GROWER RISK AVERSION AND THE COST OF MORAL HAZARD IN LIVESTOCK PRODUCTION CONTRACTS

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The use of contracts to vertically coordinate the production and marketing of agricultural commodities has become common practice in many agricultural sectors. To solve the apparent asymmetric information problems between processors and independent farmers that universally plague these relationships, the majority of contracts use high-powered incentives schemes to compensate farmers. In light of the renewed interest and increased pressure on the states and federal government to regulate production contracts, a legitimate question to ask is: How much are the producers going to loose if forced to replace the high-powered incentives schemes that include performance bonuses with some low-powered ones, such as simple piece rates? The answer to this question depends on the size of the cost of moral hazard.

The welfare cost of moral hazard emanates from the fact that contract growers are risk averse and face uncertain income streams. The degree of risk aversion generates more or less disutility from uncertainty and plays an important role in the design of the optimal contract form. The literature on the provision of incentives in firms is based on the premise that relating pay to performance increases output, but at the cost of imposing risk on the agents, which is reflected in higher compensations. Grower welfare depends on the type of contract he has signed, the distribution of random factors affecting production, and the shape of his utility function.

The objective of this article is to develop an analytical framework for the econometric estimation of the degree of risk aversion of farmers involved in the contract production of hogs and to carry out the empirical estimation of the individual risk-aversion parameters using microlevel contract performance data. These estimates are subsequently used to assess the cost of moral hazard caused by growers' risk aversions that affect both the processor and the contract producers.

The attempts to quantify the welfare losses associated with moral hazard and risk aversion in different fields of the economy are few and recent. For example, Ferrall and Shearer estimated the cost of incomplete information due to insurance (worker risk aversion) and incentives consideration and found that the two costs are of similar magnitudes. In the context of managerial compensation, Margiotta and Miller found that the costs of aligning hidden managerial actions to shareholders' goals through the compensation schedule are much less than the benefits from the resulting managerial performance. Similar to our model, the heterogeneity in agents' risk preferences is also found in Paarsch and Shearer. They estimated a structural model with moral hazard in the context of tree-planting labor contracts and found that incentives caused a 22.6% increase in productivity, only a part of which represents valuable output because workers respond to incentives by reducing quality.

Our results show that growers are heterogeneous when it comes to comparing their risk-aversion parameters and that risk-aversion heterogeneity affects the principal's allocation of contracted quantities across growers. The results provide empirical support for the central tenet of the agency theory that contracts are designed to optimally trade-off risk sharing against incentives provision.

Stylized Facts and a Model

Swine production in the United States is characterized by an increasing presence of vertically integrated firms (called integrators) that contract the production (grow-out) of hogs with independent farmers. All production contracts have two main components: (*a*) the

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division of responsibility for providing inputs and (b) the method used to determine grower compensation. Growers provide land, housing facilities, utilities (electricity and water), and labor and are also responsible for manure management and disposal of dead animals. Integrators provide animals, feed, medications, and services of field men. They also decide on the volume of production both in terms of the rotations of batches on a given farm and the density of animals inside the house. A typical scheme for compensating growers in finishing contracts is based on a base plus bonus payment per pound of gain (live weight) transferred, where a bonus payment reflects some efficiency measure, such as feed conversion.

In the finishing contract that generated the data used in this study (see Martin), the compensation to grower i for the batch of hogs under contract t is calculated on a per pound of gain basis with bonuses earned on a per-head basis. The bonus rate is based on the difference between the individual grower's feed conversion, expressed as pounds of feed divided by pounds of gain $\frac{F_{it}}{q_{it}}$, and a standard feed conversion ratio (ϕ). The total bonus payment is determined by multiplying the bonus rate by the number of pigs marketed, where the marketed pigs $(1 - m_{it})H_{it}$ are those feeder pigs that survived the fattening process and m_{it} is the grower-specific animal-mortality rate. Mathematically, the exact formula for the total compensation is

$$(1) \qquad R_{it} = \alpha q_{it} + \max\left[0, \beta\left(\phi - \frac{F_{it}}{q_{it}}\right) \times (1 - m_{it})H_{it}\right].$$

We model the integrator–grower relationship in a principal-agent framework. The agent (grower) is required to perform specific tasks that are not perfectly observable by the integrator (principal), who, therefore, faces a moral-hazard problem in the delegation of production tasks. The incentives to the grower to behave according to the principal's objective are provided through the payment scheme, which always includes a particular type of bonus (premium) mechanism. In our contract the bonus depends on a perfectly observable and verifiable performance measure, which is the feed conversion ratio. Ignoring the issues related to the contract design, we first model the agent's behavior given the terms specified in the observed contract. Then, we study the principal's behavior given the agent's optimal response.

