicates round.

A grower i's relative performance is measured as $\overline{FC}_r - FC_{itr}$. Here, $\overline{FC}_r$ is the weighted mean feed conversion ratio for the round calculated as

$$(4) \qquad \overline{FC}_r = \frac{\sum_{i=1}^{k}\sum_{t=1}^{n} FC_{itr}HD_{itr}}{\sum_{i=1}^{k}\sum_{t=1}^{n} HD_{itr}}.$$

This relative performance contract is similar to the absolute performance contract in (1), but uses the average feed conversion ratio for each round as a benchmark rather than a fixed standard. Under this RP contract, grower i's payment variability is

$$(5) \qquad \begin{aligned} \mathrm{Var}(Y^{RP}) &= X^2\sigma^2_{G_i} + (bHD)^2\sigma^2_{\overline{FC}_i} + (bHD)^2\sigma^2_{FC_i} \\ &\quad + 2(XbHD)\mathrm{Cov}_{(G_i,\overline{FC}_i)} \\ &\quad - 2(XbHD)\mathrm{Cov}_{(G_i,FC_i)} \\ &\quad - 2(bHD)^2\mathrm{Cov}_{(\overline{FC}_i,FC_i)}. \end{aligned}$$

Comparison of the two variance terms shows that the RP contract will reduce the variance of grower payment relative to the absolute performance contract if

$$(6) \qquad (bHD)^2\sigma^2_{\overline{FC}_i} + 2(XbHD)\mathrm{Cov}_{(G_i,\overline{FC}_i)} - 2(bHD)^2\mathrm{Cov}_{(\overline{FC}_i,FC_i)} < 0.$$

As a simplification, if one assumes that the $\mathrm{Cov}_{(G_i,\overline{FC}_i)}$ is zero, then relative to the absolute performance contract in (1), RP contracts will further reduce grower i's income variability if

$$(7) \qquad \sigma^2_{\overline{FC}_i} - 2\mathrm{Cov}_{(\overline{FC}_i,FC_i)} < 0.$$

Whether or not (7) is true will depend upon the size of the common production shock(s), the growers' idiosyncratic shocks, and the number of growers in a round.

Two characteristics of relative performance contracts cause this uncertainty. First, RP contracts reduce variability by sorting out production shocks common to contemporaneous

[3] Typical values for X and b are \$0.03 per pound and \$6 per head, respectively.

[4] This variance decomposition is facilitated by treating HD as a constant. Given that contract farmers operate with a standard finishing house, and contracts usually specify that the house must be filled to at least 90% capacity, treating the number of finished hogs as fixed is not altogether unrealistic. This assumption is made only for theoretical simplicity and will not alter any conclusions. Later empirical estimates of payment variability capture all variance and covariance terms.

growers. Such common shocks may arise if the integrator varies the feed or animal genetics provided to all growers in a round. Since common production shocks affect both the individual's effort level (measured by FC_i) and the average effort level (measured by $\overline{FC}_r$), the covariance term captures the size of the shock and sorts out common production risk. Second, RP contracts may increase an individual's payment variability by including a new source of randomness, the opponents' effort level. This effect is captured by the inclusion of the opponents' shocks in the round mean feed conversion ratio. Any shock specific to one farmer (i.e., an idiosyncratic shock such as a water pipe bursting) affects the round mean feed conversion ratio.[5] As discussed in Holmstrom, and in Green and Stokey, if the number of farmers in a round is sufficiently large, this term tends toward zero. Therefore, if risk reduction is an important benefit, one should expect to find relative performance contracts used when there are production shocks common to all farmers and either idiosyncratic production shocks are small or the number of contract farmers is large.

