DOES CONTRACTING RAISE FARM PRODUCTIVITY?
THE IMPACT OF PRODUCTION CONTRACTS ON HOG FARM PERFORMANCE

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Abstract. The costs and benefits of policies designed to regulate the use of production contracts will depend in part on the impact of these contracts on farm productivity. In this paper we measure the impact of contracting on 1) partial and total factor productivity and 2) the production technology for 479 US hog operations. A sample selection model accounts for the fact that unobservable variables may be correlated with both the decision to contract and farm productivity. Results also identify determinants of farmers' decisions to contract and factors influencing farm productivity.

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1. Introduction

The rapid increase in the use of production contracts is a notable feature of the structural change taking place in the US hog industry. Between 1992 and 1998, the portion of feeder pig-to-finish hog operations engaged in contracting increased from 11% to 34%. At the same time, the share of output produced under a production contract increased from 22% to 64% (McBride; ERS-USDA). Several factors could be driving the growth of contracting including efficiency gains from contracting (on-farm or upstream and downstream of the production unit) and gains in terms of grower welfare. Contracting may raise on-farm efficiency by raising the quality of managerial inputs or by speeding the transfer of technical information to growers. Contracts may also facilitate growers' access to credit, allowing for the adoption of newer, more efficient technologies or capital equipment. Contracting could increase upstream or downstream efficiency by lowering transaction costs associated with product or input transfer, and by lowering information costs in terms of timing and product quality. Growers may benefit from contracting because of lower income risk, and contractors may be able to capture the risk premium.

While the growth in contracting would seem to imply higher on-farm productivity, this is not necessarily the case. The increase in contracting may be driven by upstream and downstream efficiency gains and welfare effects that offset on-farm productivity losses. Contracting may fail to raise (or even lower) on-farm productivity if it reduces incentives for growers to work efficiently, or if it makes contractees less willing to invest in specific productive assets. In this paper we focus on identifying and measuring the farm-level productivity gains, if any, that can be attributed to contracting.

Understanding the link between contracts and farm productivity is crucial to an analysis of the distributive and efficiency implications of the recent structural changes in the hog industry, and of policies to regulate contracting. The rapid growth in contracting has lead to efforts at the various levels of government to regulate contract production, both indirectly through corporate farming laws and zoning, and directly through legislation such as the "Producer Protection Act"

(Boehlje et al). These efforts to regulate contracting may have significant social welfare costs or benefits depending in part on how contracts impact hog farm efficiency.

To measure the impact of contracting on farm productivity we must control for the fact that farmers who choose to contract could be quite different from those that choose not to. Contractees may be more credit-constrained, more risk-averse growers, have less preference for autonomy, and have less managerial or entrepreneurial ability. We use a sample selection model to account for the fact that many of the factors that determine both whether the farmer contracts and farm productivity may be unobservable. Information from the 1998 USDA Agricultural Resource Management Survey of 472 feeder pig-to-finish hog operations is used to estimate the sample selection model. We measure the impact of contracting on 1) partial and total factor productivity and 2) the production technology. Empirical results identify the determinants of hog farmers' decisions to contract and also identify the factors that influence productivity. Results also shed light on the long run implications of contracting for the scale of production.

2. Reasons for Contracting and Impact of Contracting on Farm Performance

There is a large body of research that examines the reasons why farmers and processors (or integrators) choose to contract. This past research provides insights into how contracting could impact farm productivity.

Risk sharing is one of the mostly widely cited reasons for contracting. Under the terms of a typical production contract to finish hogs, the contractor provides feed, feeder pigs, veterinary care, managerial assistance, and marketing services. The grower is paid a fee for feeding and caring for the animals based on weight gain and feed efficiency. Hog contracts lower price risks for growers because their fees usually do not depend on input or hog prices (Johnson and Foster; Martin; Kliebenstein and Lawrence.) While reducing risk, contracts also reduce farmer autonomy (Gillespie and Eidman). It is possible that autonomy-loving farmers with strong management skills may tend to reject a contract relationship that binds them to particular production practices. Rhodes notes that "in the Cornbelt their [commercial feed companies and packers] efforts to contract hog production largely subsided within a few years. The better producers were seldom interested in the quasi-employee status that did not provide access to the profits of the good years of the hog cycle."