We assume that growers' preferences over revenue (R) and effort (e) are observed by the principal and described by the utility function $U_i(R - C(e))$, where $C(\cdot)$ is a positive increasing function implying that effort is costly. We assume that growers exhibit constant absolute risk aversion and that the stochastic revenue is normally distributed. Under these assumptions, grower i's expected utility can be expressed as an increasing concave function of a mean–variance criterium (which corresponds to the certainty equivalent value of revenue) and his maximization problem can be written as

$$(2) \qquad \max_{e_{it}} W_{it}(R_{it}, e_{it}) = ER_{it} - \frac{b_i}{2}\operatorname{var}R_{it} - C(e_{it})$$

where the coefficient ($b_i > 0$) measures the grower-specific absolute risk aversion.

Since all observed feed conversion ratios in the data set are below the benchmark feed conversion (ϕ), the truncation of the bonus payment at zero can be harmlessly ignored and the payment scheme in (1) can be written as a linear function of the performance measure, i.e., the feed conversion ratio $f_{it} = \frac{F_{it}}{q_{it}}$, such that

$$(3) \qquad R_{it} = \tilde{\alpha}_{it} - \tilde{\beta}_{it}\,(f_{it} - \phi)$$

where

$$(4) \qquad \tilde{\alpha}_{it} = \alpha q_{it} = \alpha[\kappa_{it}(1 - m_{it}) - \kappa_{0it}]H_{it}$$
$$\tilde{\beta}_{it} = \beta(1 - m_{it})H_{it}$$

with κ_{it} being the weight of outgoing finished hogs and κ_{0it}, the weight of incoming feeder pigs. We assume that the parameters of this affine function are fixed at the time the grower chooses his effort.

Next, we specify how the observed outcome stochastically depends on the unobservable grower effort and assume that

$$(5) \qquad f_{it} - \phi = (\lambda_i - e_{it})u_{it}$$

where λ_i reflects some fixed ability parameter of grower i, e_{it} is the costly effort that improves (reduces) the feed conversion ratio, and u_{it} is an i.i.d. (across growers and periods) production shock with mean 1 and variance σ^2. This specification shows that a unit of effort is worth one unit of feed conversion ratio that gets transformed into revenue through $\tilde{\beta}_{it}$. Since the cost of effort is monetary, it must be in the same units as revenue. Hence, we specify

$$C(e_{it}) = \gamma \tilde{\beta}_{it} e_{it}$$

where $0 < \gamma < 1$.

Now, using (3) and (5), we can write the agent's certainty equivalent net revenue as

$$W_i(R_{it}, e_{it}) = \tilde{\alpha}_i - \tilde{\beta}_{it}[Ef_{it} - \phi] - \frac{b_i}{2}\tilde{\beta}_{it}^2 \text{var}[f_{it}] - \gamma \tilde{\beta}_{it} e_{it}$$

and the first-order condition for the maximization problem in (2) becomes

$$\gamma = -\frac{\partial}{\partial e_{it}} Ef_{it} - \frac{b_i}{2}\tilde{\beta}_{it}\frac{\partial}{\partial e_{it}}\text{var}[f_{it}].$$

Given (5), it is clear that

$$Ef_{it} - \phi = \lambda_i - e_{it}$$
$$\text{var}[f_{it}] = (\lambda_i - e_{it})^2 \sigma^2$$

which gives the following expression for the optimal effort level:

$$(6) \qquad e_{it}^* = \frac{1-\gamma}{\sigma^2 b_i \tilde{\beta}_{it}} + \lambda_i.$$

As standard in incentive problems, equation (6) reveals that more risk-averse growers, i.e., those with higher b_i, exert lower equilibrium effort and that stronger incentives power $(-\tilde{\beta}_{it})$ increases effort. This result has an important consequence for the equilibrium strategy that the integrator would pursue when it comes to deciding how to allocate feeder pigs among growers with different risk-aversion attitudes.