[5] Equation (7) can be further analyzed by treating the variable *HD* as a constant. The weighted average feed conversion ratio in (4) then becomes a simple average and (7) can be expressed as follows:

$$\text{(7a)} \quad \frac{1}{n^2}\left(\sum_{j=1}^{n} \sigma_j^2 + \sum_{j=1}^{n} \sum_{i \neq j}^{n} \sigma_{ij}\right) - \frac{2}{n}\left(\sigma_i^2 + \sum_{j \neq i}^{n} \sigma_{ij}\right) < 0.$$

Here, common shocks are captured in the σ_{ij} terms; the cost of the RP contract is including the opponents' idiosyncratic shocks, the σ_j^2 terms. Now consider the case where all production shocks are common, so that $\sigma_i^2 = \sigma_j^2 = \sigma^2$, and with pairwise correlation coefficient $\rho = 1$. In this case, (7a) reduces to $-\sigma^2$, and the RP contract dominates the absolute performance contract. Another extreme case occurs when all shocks are idiosyncratic and there are no common production shocks, i.e., $\sigma_{ij} = 0$, and $\rho = 0$. Here, the left-hand side of (7a) becomes

$$\frac{1}{n^2}\sum_{j \neq i}^{n} \sigma_j^2 + \frac{(1 - 2n)}{n^2}\sigma_i^2.$$

If the opponents' shocks are significant, then this term will be positive and the RP contract causes grower i's income to be more variable than under the absolute performance contract in (1).

Data and Empirical Methodology

To assess the risk-shifting effects of contract production, data were collected on the performance of farmers under contract with one North Carolina integrator. These data describe the performance of 123 finishing farmers who operated under the absolute performance contract described in equation (1) from September 1985 through December 1992. Included in the data are the number of hogs placed and marketed, pounds gained, feed consumed, and grower payment for each farmer and herd. Placement and removal dates for each herd also are given. There are 805 total observations (i.e., 805 groups of pigs, where each group is referred to as a herd).

Grower payment is measured per house per day, but the data are reported either per house or per farm. Farm size ranges from 1–5 houses, with a mean of 1.6. The data are transformed to a per house per day measure by first dividing grower payment by the number of days a herd occupies the house, plus seven days for preparing the house between herds.[6] If a grower's payment is reported for multiple houses, then the payment is divided by the number of houses. Thus, each payment is transformed to a per house per day basis. This measure reflects the daily return to the grower for labor and investment. The average number of observations per farmer (i.e., herds per grower over the study period) is 6.5, and ranges from two to 37.[7]

During the study period, the feed conversion standard facing growers decreased from 3.50 to 3.35. With the lower ratio, the standard for commingled pigs was kept at 3.50. Con-

[6] Seven days is used as an estimate of the days needed for cleanup between herds. Due to the record keeping procedures of this particular integrator, it was not always possible to determine the days between groups for a particular grower. As one reviewer noted, companies try to turn the house every six to seven days, but this is not always practiced or possible, thereby introducing an additional risk to the grower.

[7] Forty-six of these growers produced less than five herds during the sample period. Because of the lower numbers of observations for these growers, they are not included in the variance analysis in the following sections.

sequently, a farmer who operated under the contract described in (1) may have faced different performance standards: a benchmark of 3.50 in the early period (regardless of whether or not the pigs were commingled); in the later period, a standard ratio of 3.35 for non-commingled pigs and a standard ratio of 3.50 for commingled pigs. Because changes in performance standards are a real risk to contract growers, the two periods are not analyzed separately.[8]

Absolute Performance Contracts

To assess the effect of absolute performance contracts on income variability against the benchmark of independent farmers, it is first necessary to simulate income for independent producers. To do this, the performance data for each actual contract grower are used to construct a measure of "independent farmer" net variable income. This income is calculated for each farmer by presuming that the individual faces market prices for inputs and output, but that input use and output are identical to that of the counterpart contract grower. Net variable income here is a partial profit term defined as total revenue from hog sales less major variable input costs (feed and feeder pigs). This measure captures the major costs and revenues associated with hog production that vary significantly over time.

Feed and animal prices are required to simulate income for independent producers. Market prices for feed, feeder pigs, and finished hogs are obtained from *Agricultural Prices* (U.S. Department of Agriculture/National Agricultural Statistics Service). Quarterly feed prices for the Appalachian region are reported.[9] Since hogs are fed over a period of four to five months, it is necessary to convert the quarterly data to monthly prices. A four-month interpolation is used for this transformation. The interpolated monthly feed prices are then matched to the last shipment date. For instance, if the last shipment date is April 12, the market feed price used to decide feed cost is $\bar{P}_{April}$, an average of the interpolated prices of the previous four months. Feeder pig prices also are reported quarterly, but are listed by state. To estimate monthly prices, an interpolation of the quarterly data is again performed. The monthly prices are matched to each herd's average starting date. Finally, monthly prices received by North Carolina farmers for barrows and gilts are used as market prices for hogs. These prices are matched to the average ending date of each herd. The average ending date is a weighted average of the dates that the animals in a herd are moved to market. The number of animals moved per day determines the weight.