Because contractors supply such a large share of inputs, contracts drastically reduce the amount of production credit needed by growers. Indeed, Kliebenstein and Lawrence note that in a survey asking growers why they entered contractual arrangements, lack of capital was the second most frequently cited reason (after risk reduction). Contracting could therefore serve to relieve a binding credit constraint for certain growers freeing them to invest or apply inputs at a more efficient level. Additionally, contract relationships may also make it easier for farmers to obtain loans for setting up or expanding hog production. On the other hand, because hog production involves large investments in specific assets, contracting may make growers vulnerable to changes in contract terms. If greater investment in specific assets reduces the bargaining power of contractees vis-à-vis the contractor, contractees may draw back from socially optimal levels of investment resulting in lower productivity (Shelanski and Klein).

Contracts could serve to lower costs directly for growers by providing them with cheaper or superior technology, management techniques, or inputs. For farmers, hog production contracts may also reduce transaction costs associated with procuring inputs and in marketing – e.g., costs resulting from search, negotiation, monitoring, and transfer (Hobbs). At the same time, widespread contracting in a particular area could raise costs for those growers who are *not* contracting. Areas in which almost all production is carried out through contracts may have thin and poorly developed input or marketing channels so that independent producers would have to travel much further or experience greater difficulty in order to purchase inputs or sell their product (Laurence, *et al*).

Costs associated with measuring hog quality may result in asymmetric information between growers and purchasers of hogs that can affect productivity. If there is asymmetric information about product quality, then farmers have less incentive to invest in raising quality because they cannot be fully compensated for this investment by the purchaser (Hennessy). Production contracts that specify the genetic characteristics of the hogs largely reduce uncertainty about quality. Hence, these contracts can reduce measurement costs associated with asymmetric information and may encourage investment in quality (Martinez, Smith, and Zering). On the other hand, there may also exist asymmetric information about the quality of potential contractees, which could create an adverse selection problem for the contractor (Sheldon). Knoeber views the growers' provision of productive assets as signal of agent ability under asymmetric information. Hence, the capital requirement may act as a screening device resulting in the self-selection of contractees with high ability.

Finally, if we are interested in measuring the impact of contracting on farm performance, we should take into account the fact that contractors choose to locate and expand production in regions where they can operate most profitably. Desirable regions from the contractors' perspective may be those where the opportunity costs to hog farming are low, or where there is a high density of hog producers, which lowers transaction costs. While most hog farmers may have some opportunity to contract, the net benefits of contracting may be very low where the availability of contracting is limited.

3. Empirical model

To measure the impact of participating in a production contract on farm productivity we use a treatment effects model (Greene, 714). The net benefits to contracting compared to independent production and marketing are given by the latent variable C_i^*:

(1) $C_i^* = Z_i\gamma + u_i$

$C_i = 1$ if $C_i^* > 0$, 0 otherwise.

where Z_i is a vector of farm and regional characteristics. If the latent variable is positive then the dummy variable indicating contracting C_i equals one, and equals zero otherwise. We are interested in measuring the impact of a production contract on a measure of farm performance y_i:

(2) $y_i = X_i\beta + C_i\delta + \varepsilon_i$

where X_i is a vector of farm and regional characteristics. More generally, we can allow contracting to interact with all the exogenous variables, in which case (2) becomes:

(2') $y_i = X_i\beta + C_i X_i\delta + \varepsilon_i$

where δ is now a vector of parameters associated with the interaction terms. We cannot simply estimate (2) or (2') because the decision to contract may be determined by unobservable variables (management ability, preferences for autonomy, regional characteristics, etc.) that may also affect performance. If this is the case, the error terms in (1) and (2) will be correlated, leading to biased estimates of δ . We can account for this selection bias by assuming a joint normal error distribution with mean zero and covariance matrix:

$$\begin{bmatrix} u \\ \varepsilon \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & \sigma^2 \end{bmatrix}\right)$$

and by recognizing that the expected performance of contractees is given by:

$$E\left[y_i \middle| C_i = 1\right] = X_i\beta + \delta + \rho\sigma\lambda_i$$

where λ_i is the inverse Mills ratio. To derive an unbiased estimate of δ we can use a 2-stage approach starting with a probit estimation of (1). In the second stage, estimates of γ are used to compute the inverse Mills ratio, which is included as an additional term in an OLS estimation of (2). This two-stage Heckman procedure is consistent, albeit not fully efficient. Efficient maximum likelihood parameter estimates can be obtained by maximizing:

$$L = \prod_{C_i=0} \int_{-\infty}^{0} \int_{-\infty}^{\infty} f\left(C_i^*, y_i\right) dy dC^* \cdot \prod_{C_i=1} \int_{0}^{\infty} \int_{-\infty}^{\infty} f\left(C_i^*, y_i\right) dy dC^*$$

where $f\left(C_i^*, y_i\right)$ is the joint normal density function, which is a function of the parameters. In practice, the log of the likelihood function is maximized using the estimates from the Heckman procedure as starting values.[1]

4. Data

Data are used from two sources: the 1998 USDA Agricultural Resource Management Survey of the hog sector, and the 1997 US Agricultural Census. Because of the broad differences in production techniques among various types of hog operations, we focus on feeder pig-to-finish hog operations. This sector of producers has experienced rapid growth in contracting and accounted for about a third of total finished hog farms and production in 1998.

Table 1 reports the results of tests of equal means between operations with contracts and those without for the variables used in the estimations.[2] The table highlights several clear differences between the two groups. On average, contractees are younger and have much less experience in the hog business. Contractees are also more likely to have their major occupation be something other than farming or ranch work. Contractees do not have significantly more total assets employed in farming, yet they produce over three times as much pork.

Among the five geographical regions in which the sample is divided, contracting is significantly more common than independent production only in the east. Independent production is more common in all the other regions except the north, where there is no significant difference between the modes of production. Contract operations are more likely to be located in counties with a high net cash returns per farm, and in counties with a greater volume of hog production. We did not expect counties with higher net returns to farming to be correlated with contracting, and as we find in our regressions discussed in the next section, once we control for operator,

[1] See documentation for Limdep 7.0 for details about the optimization algorithm.
[2] In computing the difference of means, parameters, and significance tests in all the regressions in the paper, the survey data were weighted to account for sample design.

farm, and other regional characteristics, the positive relationship between county average farm revenue and contracting actually becomes negative.

Simple averages would indicate that contract producers are much more productive than independent producers: they produce much more per unit of feed and labor and capital, and have higher total factor productivity. While productivity measures of the two groups differ significantly this may be due to both observable and unobservable factors correlated with the decision to contract, rather than contracting itself. Identifying the impact of contracting on productivity is the concern of the next section.

5. Results

The Contract Decision

Table 2 lists the results of the first stage probit explaining the decision to contract versus produce independently. The model is significant and correctly predicts 84% of operators' choices. Most variables had signs consistent with the differences in means discussed in the last section. Estimation results indicate that for an average operation, an increase in education or years of experience in the hog business lowers the probability that the farmer will contract, while having a primary occupation off-farm, raises the likelihood of contracting.

An operation being located in an eastern state positively increases the likelihood of contracting, so did being located in a Northern state or not being located in a Southern state (all relative to the omitted region: Central Midwestern). As expected, being located in county with more hog production increases the likelihood of contracting, while being in a county with a higher average net return to farming lowers the probability that a farmer contracts.

We used scale of production categories in the regression equations rather than simply the scale of production for two reasons: 1) a size category can be considered exogenous to the farm in the short run – it depends on a large number of physical assets that cannot be easily scaled; and 2) the five categories allow for a flexible functional relationship between scale and the dependent variables. As shown in the table, the scale of production has a strong positive correlation with the likelihood of contracting. Controlling for individual, regional, and farm level characteristics, being in a farm scale category other than the smallest increases the likelihood of contracting, and the increase in the size of the coefficients with the size group indicates that the probability of contracting increases with scale.