Now, we model the principal's behavior given the agent's optimal response. As is customary, we assume that the principal is risk neutral and maximizes the expected profit per grower by deciding how many feeder pigs to place on a grower's farm. The integrator's objective function is

$$(7) \qquad \max_{H_{it}} E\pi_{it} = E[pQ_{it} - R_{it} - w_F F_{it} - w_H H_{it}]$$

where p is the market price of hogs, $Q_{it} = \kappa_{it}(1 - m_{it}) H_{it}$ is the total live weight removed from the grower's farm, R_{it} is grower payment as specified in (1), w_F is the market price of feed, and w_H is the market price of feeder pigs.

It is intuitively obvious that the number of animals placed on a grower's farm cannot be infinite given that the housing facilities are of finite size. The mortality rate will be increasing and necessarily approaching 100% when H approaches infinity. This implies that profits will obtain a maximum for $H < \infty$. To simplify, we assume that the mortality rate function, $m_{it}(H_{it})$, is such that the profit function has a unique maximum.

In particular, we assume that $m_{it}(H_{it})$ is increasing concave with $m''(1-m) + 2m'^2 \geq 0$ and $2m' + m''H > 0$. For example, this assumption is satisfied on $[0, 2\eta]$ with a mortality rate function

$$(8) \qquad m_{it}(H_{it}) = 1 - \exp\left(-\frac{H_{it}}{\eta}\right); \text{ with } \eta > 0.$$

Now, we are in the position to state the following result.

PROPOSITION 1. *The optimal $H_{it}^*(b_i)$ chosen by the integrator is such that $H_{it}^{*\prime}(b_i) < 0$, which means that more risk averse growers will receive fewer animals.*

Proof: Using (4) and optimal grower effort (7), the first-order condition for the integrator's expected profit maximization becomes

$$0 = \left[p - w_F\left(\phi - \frac{\alpha}{w_F}\right)\right]\kappa_{it} \times \left(\frac{\partial}{\partial H_{it}}\left[\left(1 - m_{it}\left(H_{it}^*\right)\right)H_{it}^*\right]\right) + w_F\frac{(\gamma-1)\kappa_{0it}}{\beta\sigma^2 b_i}\frac{m_{it}'\left(H_{it}^*\right)}{\left(1 - m_{it}\left(H_{it}^*\right)\right)^2} + \left[w_F\left(\phi - \frac{\alpha}{w_F}\right)\kappa_{0it} - w_H\right]$$

from which it follows that $H_{it}^*(b_i)$ is a solution of the following implicit equation

$$\frac{\partial}{\partial H_{it}}\left[\left(1 - m_{it}\left(H_{it}^*(b_i)\right)\right)H_{it}^*(b_i)\right] = \Psi\left(b_i, H_{it}^*(b_i)\right)$$

where

$$\Psi(b_i, H_{it}^*) = \frac{\left[w_H - w_F\left(\phi - \frac{\alpha}{w_F}\right)\kappa_{0it}\right] - w_F \frac{(\gamma-1)\kappa_{0it}}{\beta\sigma^2} \frac{1}{b_i} \frac{m'_{it}(H_{it}^*)}{\left(1-m_{it}(H_{it}^*)\right)^2}}{[p - \phi w_F + \alpha]\kappa_{it}}.$$

After taking derivatives of the first-order condition, it becomes clear that $\frac{\partial}{\partial b_i}\Psi(b_i, H_{it}^*(b_i)) > 0$ and $\frac{\partial^2}{\partial H_{it}^2}[(1 - m_{it}(H_{it}^*(b_i)))H_{it}^*(b_i)] < 0$ because the function m_{it} is increasing concave. The assumption that $m''(1-m) + 2m'^2 \geq 0$ implies that $\frac{\partial}{\partial H_{it}}\Psi(b_i, H_{it}^*(b_i)) > 0$ and, therefore, $H_{it}^{*\prime}(b_i) < 0$. Actually, $\frac{\partial}{\partial H_{it}}\Psi(b_i, H_{it}^*(b_i))$ is of the sign of

