

## Appendix II: Modeling the Impact of Contract Production on Productivity

Two approaches were used to evaluate the impact of contract production on productivity in the hog sector: 1) measurement of the impact on partial and total factor productivity, and 2) measurement of the impact on the production technology. A treatment-effects model was used with both approaches (Greene). Applying the treatment-effects model, the decision to contract versus independent production and marketing can be expressed with the latent variable  $C_i^*$  as:

$$(1) C_i^* = Z_i \gamma + u_i; \text{ where } C_i = 1 \text{ if } C_i^* > 0, 0 \text{ otherwise,}$$

where  $Z_i$  is a vector of operator, farm, and regional characteristics. If the latent variable is positive, then the dummy variable indicating contracting  $C_i$  equals one, and equals zero otherwise. A measure of the impact of contract production on a measure of farm performance  $y_i$  can be expressed by:

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

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

$$(3) y_i = X_i \beta + C_i X_i \delta + \varepsilon_i$$

where  $\delta$  is now a vector of parameters associated with the interaction terms.

Equations (2) or (3) cannot be estimated directly because the decision to contract may be determined by unobservable variables (management ability, regional characteristics, etc.) that may also affect performance. If this is the case, the error terms in equations (1) and (2) will be correlated, leading to biased estimates of  $\delta$ . This selection bias can be accounted for by assuming a joint normal error distribution with the following form:

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

and by recognizing that the expected performance of contract growers is given by:

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

where  $\lambda_i$  is the inverse Mills ratio. To derive an unbiased estimate of  $\delta$ , a two-stage approach can be used starting with a probit estimation of equation (1). In the second stage, estimates of  $\gamma$  are used to compute the inverse Mills ratio, which is included as an additional term in an ordinary-least-squares estimation of equation (2). This two-stage Heckman procedure is consistent, albeit not efficient. Efficient maximum likelihood parameter estimates can be obtained by maximizing:

$$L(\gamma, \beta, \sigma, \rho) = \prod_{C_i=0} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(C_i^*, y_i, \gamma, \beta, \sigma, \rho) dy dC^* \\ \cdot \prod_{C_i=1} \int_0^{\infty} \int_{-\infty}^{\infty} f(C_i^*, y_i, \gamma, \beta, \sigma, \rho) dy dC^*$$

where  $f(C_i, y_i, \gamma, \beta, \sigma, \rho)$  is the joint normal density function, which is a function of the parameters. In practice, the negative of the log of the likelihood function is minimized using the estimates from the Heckman procedure as starting values. The solution gives estimates of the impact of contracting on partial and total factor productivity.

The second approach was to measure the impact of contracting on the hog production technology by estimating a production function that takes into account the selection process. In this approach, equation (3) was specified with a translog production function in the form:

$$\log q_i = \beta_0 + \sum_k \beta_k \log x_{ik} + \frac{1}{2} \sum_k \sum_l \beta_{kl} \log x_{ik} \\ \log \log x_{il} + \delta_0 C_i + \sum_k \delta_k C_i \log x_{ik} + \frac{1}{2} \sum_k \sum_l \\ \delta_{kl} C_i \log x_{ik} \log x_{il} + \sum_m \alpha_m z_{im} + \varepsilon_i$$

where  $\beta_{ij} = \beta_{ji}$ ,  $x_{ik}$  are the inputs (i.e., feed, labor, capital, other),  $z_{im}$  are exogenous shifters, and  $C_i$  is a dummy vari-

able equal to one if operation  $i$  uses a production contract, and equal to zero otherwise. Interacting the contract dummy with all the inputs allows the impact of contracting to vary non-linearly with the scale of production.

To evaluate the results of this model, a likelihood ratio test was used to test the joint null hypothesis of no technical difference between contract and independent producers, as in:

$$H_0 : \delta_0 = \delta_k = \delta_l = \delta_m = 0 \text{ for all } k, l, m.$$

In addition, a discrete index of technical change ( $\tau$ ) was constructed using the estimated production function:

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

where  $\hat{q}$  is the estimated production function evaluated at the input levels and with the exogenous characteristics of an average operation. 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.