Independent grower simulations are constructed for a farmer who purchases feeder pigs and feed on the market and sells finished hogs. Using actual production data for a contract farmer and these monthly price series, the net variable income of a simulated independent grower is calculated as follows:[10]

$$(8) \qquad Y_{it}^{IND} = (P_j^H Q_{ijt}^H) - (P_j^F Q_{ijt}^F) - (P_j^P Q_{ijt}^P),$$

where Y_{it}^{IND} = income for independent finishing farmer, P_j^H = price per pound of hog, Q_{ijt}^H = pounds of hog produced, P_j^F = price per pound of feed, Q_{ijt}^F = pounds of feed consumed, P_j^P = price per pound of feeder pig, Q_{ijt}^P = pounds of pig purchased, i = farmer (i = 1, . . . , 123), j = month, and t = herd (t = 1, . . . , n).

For each farmer, risk shifting is examined by testing the hypothesis of equal payment variances, H_0: $\sigma^2_{i,Y^{IND}} = \sigma^2_{i,Y^{AP}}$. The alternative hypothesis is a greater variance for the independent farmer. Since the simulated payments and actual contract payments are correlated, a

[8] The distinction between commingled and non-commingled feeder pigs becomes more important when relative performance payments are simulated in the following sections.

[9] Prices for 1985 are reported monthly. All other years are reported as noted.

[10] Although other input costs, such as utilities and capital payments, may be stochastic, it is assumed that both contract farmers and independent farmers face the same costs. Therefore, these expenses are not included to describe variability.

conventional F-test is not appropriate.[11] Instead, the Pitman test, which is an exact test for the equality of two variances for correlated variables, is used. Two variables are first constructed from the data: $U_i = Y_i^{AP} + Y_i^{IND}$, and $V_i = Y_i^{AP} - Y_i^{IND}$. The $\text{Cov}(U_i, V_i)$ then equals the difference in the two payment variances, $\text{Cov}(U_i, V_i) = \sigma^2_{i,Y^{IND}} - \sigma^2_{i,Y^{AP}}$ (Morrison). The exact distribution of r, the sample correlation coefficient, under normality and the null hypothesis, is used to test the hypothesis that the $\text{Cov}(U_i, V_i)$ equals zero. The Pitman test is conducted as an individual test for each farmer and not a joint test for contract farmers as a group.[12] As shown in table 1, each of the 77 growers rejects the null hypothesis of equal payment variances at both the .05 and .10 significance levels. Clearly, those farmers who operated under this particular absolute performance contract reduced the risk associated with variable farm income.

Recognizing that the above test statistic may be sensitive to small sample size and deviations from normality, a second criterion is used to evaluate risk shifting. For each farmer, a ratio is formed which consists of the standard deviation of the simulated independent payment to the standard deviation of the actual payment (Knoeber and Thurman). A ratio greater than one implies the simulated payment is more variable than the contract payment. All farmers have ratios greater than one. The mean ratio is equal to 10.55, and ranges from 2.76–28.41. This implies that, on average, the income variability of the simulated independent farmer is more than 10 times greater than his or her counterpart contract grower. Alternatively, one can interpret the standard deviation of independent farmer income as a measure of pork production risk and conclude that contract producers face only 9.5% of the risk borne by their independent counterparts. This implies that approximately 90% of pork production risk is shifted to the integrator.