$$\frac{\partial}{\partial H_{it}} \frac{m'_{it}(H_{it}^*)}{\left(1 - m_{it}(H_{it}^*)\right)^2} = \frac{m''_{it}(H_{it}^*)\left(1 - m_{it}(H_{it}^*)\right) + 2m'^2_{it}(H_{it}^*))}{\left(1 - m_{it}(H_{it}^*)\right)^3}$$

which is positive if $m''(1-m) + 2m'^2 \geq 0$. ■

Estimation and Empirical Results

The data set used in this study is an unbalanced panel that contains a sample of contract settlements for individual growers who contracted the finishing stage of hog production with an integrator in North Carolina. The data set spans the period between December 1985 and April 1993, for a total of 802 observations. The panel is used to estimate the structural model developed so far.

Substituting (6) in (5) yields the formula for the difference between the benchmark feed conversion and the equilibrium feed conversion

$$(9) \qquad \phi - f_{it}^* = \frac{1-\gamma}{\tilde{\beta}_{it}\sigma^2 b_i} u_{it}$$

which, by taking logs, gives the following equation

$$(10) \qquad \ln((\phi - f_{it})\tilde{\beta}_{it}) = \ln\left(\frac{1-\gamma}{\sigma^2}\right) - \ln(b_i) + \ln(u_{it}).$$

The individual level parameters (b_i) in (10) can be estimated with a linear regression including growers' fixed effects. Notice, however, that b_i's are identified only up to scale since $\ln(\frac{1-\gamma}{\sigma^2}) - \ln(b_i) = \ln(\frac{1-\gamma}{\sigma^2}\lambda) - \ln(b_i\lambda)$ for any $\lambda > 0$. Nevertheless, once the estimates of b_i are known, one can test for the heterogeneity of risk aversions across growers.

The estimation of (10) shows that the unexplained variance accounts for around 50% of the total variance. An F test that all $\ln(b_i)$ are equal strongly rejects the homogeneity of growers with respect to their risk aversion ($F(121, 680) = 5.34$). The distribution of risk-aversion parameters (b_i) displayed in figure 1 is characterized by the fact that the median risk aversion is 43% higher than the value of the 25th percentile of the distribution and 21% lower than the value of the 75th percentile of the distribution. These measures are independent of the scale of coefficients and show substantial heterogeneity across growers regarding their risk aversion.

Next, using the structural estimates of risk-aversion parameters (b_i), we want to test the main proposition of the paper that more risk-averse growers receive fewer animals. We first check whether the sufficient conditions on the mortality function, $m_{it}(H_{it})$, are satisfied. The data do not allow us to estimate function $m(\cdot)$ and its first and second derivatives nonparametrically because the sample size is not large enough for such a demanding estimation, but one can use the parametric form (8) for mortality from which it follows that

$$H_{it} = -\eta \ln(1 - m_{it})$$

and then estimate parameter η by least squares. The results show that $\hat{\eta} = 26{,}300$ (with the standard error of 445), and the functional fit is quite good with $R^2 = 79\%$. When estimating η's that vary across feeder pigs type, the R^2 goes up to 85% while the estimates of η are 26,000 (s.e. 638); 27,300 (s.e. 724); and 15,100 (s.e. 708). Notice that, for the mortality function in (8), the assumption that led to our Proposition, i.e., $2m' + m''H > 0$, is satisfied if $H < 2\eta$. Since the observed values of H_{it} are between 1,100 and 1,500 per house, this condition is easily satisfied. Then, one can test whether the integrator supplies more feeder pigs to less risk-averse growers by looking into the relationship between H_{it} and b_i.