## Model Specification

Data from feeder pig-to-finish operations were used to estimate both forms of the sample selection model. Appendix table II-1 includes mean values for the variables used in the estimation and results of tests of equal means between contract and independent operations for the variables used in the estimations. Each operation was categorized into one of five scale classes based on the total hundredweight (cwt) of gain produced on the operation. Regional differences among hog operations were accounted for using binary variables indicating whether the operation was in one of five regions. County-level measures of income and hog farm concentration were included as measures of the availability, and consequently the net benefits, of contracting to growers. Five measures of productivity were developed based on the ratio of total output (cwt of animal gain) to the input levels of feed, labor, capital, other inputs, and all inputs.

Since contractors provide some of the inputs used in the production of hogs, care was taken to account for inputs supplied by both the grower and the contractor. Fortunately, the survey explicitly asked respondents for both the contractor's and grower's contribution for all the compo-

nents in the "other inputs" category, including medicine and marketing. However, for some capital items it was not possible to determine the contractor's contribution. For this reason, we excluded feed handling and livestock hauling equipment, such as feed grinders and mixers, feed wagons, feed trucks, and stock trailers from the capital variable, as these items are associated with services often provided by a contractor, but not recorded in the survey. The labor variable included all paid and unpaid labor used on the hog operation. For paid labor, the survey asks for the contributions from the operator and partners, landlord, and contractor so we are able to compute the total quantity. However, for unpaid labor we only know the contribution from the grower. Consequently, if the contractor provides unpaid labor towards production activities performed by an independent operation (such as feed milling or hauling hogs) this would not be included in the labor variable, and labor productivity would appear higher for contract operations. However, because labor represents such a small share of the total cost (about 8 percent) it is unlikely that this would significantly alter the results of the total factor productivity or production function estimates.

The information presented in Appendix table II-1 highlights several clear differences between the two groups. On average, contract growers were younger and have much less experience in the hog business. Contract growers were also more likely to have their major occupation be something other than farming or ranch work. Contract growers 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 Eastern States. Independent production is more common in all the other regions except the Northern States, where there is no significant difference between the modes of production.

## Model Results

Appendix table II-2 lists the results of the first-stage probit explaining the decision to contract versus produce independently. The results of the probit are used to compute the inverse Mills ratio used in the two-stage procedure, the results of which are used as starting values for the likelihood estimation. The model is significant and correctly predicts 83 percent of operators' choices. Most variables had signs consistent with expectations. 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. It is possible that more

**Appendix table II-1—Variable means for independent and contract hog operations used in the contract impact model**

Variables	Independent operations	Contract operations	t-stat	Prob > t
<b>Operator Characteristics</b>				
Age (years)	50.6	47.0	3.78	0.000
Education (years)	13.0	12.9	0.06	0.953
Major occupation is off-farm (yes=1; no=0)	0.14	0.23	-2.41	0.016
Years in hog business	24.1	14.8	9.03	0.000
<b>Farm Characteristics</b>				
Total farm assets (\$100,000)	7.62	8.70	-1.25	0.211
Scale class 1: production (<1,000 cwt.)	0.408	0.065	9.68	0.000
Scale class 2: production (1,000-1,999 cwt.)	0.224	0.098	3.79	0.000
Scale class 3: production (2,000-4,999 cwt.)	0.196	0.221	-0.67	0.505
Scale class 4: production (5,000-9,999 cwt.)	0.130	0.254	-3.47	0.001
Scale class 5: production (≥10,000 cwt.)	0.041	0.361	-9.40	0.000
<b>Regional Characteristics</b>				
Northern State (MI, MN, SD, WI)	0.194	0.232	-1.02	0.306
Eastern State (NC, SC, VA)	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
Midwestern State (IL, IN, IA, OH)	0.548	0.463	3.17	0.064
County net cash return per farm (\$1,000)	34.86	46.54	-4.64	0.000
County swine sales per farm (\$1,000)	23.63	70.73	-6.8	0.000
<b>Output and Inputs<sup>1</sup></b>				
Hog production (cwt. gain)	2,678	10,672	-9.67	0.000
Feed (cwt.)	9,874	26,163	-7.84	0.000
Labor (hours paid and unpaid)	1,226	1,608	-3.40	0.001
Capital (\$)	22,185	61,091	-8.51	0.000
Other inputs (\$)	7,928	24,473	-6.29	0.000
<b>Productivity</b>				
Feed productivity (cwt. hog/cwt. feed) X 10 <sup>-1</sup>	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 <sup>-2</sup>	9.66	17.04	-11.75	0.000
Other inputs productivity (cwt. hog/\$) X 10 <sup>-2</sup>	50.01	65.84	-4.16	0.000
Total factor productivity <sup>2</sup> (cwt. hog/\$) X 10 <sup>-2</sup>	2.04	3.29	-14.15	0.000
Number of Observations	233	244		