Relative Performance Contracts

A second objective of this study is to explore the potential for additional risk shifting if *relative* performance contracts, similar to those used in the broiler chicken industry, replaced existing absolute performance contracts. To evaluate this potential, it is necessary to simulate grower payments based on a relative measure. Three potential RP contracts similar to equation (3) are simulated. Each RP simulation restricts the sum of all grower payments to equal the actual total payments of the integrator, i.e., the simulated mean payment per pound gained (per head) equals the actual mean payment per pound (per head) paid by the integrator. This restriction is imposed to preserve the total payments paid by the integrator, but to allow the variance of the RP payments to individual growers to differ from that of the actual absolute performance contract payment.

For purposes of the relative performance simulations, farmers are grouped into rounds based on the contract specifications under which they operated. For example, all farmers who closed out their finishing houses in June of 1992 are grouped together. If a farmer finished commingled pigs in the same month, he or she would be in a different round. In this way, farmers are compared only to those growers facing similar conditions. One hundred thirty-two rounds are formed from this grouping. The mean number of farmers per round is equal to 6.09, but ranges from one to 44.

The first simulated RP contract parallels the actual absolute performance contract, but uses the round mean feed conversion ratio de-

[11] In addition, the prices used in the construction of the market payments may be biased. Each of the market prices used in this analysis is an average regional price and not an individual price facing the farmer. Generally, the average price will be less variable than the local market price. Note, however, that this study is interested in testing the hypothesis that income variability for a contract farmer is equal to that facing an independent farmer with an alternative hypothesis of greater income variability for the independent farmer. Therefore, any test that rejects the null hypothesis using the less variable average feed price would certainly lead to rejection of the null had the more variable individual price been available.

[12] A Bartlett test soundly rejects the hypothesis of equal variances among farmers.

Table 1. Testing for Equal Payment Variances Between Actual Absolute Performance Grower and Simulated Independent and Relative Performance Growers

Null Hypothesis	Percentage of Growers Who Reject H_0	
	$\alpha = .05$	$\alpha = .10$
	(%)	
Simulated Independent Grower:[a]		
$\sigma^2_{i,Y^{IND}} = \sigma^2_{i,Y^{AP}}$	100.0	100.0
Simulated Relative Performance Grower:[a]		
(1) $\sigma^2_{i,Y^{AP}} = \sigma^2_{i,Y^{RP1}}$	25.9	36.4
(2) $\sigma^2_{i,Y^{AP}} = \sigma^2_{i,Y^{RP2}}$	63.6	70.0
(3) $\sigma^2_{i,Y^{AP}} = \sigma^2_{i,Y^{RP3}}$	44.2	51.9

Notes: $\sigma^2_{i,Y^{IND}}$ = payment variance for simulated independent grower i; $\sigma^2_{i,Y^{AP}}$ = payment variance for actual absolute performance contract grower i; $\sigma^2_{i,Y^{RP1}}$ = payment variance for the first simulated relative performance contract, grower i; $\sigma^2_{i,Y^{RP2}}$ = payment variance for the second simulated relative performance contract, grower i; and $\sigma^2_{i,Y^{RP3}}$ = payment variance for the third simulated relative performance contract, grower i.

[a] Analysis includes only those growers with at least five observations.

scribed in equation (4) instead of the absolute standard:

$$(9) \qquad Y^{RP1}_{itr} = XG_{itr} + b(\overline{FC}_r - FC_{itr})HD_{itr} + \lambda_c,$$

where Y^{RP1}_{itr} = relative performance payment one, $\overline{FC}_r$ = head-weighted mean feed conversion ratio, λ_c = a constant equal to the mean bonus payment actually made by the integrator for each contract type, b = performance incentive coefficient $\approx$ 6.0, i = grower (i = 1, . . . , 123), t = herd (t = 1, . . . , n), and r = round (r = 1, . . . , 132).

Here, the piece-rate payment, X, and the incentive coefficient, b, are kept at the same levels as in the actual contract. The second simulated RP contract also is similar to the actual contract, but the incentive coefficient is set equal to $1 per head, a substantial reduction from the original value of approximately $6 per head. The second RP contract payment, Y^{RP2}, is specified as

$$(10) \qquad Y^{RP2}_{itr} = XG_{itr} + (\overline{FC}_r - FC_{itr})HD_{itr} + \lambda_c.$$

In contrast to the actual contract, the final relative performance scheme bases grower compensation on only the number of hogs in a herd and the grower's relative performance. Similar to broiler contracts, the difference between the grower's feed conversion ratio and the average feed conversion ratio for his or her round is multiplied by the number of animals. This third relative performance contract is simulated as

$$(11) \qquad Y^{RP3}_{itr} = [\delta_c + (\overline{FC}_r - FC_{itr})]HD_{itr},$$

where Y^{RP3}_{itr} = relative performance payment three, and δ_c is a constant equal to the mean per head payment made by the integrator for each contract type.