Factor Productivity

In order to estimate the impact of contracting on partial and total factor productivity, we assume factor productivity can be approximated with a linear function of the explanatory variables. There is no theoretical reason to expect county hog production nor county average farm income to affect on-farm productivity, so these are omitted from the equation. The maximum likelihood estimates of the sample selection model are presented in table 3. Contracting is significant in all factor productivity equations except capital. As shown in table 5, for an average hog farm, contracting raises feed, labor, other inputs, and total factor productivity by 39.5%, 55.5%, 47.3% and 23.7% respectively. It is possible that not all of the returns to scale effect is accounted for with the scale class variables, resulting in the large productivity values for contracting – which is correlated with scale. This problem is addressed in our production function estimation in the next subsection.

In addition to contracting, most of the indicators of scale of production were significant determinants of productivity, except in the case of "other inputs." Having off-farm work as a primary occupation increased the likelihood of contracting, but also, surprisingly, raises productivity. The number of years in the hog business has two confounding effects on total productivity: an extra year in business *increases* productivity directly, however an extra year in business also reduces the chance that farmer will contract thereby *decreasing* productivity indirectly. The net marginal impact of an extra year in the business is computed to be positive but small (0.00854).

Technology

The second empirical approach measures the impact of contracting on the production technology, taking into account the selection process. We use a translog production function, so

(2') takes the form:

$$\log q_i = \beta_0 + \sum_k \beta_k \log x_{ik} + \frac{1}{2}\sum_k \sum_l \beta_{kl} \log x_{ik} \log x_{il} + \sum_m \alpha_m z_{im} +$$

$$\delta_0 C_i + \sum_k \delta_k C_i \log x_{ik} + \frac{1}{2}\sum_k \sum_l \delta_{kl} C_i \log x_{ik} \log x_{il} + \sum_m \delta_m C_i z_{im} + \varepsilon_i$$

where $\beta_{ij} = \beta_{ji}$, x_i are inputs, z_i are exogenous shifters, and C_i is a dummy variable equal to one if operation *i* uses a production contract, and equal to zero otherwise.

Table 4 reports the result of the maximum likelihood estimation where for convenience input levels have been normalized by dividing by their mean value. The production function appears well behaved with the estimated marginal productivity being positive for each input. Parameters for the selection equation are very close to those obtained in the probit equation. To test the joint null hypothesis of no technical difference between contractees and independent producers:

$$H_0 : \delta_0 = \delta_k = \delta_{kl} = \delta_m = 0 \quad \text{for all } k, l, m$$

we conduct a likelihood ratio test. The likelihood ratio test statistic has a value of 93.43, the P-value associated with the chi-square distribution with 24 restrictions is less than 0.001. Hence, we reject that null hypothesis that contractees and independent producers use the same technology.

A discrete index of technical change can be constructed using the estimated production function:

$$\tau = \frac{\hat{q}(\bar{x}, C = 1)}{\hat{q}(\bar{x}, C = 0)}$$

The index is simply the ratio of what can be produced using the contracting technology relative to what can be produced using the independent technology with the same input bundle $\bar{x}$. We find that contracting raises productivity for an average producer by 28.6%. This estimate is in line with our earlier estimate of total factor productivity gains of 23.7%.

Scale of Production

To test whether contracting has a greater relative impact on smaller or larger scale operations, we compute the average input levels for average producers in the five scale classes *i*:

$$\tau_i = \frac{\hat{q}(\bar{x}_i, c=1)}{\hat{q}(\bar{x}_i, c=0)} \text{ for } i = 1...5$$

As shown in table 5, we find that for an average operator in each category contracting would raise productivity by 31.8%, 22.3%, 27.9%, 36.0%, and 35.1%, for categories 1 through 5, respectively. The results indicate that contracting does not have large scale-effects. In other words, contracting appears to raise productivity for all size operations.

A second relationship between contracting and scale is illustrated with the elasticity of scale, which for the translog is:

$$\varepsilon = \sum_k \left[\beta_k + \sum_l \beta_{kl} \log x_k \right].$$

Based on the production function estimates we find that contracting lowers the average scale elasticity slightly from 1.153 to 1.140 for an average operation. This result implies that hog production displays increasing returns to scale, and that contracting has little effect on the returns to scale.