Notes: Data are from the 1998 ARMS except county average variables, which are from the 1997 Agricultural Census. Prob>|t| is the two-tailed significance probability under the null hypothesis of equal means. Scale class and region are specified with a binary variable equal to 1 if the hog operation is in the group, 0 otherwise.

<sup>1</sup>Feed includes homegrown and purchased feed. Labor includes own and hired labor. Capital is an estimate of economic depreciation and interest using the capital recovery method. Other inputs include veterinary, bedding, marketing, custom work, energy, and repair expenses.

<sup>2</sup>Total factor productivity is defined as the inverse unit cost for all of the input categories.

experienced, better educated, full-time farmers are less likely to accept a contract because these farmers could earn relatively more producing independently than could less educated, less experienced, part-time farmers.

An operation being located in an Eastern State positively increases the likelihood of contracting, as did being located in a Northern State or not being located in a Southern State (all relative to the omitted region, Midwestern States). As expected, being located in a county with more hog production increases the likelihood of con-

tracting, probably because this lowers transactions costs for the contractor. Also as expected, being in a county with a higher average net return to farming lowers the probability that a farmer contracts. Higher incomes mean that growers have a higher reservation wage to be induced into contract production.

The scale of production has a strong positive correlation with the likelihood of contracting. Controlling for other characteristics, operations in a farm scale category other than the smallest are associated with an increased likeli-

**Appendix table II-2—Binomial probit maximum likelihood estimates for the decision to produce hogs under contract**

Variable	Coefficient	Std. error	t-ratio	P-value
Constant	0.975	0.775	1.259	0.208
Age (years)	0.003	0.009	0.304	0.761
Education (years)	-0.163	0.050	-3.258	0.001
Major occupation is off-farm (yes=1; no=0)	0.631	0.217	2.911	0.004
Years in hog business	-0.024	0.008	-2.870	0.004
Total farm assets (\$100,000)	-0.006	0.009	-0.614	0.539
Scale class 2: production (1,000-1,999 cwt.)	1.040	0.261	3.978	0.000
Scale class 3: production (2,000-4,999 cwt.)	1.507	0.267	5.651	0.000
Scale class 4: production (5,000-9,999 cwt.)	1.729	0.259	6.665	0.000
Scale class 5: production (=10,000 cwt.)	2.635	0.325	8.116	0.000
Southern State (AL, AR, GA, MO, KY, TN)	-0.843	0.373	-2.258	0.024
Western State (CO, KS, OK, UT, NE)	-0.309	0.267	-1.159	0.246
Northern State (MI, MN, SD, WI)	0.297	0.185	1.606	0.108
Eastern State (NC, SC, VA)	0.774	0.430	1.801	0.072
County net cash return per farm (\$1,000)	-0.015	0.006	-2.544	0.011
County swine sales per farm (\$1,000)	0.006	0.003	2.150	0.032

Notes: Dependent variable: Uses a production contract=1; otherwise=0; Number of observations: 477; Log likelihood function: -195.288; Restricted log likelihood: -330.504; Chi-squared: 270.433; Degrees of freedom: 15; Significance level: 0.000; 83 Percent correct predictions.

hood of contracting. The increase in the magnitude of the coefficients with the size groups indicates that the probability of contracting increases with scale.

In order to estimate the impact of contracting on partial and total factor productivity, a linear function of the explanatory variables was used. There is no theoretical reason to expect county hog production nor county average farm income to affect onfarm productivity, so these were omitted from the estimation. The maximum likelihood estimates of the sample selection model are presented in Appendix table II-3. The estimated coefficients in the top half of the table correspond to the selection equation, and are consistent with the results of the probit model.