From the integrator's viewpoint, the sum of all bonuses is zero; therefore, the mean payment per pound (per head) for each simulated contract type is equal to the actual average payment per pound (per head) paid by the integrator. To determine if RP contracts have the potential for additional risk shifting, the hypothesis of equal payment variances is tested. This is a one-sided test with an alternative hypothesis of a greater payment variance for the absolute performance payment. Again, the Pitman test is used to test the hypothesis. Results from this test are inconclusive. However, the results do show that the value of the incentive coefficient greatly affects the percentage of farmers who further reduce income variability under potential relative performance contracts.

Recall that the first two RP payments are similar to the actual absolute performance contract, but Y^{RP2} uses a smaller incentive coefficient. Evaluating the first RP payment simulation, only 36.4% of the farmers show sta-

tistically significant income variance reduction at the .10 significance level (table 1). However, under the second RP simulation at the .10 significance level, the percentage of farmers that reject the null hypothesis of equal income variances increases to 70%. The third RP contract simulation more closely corresponds to modern broiler contract specifications. With this payment, 51.9% of the farmers show statistically significant income variance reduction at the .10 significance level.

As a second criterion to evaluate risk reduction, the ratio of the standard deviation of the simulated relative performance payment to the standard deviation of the actual contract payment is constructed. A ratio less than one implies less payment variability with the RP contract than with the actual absolute performance contract. The mean ratios of the standard deviation of the RP payments to the actual contract payment are all less than one. However, several farmers produce ratios greater than one for each simulation. The ratio of the standard deviation of the first RP payment to the actual contract has a mean of 0.89, but a range from 0.49–1.61; when Y^{RP2} is analyzed, the ratio ranges from 0.35–1.46 with a mean of 0.69; and the third simulation leads to a mean ratio of 0.74 and a range from 0.36–1.76. Again, using the mean ratios as a measure of risk shifting, these values suggest that, on average, absolute performance contracts are slightly more risky than the three relative performance contracts analyzed here (approximately 1.12 to 1.45 times more risky). The mean ratios also indicate that relative performance contracts may shift as much as 93.5% of pork production risk to the integrator (6.5% borne by the grower under Y^{RP2}).

Given the varying rejection percentages and the sensitivity of income variability to incentive levels, two issues merit further discussion. First, the question addressed in this study is direct: Would the growers who operated under the absolute performance contract have reduced income variability with these possible RP contracts given that their performance *does not change*? This study suggests that the answer may be yes, but it will depend upon the contract specifications and types of shocks. This study does not address the possibility of contract design affecting performance. Clearly, this is an important extension. Second, the first two RP simulations suggest a tradeoff between performance incentive and income variability. More growers reject the null hypothesis when the incentive coefficient equals 1.0 instead of 6.0. For a sample farmer, figure 1 displays the effect on payment variability of changing the incentive coefficient. Again, what cannot be analyzed is the effect of greater incentive on grower performance, but the direction of the effect is clear. As b increases, grower pay is tied more closely to performance. So raising b implies more incentive, but also more risk.

Sources of Income Variability

As demonstrated in equations (6) and (7), the effectiveness of an RP contract as a risk-shifting mechanism depends upon the sources of shocks. To evaluate the relative contributions of different shocks to income variability, grower income variance is decomposed into three components: idiosyncratic production variability, common production variability, and price variability (Knoeber and Thurman). The idiosyncratic portion stems from a farmer's actions and is specific to the individual farmer; the common production shock arises in situations where all contract farmers face the same production shock; and price variability reflects shocks in input and output prices.