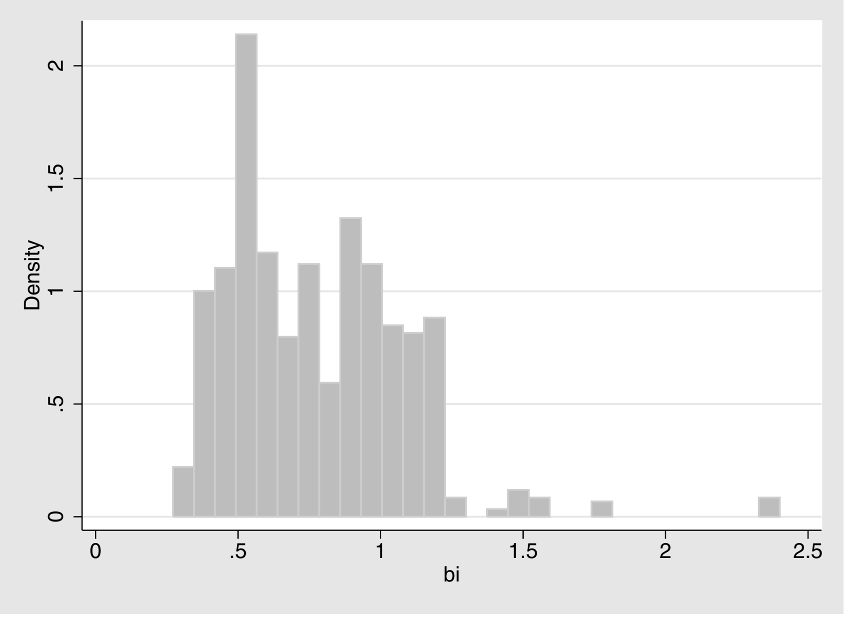

Figure 1. Distribution of estimated b_i

First, a nonparametric test of independence between H_{it}, or the average over contracts of H_{it} for grower i, and b_i shows that independence is strongly rejected. The Spearman rank correlation coefficient is negative and strongly significant. Next, a nonparametric estimate of $E(H_{it} \mid b_i)$, obtained by using a standard kernel regression method (shown in figure 2), clearly indicates that $E(H_{it} \mid b_i)$ is a strictly decreasing function of b_i and so does a linear-regression model (results are not reported here).

Second, although the scale of risk aversion is not identified, the elasticity of the number of animals placement with respect to risk aversion is uniquely identified. A nonparametric estimation of $E(\ln H_{it} \mid \ln b_i)$ shows that the function is linear, and the linear regression gives the estimate $\frac{\partial E(\ln H_{it} \mid \ln b_i)}{\partial \ln b_i} = -0.84$ with a robust standard error of 0.02. This result shows that a 10% increase in absolute risk aversion results in a 8.4% decrease in the number of animals that the integrator would place on the grower's farm.

Finally, we look at the cost of moral hazard associated with growers' risk aversion. The volatility of income in production contracts constitutes a direct real cost to growers and can be thought of as the cost of moral hazard in the sense that, without moral hazard, integrators could pay growers constant wages to compensate them for their effort in case effort were observable and verifiable. However, obtaining welfare estimates of the cost of moral hazard is impossible because the marginal cost of effort and the absolute risk aversion are not identified. Nevertheless, it is interesting to look at the relationship between the mean and the variance of growers' revenues and their risk-aversion parameters. First, 60% of the variance of total payments to growers R_{it} is explained by the "between-growers variance." Second, a linear regression shows a significant negative relationship between the "within-grower variance" (estimated for each grower along the time dimension of the panel data) and risk aversion. Also, the mean payment is significantly decreasing with risk aversion. The grower variability of income is such that the average standard deviation is \$3,960 with a median of \$2,856. The above results point out that the cost of moral hazard to growers is substantial.

Moreover, it is important to note that the costs of asymmetric information arise not only from the fact that part of the performance risk (in terms of feed conversion) has to be borne by growers (because they have to be given the correct incentives to perform) but also from the fact that the integrator allocates different number of animals to different growers according to their risk aversions. We anticipate that more risk-averse growers would have lower revenues because, ceteris paribus, they perform worse in terms of the feed conversion