Selection Bias

Selectivity bias results from correlation of the errors, indicated by the coefficient ρ. There is a positive correlation in the capital productivity equation and the production function equation. The positive correlation between the errors indicates that there are unobservable factors such as farming skill or work ethic that are positively correlated with the decision to contract and production (the impact of contracting on capital productivity is not significant). If we had not accounted for this positive correlation, we would have over estimated the impact of contracting on production.

6. Conclusions

Contracting appears to enhance the productivity of three of the four inputs to hog production and results in 23.7% higher total factor productivity. In addition, contracting was found to be a technological improvement over independent production resulting in 28.6% more output for an average farm. Interestingly, contracting alone does not cause farms to use significantly more or less capital per unit output than non-contracting farms. In addition, a further analysis (not reported here) reveals no significant difference between contractees and independent producers in terms of their debt-asset ratio. Hence, contracting appears to raise productivity despite the fact that the contracting operations do not use more capital per unit output or take on relatively more debt.

The higher productivity that results from contracting may be due to a transfer of “know how” from integrators to growers, a transfer that may be particularly important given the relative lack of hog experience of the contractees. This information exchange may involve know how concerning feed mixtures or feed timing that results in higher feed productivity and lower labor costs. In addition, goods and services provided by the contractor such as veterinary care, feed, and especially the genetic quality of the animals may be superior to that available to an independent producer, resulting in healthier animals, and greater weight gain.

The magnitude of the productivity gains that we estimate implies these gains are an important factor in the recent growth in contracting. There is a role for future work in discerning how the productivity gains are distributed among contractors and growers.[3] While the impact of contracting on productivity appears to be sizeable, there is little differential impact according to scale. This result suggests that the impact of contracting on productivity is not a major force driving the increase in the scale of production of hog farms that has been widely documented

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[3] McBride and Key examine the factors that affect the financial performance of contractors and growers in a contract arrangement.

elsewhere. On the other hand, the production technology - which displays increasing returns to scale regardless of the contracting arrangement - does serves as a motive for increasing the scale of production.

The higher level of farm productivity associated with contracting implies that policies to regulate contracting have economic costs. However, it is possible that negative producer welfare effects (loss of autonomy) or upstream and downstream *costs* to contracting (increased transactions costs) could reduce or even reverse the potential efficiency gains from contracting. Hence, it is not possible to conclude from this study what the overall impact of policies to regulate contracting is on producers or society. In addition, while the paper suggests that contracting raises on-farm productivity, it is important to stress that we have considered only standard accounting measures of costs and benefits, and have not considered non-market costs of production such as odor, water pollution, etc. It is possible that contracting is associated with particular manure management practices that result in greater environmental costs (Kaplan). Future work might examine how production contracts affect production practices with social and environmental implications.

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Table 1. Variable Names and Definitions, and Test of Equality of Means for Contracting and Non-contracting Operations