Recall that the independent farmer faces all three risks: idiosyncratic production, common production, and price. The farmer who operates under the absolute performance contract avoids price risk since the integrator provides major variable inputs and sets output price. Finally, relative performance contracts potentially sort out the common production risk that remains under absolute performance contracts. Using earlier notation and omitting the grower subscript, let each of the payment series for herd t be written as follows:

$$Y_t^{RP} = \mu_1 + \epsilon_t^I,$$

$$Y_t^{AP} = \mu_2 + \epsilon_t^I + \epsilon_t^C,$$

$$Y_t^{IND} = \mu_3 + \epsilon_t^I + \epsilon_t^C + \epsilon_t^P.$$

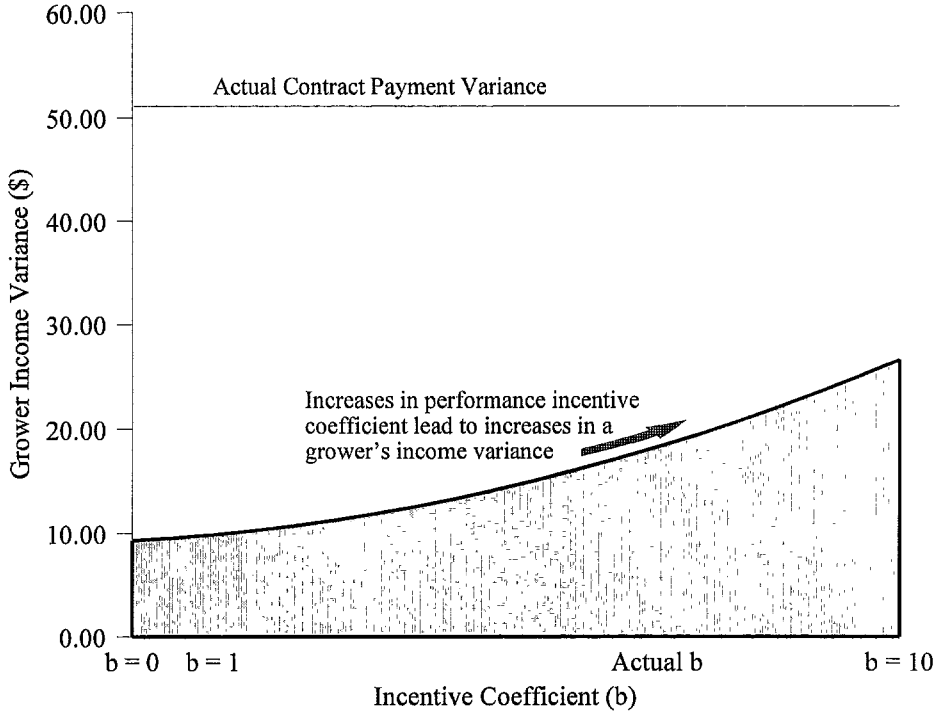

Figure 1. Relationship between incentive level and payment variance for a representative contract grower

Here, ϵ_t^I, ϵ_t^C, and ϵ_t^P represent idiosyncratic, common production, and price shocks, respectively. The above equations can be written as the matrix equation $Y_t = \mu + \omega\epsilon_t$, with each matrix defined as

$$Y_t = \begin{bmatrix} Y_t^{RP} \\ Y_t^{AP} \\ Y_t^{IND} \end{bmatrix}, \qquad \mu = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \end{bmatrix},$$

$$\omega = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 1 & 1 & 1 \end{bmatrix}, \quad \text{and} \quad \epsilon_t = \begin{bmatrix} \epsilon_t^I \\ \epsilon_t^C \\ \epsilon_t^P \end{bmatrix}.$$

To recover the covariance matrix of the unobservable ϵ_ts, the covariance matrix of the observable Y_t is first estimated. Recognizing that the covariance matrix of Y_t can be described by $\text{Cov}_Y = \omega\text{Cov}_\epsilon\omega'$, then the covariance matrix of the unobservable ϵ_ts is $\text{Cov}_\epsilon = \omega^{-1}\text{Cov}_Y(\omega^{-1})'$, which yields the following covariance matrix:

$$\text{Cov}_\epsilon = \begin{bmatrix} \sigma_I^2 & \sigma_{IC} & \sigma_{IP} \\ \sigma_{CI} & \sigma_C^2 & \sigma_{CP} \\ \sigma_{PI} & \sigma_{PC} & \sigma_P^2 \end{bmatrix}.$$