The coefficients in the bottom half of Appendix table II-3 correspond to the factor productivity equations. Most of the indicators of scale of production were significant determinants of productivity, except in the case of “other inputs.” Among the operator characteristics, age appears to lower labor and total factor productivity, perhaps because some older farmers may be semi-retired, or because older farmers are more likely to be using aging capital equipment that they do not plan to replace due to their impending retirement. Education reduces the probability that a farmer will contract, but also has a significant negative effect on feed and total factor productivity.<sup>21</sup> A further analysis of the data revealed that the highest educated producers (with 16 years of education or more) have smaller scale operations, are more likely to work off-farm,

and have greater wealth than do average producers. This relatively affluent, well-educated group may be more likely to view farming as a “hobby” or secondary activity, resulting in lower factor productivity. Having off-farm work as a primary occupation increases the likelihood of contracting, but also, surprisingly, raises productivity. Number of years in the hog business has two confounding effects on productivity: an extra year in business increases productivity directly, but also reduces the likelihood of contracting, which decreases productivity indirectly. The net marginal impact of an extra year in the hog business on productivity is small—on total factor productivity, for example, it is computed to be only 0.00921.

Contracting is significant in all factor productivity equations. The estimated correlation between the errors of the two equations  $\rho$  is significant and negative in the labor productivity equation. This result indicates that we would have underestimated the impact of contracting on productivity had we not taken into account the selectivity bias. Using the estimated coefficients on the contracting variable from Appendix table II-3 and evaluating the impact at the mean of each factor productivity measure, contracting raises feed, labor, capital, other inputs, and total factor productivity by 36, 44, 16, 52, and 23 percent, respectively, for the average hog operation.

<sup>21</sup> A quadratic functional form that includes education and education squared in the productivity equations was also tested. The education coefficient was positive and significant and the education-squared coefficient was negative and significant in the quadratic form of both the feed and total factor productivity equations. Hence, the net impact of education appears to be positive at low levels of education and negative at high levels.

**Appendix table II-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
<b>Selection equation</b>										
Constant	1.256	0.164	1.239	0.189	1.159	0.130	0.954	0.309	1.127	0.199
Age	-0.001	0.932	-0.003	0.756	0.001	0.911	0.003	0.780	0.003	0.796
Education	-0.177	0.003	-0.162	0.010	-0.174	0.001	-0.162	0.011	-0.172	0.006
Off-farm occup.	0.631	0.013	0.607	0.013	0.774	0.001	0.625	0.015	0.595	0.017
Years in bus.	-0.022	0.029	-0.021	0.038	-0.022	0.010	-0.025	0.013	-0.024	0.010
Total farm assets	-0.005	0.706	-0.004	0.798	-0.003	0.790	-0.005	0.718	-0.005	0.682
Scale class 2	0.990	0.003	0.956	0.004	0.966	0.001	1.006	0.002	0.945	0.004
Scale class 3	1.518	0.000	1.249	0.000	1.583	0.000	1.476	0.000	1.450	0.000
Scale class 4	1.793	0.000	1.789	0.000	1.714	0.000	1.717	0.000	1.790	0.000
Scale class 5	2.638	0.000	2.647	0.000	2.193	0.000	2.608	0.000	2.585	0.000
Southern State	-0.664	0.160	-0.706	0.154	-0.854	0.016	-0.853	0.073	-0.713	0.121
Western State	-0.395	0.307	-0.321	0.346	-0.318	0.296	-0.308	0.403	-0.313	0.389
Northern State	0.303	0.109	0.213	0.306	0.527	0.002	0.281	0.168	0.337	0.079
Eastern State	0.710	0.277	0.867	0.159	0.675	0.087	0.723	0.261	0.738	0.220
Co. net returns	-0.015	0.055	-0.013	0.077	-0.016	0.009	-0.014	0.103	-0.015	0.045
Co. swine sales	0.007	0.149	0.006	0.162	0.007	0.028	0.006	0.186	0.006	0.180
<b>Factor productivity</b>										
Constant	3.707	0.000	3.584	0.003	6.935	0.090	54.456	0.021	2.738	0.000
Age	0.002	0.862	-0.030	0.023	0.031	0.534	0.261	0.335	-0.008	0.098
Education	-0.133	0.007	-0.104	0.174	0.488	0.065	-2.130	0.107	-0.092	0.000
Off-farm occup.	0.627	0.004	-0.203	0.568	-0.885	0.487	-8.451	0.246	0.158	0.159
Years in bus.	0.010	0.260	0.007	0.589	-0.050	0.312	0.136	0.577	0.013	0.001
Total farm assets	0.000	0.997	0.024	0.034	0.026	0.656	-0.096	0.745	0.002	0.693
Scale class 2	0.414	0.078	0.496	0.547	-0.654	0.680	11.482	0.120	0.591	0.000
Scale class 3	0.448	0.154	1.141	0.111	2.393	0.099	11.656	0.138	0.997	0.000
Scale class 4	1.056	0.000	2.915	0.000	4.451	0.004	2.699	0.755	1.482	0.000
Scale class 5	1.480	0.000	6.566	0.000	4.261	0.023	7.465	0.456	2.043	0.000
Southern State	0.699	0.008	0.409	0.444	7.319	0.000	22.103	0.003	0.591	0.000
Western State	-0.083	0.786	0.551	0.212	3.334	0.034	20.820	0.001	0.462	0.000
Northern State	-0.013	0.942	0.379	0.330	2.268	0.040	-2.821	0.665	0.316	0.001
Eastern State	-0.358	0.320	0.258	0.514	-1.676	0.386	-24.693	0.070	-0.520	0.006
Contract	1.328	0.000	2.308	0.000	3.054	0.020	26.402	0.000	0.661	0.000
Sigma	1.460	0.000	2.376	0.000	8.619	0.000	39.111	0.000	0.765	0.000
Rho	-0.230	0.112	-0.328	0.006	-0.519	0.000	-0.093	0.552	-0.269	0.051
Log likelihood	-1,047.4		-1,274.4		-1,909.1		-2,620.2		-737.2	