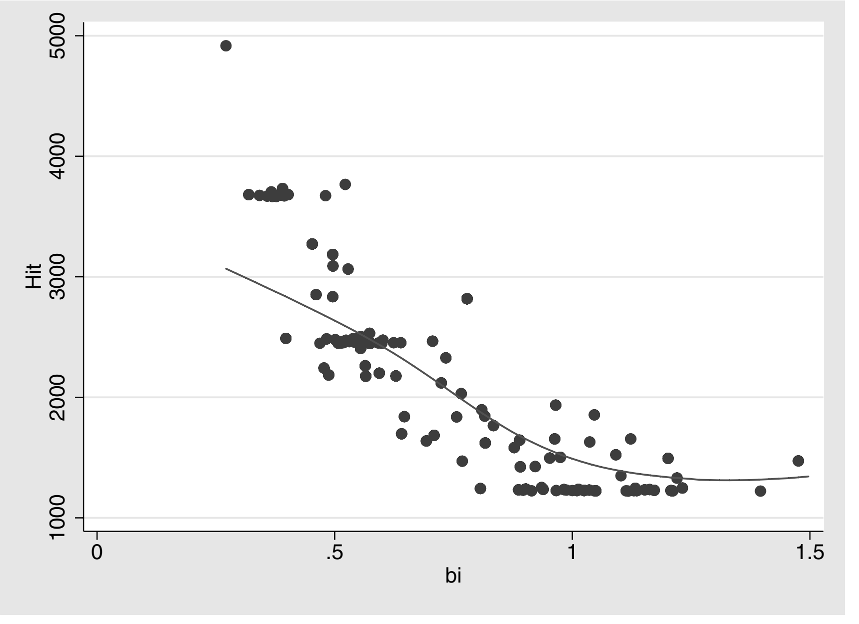

Figure 2. Nonparametric estimate of $E(H_{it} \mid b_i)$

ratio (which reduces their bonus payment) and they receive fewer animals compared to the less risk-averse growers.

Notice, however, that the relationship between grower risk aversion and his expected revenue is theoretically ambiguous. Looking at the equilibrium effort equation (6), it follows that the optimal effort decreases with higher risk aversion, with $\tilde{\beta}$, and, hence, with H_{it}. Therefore, since more risk-averse growers received fewer animals, the overall comparative statics effect of risk aversion on the optimal effort and, hence, on the expected revenue is undetermined.

The empirical results confirm our conjecture that the revenues of more risk-averse growers are less volatile and, on average, lower. Table 1 shows the average of the means and standard deviations of each grower's revenue for different percentiles of the distribution of b_i. Except for the 50–60 percentiles of the distribution, the relationship shows a negative link between the mean and the variance of grower revenue and risk aversion. This empirical result shows that, even if more risk-averse growers somehow mitigated the effect of receiving fewer animals by achieving better feed conversion, the net effect on revenue is still negative. This effect constitutes the second source of the cost of moral hazard.

Table 1. Risk Aversion and Revenue

% Distribution of b_i	Mean R_{it} (in US$)	Standard Deviation R_{it}
0–10%	32,709	6,491
10–20%	25,087	5,914
20–30%	23,623	3,969
30–40%	21,227	3,195
40–50%	17,947	2,197
50–60%	18,408	5,971
60–70%	12,906	2,570
70–80%	12,651	3,164
80–90%	11,466	1,999
90–100%	10,995	1,949

Conclusions

In this article, we develop an analytical framework for the econometric estimation of the degree of risk aversion of contract producers in the swine industry and carry out its empirical estimation using individual growers' performance data. We show that the heterogeneity of growers in terms of their degree of risk aversion can be identified structurally (up to a scale) using observed performance measures. The results, independent of the scale of coefficients, show that growers are heterogeneous when it comes to comparing their risk aversions.

The obtained results are used to look at the cost of moral hazard associated with growers' risk aversion. We show that the costs of asymmetric information arise not only from the fact that part of the performance risk has to be borne by growers (because they have to be given the correct incentives to perform) but also from the fact that the integrator allocates a different number of animals to different growers according to their risk aversions. More risk-averse growers will have lower expected revenues because, on average, they perform worse and they receive fewer animals compared to the less risk-averse growers. These results were confirmed in a variety of different empirical tests.

This article ties well to the larger literature on the provision of incentives in firms, particularly to the growing debate about the trade-off between risk and incentives and the related literature on the determinants of contract choice (see Prendergast). It provides empirical evidence that agents' risk attitudes matter for the determination of the principal-agent contractual relationships in the sense that they impose constraints on offering incentives. These results are especially valuable in light of the fact that the empirical evidence that contracts are designed to optimally trade-off risk against incentives is hardly overwhelming.

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