Variables	Mean Independent Operations	Mean Contract Operations	t-stat	Prob > $\|t\|$
Operator Characteristics				
Age (years)	50.6	47.0	3.78	0.000
Education (years)	13.0	12.9	0.06	0.953
Major occupation is not farm or ranch work*	0.14	0.23	-2.41	0.016
Years in hog business	24.1	14.8	9.03	0.000
Farm Characteristics				
Total farm assets ($100,000)	7.69	8.79	-1.23	0.221
Scale Class 1: Hog production (cwt.) < 750*	0.375	0.030	10.41	0.000
Scale Class 2: 750 $\leq$ Hog production (cwt.) < 2000*	0.258	0.133	3.51	0.000
Scale Class 3: 2000 $\leq$ Hog production (cwt.) < 5000*	0.255	0.266	-0.27	0.790
Scale Class 4: 5000 $\leq$ Hog production (cwt.) < 15000*	0.093	0.298	-5.80	0.000
Scale Class 5: 15000 $\leq$ Hog production (cwt.)*	0.020	0.273	-8.31	0.000
Regional Characteristics				
Northern state (MI, MN, SD, WI)*	0.194	0.232	-1.02	0.306
Eastern state (NC, SC, VI)*	0.014	0.205	-6.94	0.000
Southern state (AL, AR, GA, MO, KY, TN)*	0.085	0.032	2.50	0.013
Western state (CO, KS, OK, UT, NE)*	0.159	0.067	3.20	0.001
Central Midwestern state (IL,ID,IA,OH)*	0.548	0.463	3.17	0.064
County average net cash return per farm ($1000)	34.86	46.54	-4.64	0.000
County average swine sales per farm ($1000)	23.63	70.73	-6.8	0.000
Output and Inputs(1)				
Hog production (cwt.)	3138	11036	-5.27	0.000
Feed (cwt.)	11114	26710	-4.20	0.000
Labor (hours)	1346	1614	-0.88	0.381
Capital ($)	26745	62143	-2.99	0.004
Other Inputs ($)	8844.9	27228	-3.17	0.002
Productivity				
Feed Productivity (cwt. hog/cwt. feed) X 10^{-1}	2.69	4.34	-11.13	0.000
Labor Productivity (cwt. hog/labor hour)	1.96	6.54	-13.50	0.000
Capital Productivity (cwt. hog/$) X 10^{-2}	9.66	17.04	-11.75	0.000
Other Inputs Productivity (cwt. hog/$) X 10^{-2}	50.01	65.84	-4.16	0.000
Total Factor Productivity(2) (cwt. hog/$) X 10^{-2}	2.04	3.29	-14.15	0.000
Number of Observations	234	245		

All data are from the 1998 USDA-ERS ARMS except county-level variables, which are from the 1997 US Agricultural Census. All operations are Means are weighted to account for survey design. Prob> $|t|$ is the two-tailed significance probability under the null hypothesis of equal means.

* Dummy variable equal to 1 if statement is true or located in region, 0 otherwise.

(1) Hog production is measured as hundredweight of hogs sold or removed under contract less hundredweight of hogs purchased or placed under contract, plus hundredweight of inventory change. Labor includes own and hired labor; Capital is the capital replacement value; Other inputs include veterinary, bedding, marketing, custom work, energy, repair.

(2) The total factor productivity is defined as the inverse unit cost.

Table 2. Binomial Probit Maximum Likelihood Estimates: Contract Decision

Variable	**Coeff.**	**Std.Err.**	**t-ratio**	**P-value**
Constant	1.064	0.806	1.321	0.187
Age (years)	-0.006	0.010	-0.608	0.543
Education (years)	-0.166	0.051	-3.272	0.001
Major occupation is not farm or ranch work	0.580	0.217	2.671	0.008
Years in hog business	-0.022	0.009	-2.479	0.013
Total farm assets ($100,000)	-0.009	0.008	-1.150	0.250
Scale Class 2	1.480	0.292	5.074	0.000
Scale Class 3	1.803	0.299	6.022	0.000
Scale Class 4	2.374	0.307	7.726	0.000
Scale Class 5	3.386	0.409	8.275	0.000
Southern state (AL, AR, GA, MO, KY, TN)	-0.741	0.369	-2.006	0.045
Western state (CO, KS, OK, UT, NE)	-0.387	0.276	-1.402	0.161
Northern state (MI, MN, SD, WI)	0.340	0.190	1.790	0.073
Eastern state (NC, SC, VI)	0.897	0.453	1.980	0.048
Co. average net return per farm ($1000)	-0.016	0.006	-2.679	0.007
Co. average swine sales per farm ($1000)	0.007	0.003	2.141	0.032

Dependent variable: Uses a Production Contract; Number of observations: 479
Log likelihood function: -185.0746; Restricted log likelihood: -331.8912
Chi-squared: 293.6332; Degrees of freedom: 15; Significance level: 0.000

	Predicted		
Actual	0	1	Total
0	204	30	234
1	48	197	245
Total	252	227	479

Table 3. Selection Model Maximum Likelihood Estimates: Partial and Total Factor Productivity