Interpreting total income variability as the income variability resulting from the independent payment, six potential sources of income variability are identified:

$$\begin{aligned} \text{Var}(Y_t^{IND}) &= \text{Var}(\epsilon_t^I + \epsilon_t^C + \epsilon_t^P) \\ &= \sigma_I^2 + \sigma_C^2 + \sigma_P^2 \\ &\quad + 2(\sigma_{IC} + \sigma_{IP} + \sigma_{CP}). \end{aligned}$$

The relative importance of each of these sources is assessed by determining the proportional contribution of each source. Specifically, these shares are

Table 2. Means and Standard Deviations of Various Sources of Income Variation Under Alternative Relative Performance Payment Schemes

	Alternative Relative Performance Schemes		
Sources	Mean RP1	Mean RP2	Mean RP3
Idiosyncratic (α_I)	0.0139	0.0084	0.0097
	(0.0184)	(0.0132)	(0.0135)
Common Production (α_C)	0.0027	0.0060	0.0075
	(0.0027)	(0.0071)	(0.0121)
Price (α_P)	0.9417	0.9417	0.9417
	(0.1494)	(0.1494)	(0.1494)
Idiosyncratic × Production (α_{IC})	0.0012	0.0034	0.0006
	(0.0062)	(0.0089)	(0.0161)
Idiosyncratic × Price (α_{IP})	0.0510	0.0296	0.0298
	(0.1209)	(0.0984)	(0.1077)
Production × Price (α_{CP})	−0.0104	0.0109	0.0107
	(0.0434)	(0.0633)	(0.0717)
$\alpha_I + \alpha_C + \alpha_P$	0.96	0.96	0.96
	(0.15)	(0.15)	(0.15)

Notes: Numbers in parentheses are standard deviations. The terms α_I, α_C, and α_P represent the proportional contribution of idiosyncratic, common production, and price risk, respectively, to total payment variability inherent in pork production for the hog finisher; the covariance proportion terms α_{IC}, α_{IP}, and α_{CP} show the joint contributions of two shocks. Analysis includes only those growers with at least five observations.

$$\alpha_I = \frac{\sigma_I^2}{\mathrm{Var}(Y_t^{IND})}, \quad \alpha_C = \frac{\sigma_C^2}{\mathrm{Var}(Y_t^{IND})},$$

$$\alpha_P = \frac{\sigma_P^2}{\mathrm{Var}(Y_t^{IND})}, \quad \alpha_{IC} = \frac{\sigma_{IC}}{\mathrm{Var}(Y_t^{IND})},$$

$$\alpha_{IP} = \frac{\sigma_{IP}}{\mathrm{Var}(Y_t^{IND})}, \quad \alpha_{CP} = \frac{\sigma_{CP}}{\mathrm{Var}(Y_t^{IND})}.$$

Note that the sum of the six ratios must equal one. Also, adopting the terminology of Knoeber and Thurman (K-T), the "pure" contribution of an individual shock (α_I, α_C, and α_P) must be positive. There are no a priori restrictions placed on the covariance terms. Table 2 provides the relative contribution of idiosyncratic, common production, and price risk, as well as their corresponding covariance terms. The final row in the table presents the sum of the pure contributions. The columns in table 2 show the mean ratios across all growers, $\bar{X}$, and their standard deviations. Each of the three different relative performance simulations results in a different measure of idiosyncratic risk.

Price shocks have the largest influence on income variability—approximately 94% (table 2). This percentage is higher than the 84% determined by K-T for the broiler chicken industry. In pork production, the pure contributions of idiosyncratic and common production shocks are small, between 0–1%. In contrast, each of these shocks accounts for 3% of total broiler production variability. The sum of the pure contributions accounts for approximately 96% of total variability, slightly higher than the 90% found in the broiler industry.