	Feed		Labor		Capital		Other Inputs		TFP	
	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
Selection Equation										
Constant	1.192	0.186	1.114	0.228	0.298	0.638	1.038	0.265	1.076	0.238
Age	-0.008	0.435	-0.007	0.533	-0.003	0.673	-0.006	0.601	-0.006	0.596
Education	-0.175	0.002	-0.167	0.005	-0.089	0.029	-0.165	0.008	-0.168	0.005
Off-farm occup.	0.594	0.013	0.583	0.016	0.210	0.218	0.575	0.019	0.580	0.016
Years in hog bus.	-0.021	0.030	-0.022	0.026	-0.013	0.073	-0.023	0.020	-0.023	0.021
Total farm assets	-0.008	0.402	-0.008	0.510	-0.015	0.001	-0.009	0.378	-0.009	0.352
Scale Class 2	1.475	0.000	1.451	0.000	0.813	0.002	1.453	0.000	1.459	0.000
Scale Class 3	1.879	0.000	1.774	0.000	1.066	0.000	1.783	0.000	1.808	0.000
Scale Class 4	2.419	0.000	2.385	0.000	1.327	0.000	2.356	0.000	2.378	0.000
Scale Class 5	3.362	0.000	3.344	0.000	2.798	0.000	3.368	0.000	3.358	0.000
Southern state	-0.549	0.261	-0.693	0.139	-0.589	0.054	-0.754	0.111	-0.706	0.130
Western state	-0.450	0.245	-0.391	0.271	-0.071	0.748	-0.386	0.301	-0.384	0.291
Northern state	0.360	0.066	0.335	0.113	0.299	0.061	0.323	0.124	0.351	0.082
Eastern state	0.878	0.214	0.911	0.202	0.752	0.047	0.844	0.235	0.896	0.192
Co. farm net return	-0.015	0.056	-0.015	0.061	-0.005	0.345	-0.015	0.096	-0.016	0.039
Co. swine sales per farm	0.007	0.162	0.006	0.199	0.004	0.273	0.007	0.190	0.007	0.158
Factor Productivity										
Constant	3.550	0.000	3.961	0.002	6.561	0.013	52.647	0.027	2.353	0.000
Age	0.003	0.764	-0.044	0.001	-0.010	0.729	0.240	0.392	-0.007	0.080
Education	-0.134	0.007	-0.106	0.190	-0.262	0.135	-1.808	0.170	-0.088	0.000
Off-farm occup.	0.592	0.005	-0.360	0.326	0.959	0.137	-9.043	0.196	0.094	0.381
Years in hog bus.	0.009	0.317	0.016	0.271	0.040	0.227	0.126	0.609	0.012	0.001
Total farm assets	0.003	0.766	0.030	0.000	-0.036	0.159	-0.096	0.732	0.001	0.745
Scale Class 2	0.504	0.028	0.299	0.722	2.792	0.012	8.746	0.235	0.694	0.000
Scale Class 3	0.719	0.021	1.229	0.079	5.729	0.000	7.547	0.329	1.206	0.000
Scale Class 4	1.164	0.000	3.500	0.000	10.293	0.000	5.997	0.499	1.798	0.000
Scale Class 5	1.415	0.000	7.354	0.000	15.974	0.000	5.900	0.596	2.280	0.000
Southern state	0.776	0.005	0.834	0.113	4.164	0.000	22.297	0.003	0.654	0.000
Western state	-0.054	0.861	0.586	0.219	0.862	0.244	20.321	0.001	0.388	0.000
Northern state	0.050	0.784	0.392	0.370	1.876	0.007	-4.262	0.521	0.375	0.000
Eastern state	-0.139	0.702	1.050	0.014	2.164	0.043	-25.304	0.061	-0.309	0.049
Contract	1.289	0.000	1.960	0.000	-0.052	0.945	26.218	0.000	0.586	0.000
Sigma	1.468	0.000	2.439	0.000	6.050	0.000	39.242	0.000	0.700	0.000
Rho	-0.190	0.201	-0.088	0.603	0.812	0.000	-0.095	0.568	-0.050	0.737

Table presents maximum likelihood parameter estimates for sample selection model. Dependent variable in the selection equation is Contract (1,0); Dependent variables in the Factor Productivity equations are feed, labor, capital, other inputs, and total factor productivity. The P-value is the value for a two-tailed test of the hypothesis that the coefficient equals zero.

Table 4. Selection Model Maximum Likelihood Estimates: Production Function

	Coeff.	P-value		Coeff.	P-value
Selection Equation			**Production Function (cont.)**		
Constant	0.836	0.395	Age	0.005	0.142
Age	-0.004	0.739	Education	0.003	0.839
Education	-0.164	0.014	Major occup. off-farm	-0.100	0.112
Major occup. off-farm	0.661	0.024	Years in hog business	0.001	0.689
Years in hog business	-0.020	0.090	Total farm assets	0.003	0.465
Total farm assets	-0.011	0.457	Southern state	0.220	0.014
Scale Class 2	1.519	0.001	Western state	0.208	0.006
Scale Class 3	1.919	0.000	Northern state	-0.080	0.167
Scale Class 4	2.460	0.000	Eastern state	0.013	0.941
Scale Class 5	3.499	0.000	C (Contract)	1.468	0.006
Southern state	-0.863	0.059	C*lnx1	0.030	0.824
Western state	-0.458	0.312	C*lnx2	-0.017	0.900
Northern state	0.365	0.126	C*lnx3	-0.121	0.493
Eastern state	0.932	0.202	C*lnx4	0.095	0.379
Co. farm net return	-0.014	0.122	C*lnx1lnx1	-0.164	0.127
Co. swine sales per farm	0.005	0.344	C*lnx2lnx2	0.141	0.206
			C*lnx3lnx3	0.405	0.077
Production Function			C*lnx1lnx2	0.246	0.166
Constant	-1.271	0.000	C*lnx1lnx3	-0.054	0.847
lnx1	0.588	0.000	C*lnx2lnx3	-0.557	0.016
lnx2	0.100	0.283	C*lnx4lnx4	-0.011	0.907
lnx3	0.402	0.000	C*lnx1lnx4	0.311	0.052
lnx4	0.063	0.474	C*lnx2lnx4	0.017	0.913
lnx1lnx1	-0.016	0.661	C*lnx3lnx4	-0.401	0.035
lnx2lnx2	-0.132	0.032	C*Age	-0.006	0.278
lnx3lnx3	-0.027	0.718	C*Education	-0.047	0.141
lnx1lnx2	0.014	0.856	C*Major occup. off-farm	0.211	0.118
lnx1lnx3	-0.009	0.905	C*Years in hog business	-0.003	0.563
lnx2lnx3	0.108	0.255	C*Total farm assets	-0.002	0.773
lnx4lnx4	-0.019	0.713	C*Southern state	0.093	0.708
lnx1lnx4	0.043	0.541	C*Western state	-0.467	0.010
lnx2lnx4	0.035	0.686	C*Northern state	0.116	0.328
lnx3lnx4	0.000	1.000	C*Eastern state	0.013	0.953
			Sigma	0.356	0.000
			Rho	0.402	0.032

Table presents maximum likelihood parameter estimates for sample selection model. Dependent variable in the selection equation is Contract (1,0); Dependent variable in the Production Function equation is log of production ($x10^{-4}$). The P-value is the value for a two-tailed test of the hypothesis that the coefficient equals zero. In the regression all inputs (x1=feed, x2=labor, x3=capital, x4=other) have been normalized relative to the sample mean.

Table 5. Impact of Contracting on Factor Productivity and Production Technology

Variable		
Factor Productivity	**Contract/Independent**	**Input Cost Share**
Partial Factor Productivity		
Feed	1.439	0.616
Labor	1.663	0.101
Capital	0.995*	0.203
Other Inputs	1.545	0.079
Total Factor Productivity	1.257	n.a.
Production Technology	**Contract/Independent**	**Share of Operations**
Output		
All Operations	1.286	1.000
Scale Class 1	1.318	0.256
Scale Class 2	1.223	0.215
Scale Class 3	1.279	0.259
Scale Class 4	1.360	0.164
Scale Class 5	1.351	0.107
	Contract	Independent
Elasticity of Scale	1.140	1.153

* Parameter on contract dummy variable is not significant in capital productivity equation. Input cost share and share of operations are weighted to account for the survey design.