The largest interactive effect comes from the relationship between idiosyncratic and price risk, σ_{IP}. This interactive term accounts for roughly 3–5% of total variability, similar to the 5% determined by K-T. The joint influence of idiosyncratic and common production risk accounts for the smallest proportion of variability. Similar to broiler production, this study attributes the interactive effect of idiosyncratic and common production risk to be less than 1% of total variability.

The magnitude and direction of the interactive effect of common production and price

risk strongly depend upon the RP payment design. Both the second and third RP designs lead to a 1% contribution from the joint effect, but the joint effect with the first RP contract causes a slight decrease in variability (table 2). Regardless of the payment design used, the interactive effect is minimal, and contrasts with results reported by K-T. In broiler chicken production, σ_{CP} determines 4% of total risk. At first glance, this contrast with pork production may seem puzzling. However, when one considers the source of the interactive term, the estimates are more plausible.

In broiler production, broiler price accounts for the largest component of price risk. A positive covariance term between price and common production risk suggests that when broiler prices increase, integrators increase flock size and contemporaneous growers receive larger payments. With broilers, the lag period between chick placement and harvest is a short six to seven weeks. With finishing hogs, however, that interval expands to nearly five months. A smaller, but still positive, combined effect of price and common production risk for hogs suggests that integrators are less likely, or less able, to alter herd size in order to capture higher output prices. This may be due either to more restrictive housing requirements (space per animal) or to the duration of the gestation and weaning cycles for swine relative to poultry. Finally, a plausible explanation for a negative interactive term is that integrators do alter herd size in response to higher hog prices, but the larger herd sizes lead to more inefficient feed conversion ratios, and contemporaneous growers receive lower payments rather than higher payments. In either case, the small estimates for the combined effect in table 2 imply that the relationship between price and common production risk currently is much less important in pork production than in broiler production.

Conclusions

The results presented here strongly support the argument that relative to independent production, contract farming reduces grower income variability. Moreover, relative performance contracts have the potential to further reduce income variability. The relative performance contracts examined in this study show a reduction in income variability for 36–70% of the contract growers. Knoeber and Thurman found much stronger evidence of risk reduction in the broiler chicken industry under relative performance contracts. Their research concluded that 89% of the broiler growers showed statistically significant variance reduction with relative performance contracts as opposed to an absolute performance contract.

One reason for the difference is that in the simulated relative performance contracts, the number of growers per round tends to be small. In this study, the mean number of farmers in a round is equal to 6.09, thereby making the relative contribution of each farmer to the mean feed conversion ratio significant. With a small pool of farmers in a given round, the increased variability caused by the introduction of opponents' idiosyncratic shocks outweighs the decrease from sorting out common production risks. For example, if the feed conversion ratio for one farmer is particularly variable, it also will cause the mean feed conversion ratio to be variable. Consequently, farmers with stable absolute performance from round to round will exhibit variable relative performance. This would not be true if the farmer is evaluated against many growers. Therefore, a consequence of small pools in the hog industry may be an increased income variability caused by the introduction of opponents' idiosyncratic shocks, i.e., a significantly large $\sigma^2_{\overline{FC}_r}$ in (7).

A second plausible explanation of the weak evidence for additional risk shifting is the nature of the pork industry. Unlike broiler chickens that are very homogeneous, pork production is not yet characterized by such uniformity. Whereas a broiler chicken is harvested at a uniform weight, a hog may go to market at a weight between 220–280 pounds. In addition, feeder pigs are placed on farms at a weight between 30–60 pounds. This lack of uniformity means that more variation in performance in hog production will be idiosyncratic, and less will be common. Since it is only the common variation that can be sorted

out by relative performance contracts, there is less that these contracts can do to reduce grower risk in hog production relative to broiler production. However, as integrators adopt more uniform placement and market practices, the advantage of relative performance contracts grows. Nevertheless, results from this study do show that regardless of the contract, relative to independent pork production, production contracts do reduce the risk associated with variability in income. Furthermore, the majority of this risk comes from input and output price uncertainty and is shifted from the farmer to the integrator. Still, the potential exists that relative performance contracts may lead to additional risk shifting if more variation in grower performance is due to common production shocks rather than to idiosyncratic production shocks.

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