Notes: Table presents maximum likelihood parameter estimates for the sample selection model. Dependent variable in the selection equation: uses a production contract=1, otherwise=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.

The second approach used to measure the impact of contracting on productivity involves estimating a production function, taking into account the selection process. Appendix table II-4 reports the result of the maximum likelihood estimation of the production function where for convenience input levels have been normalized by dividing by their mean value. The top of the first column presents the estimates of the bivariate selection equation, which again are similar to those obtained in the probit equation. The remaining coefficients correspond to the production function.

The analysis of the impact of contracting on the production technology yielded similar results as the analysis of the impact on factor productivity. Statistical testing indicated that contract and independent operations were using different levels of technology. The index of technical change constructed from production functions for the contract and independent operations indicate that contracting raises productivity, on average, by about 20 percent.

**Appendix table II-4—Selection model maximum likelihood estimates: production function**

	Coeff.	P-value		Coeff.	P-value
<b>Selection equation</b>			<b>Production function (cont.)</b>		
Constant	1.195	0.211	C (Contract)	0.509	0.000
Age	0.000	0.992	C*lnx1	-0.095	0.509
Education	-0.165	0.008	C*lnx2	-0.078	0.578
Major occup. off-farm	0.603	0.033	C*lnx3	-0.092	0.541
Years in hog business	-0.025	0.020	C*lnx4	0.089	0.399
Total farm assets	-0.005	0.729	C*lnx1lnx1	-0.158	0.265
Scale class 2	0.974	0.005	C*lnx2lnx2	0.108	0.374
Scale class 3	1.428	0.000	C*lnx3lnx3	0.327	0.144
Scale class 4	1.691	0.000	C*lnx4lnx4	-0.062	0.463
Scale class 5	2.565	0.000	C*lnx1lnx2	0.291	0.165
Southern State	-0.765	0.095	C*lnx1lnx3	-0.184	0.562
Western State	-0.383	0.373	C*lnx1lnx4	0.334	0.045
Northern State	0.288	0.169	C*lnx2lnx3	-0.513	0.036
Eastern State	0.722	0.291	C*lnx2lnx4	-0.014	0.932
Co. farm net return	-0.015	0.052	C*lnx3lnx4	-0.235	0.201
Co. swine sales	0.007	0.153	Age	0.002	0.432
			Education	-0.012	0.338
<b>Production function</b>			Major occup. off-farm	0.008	0.889
Constant	-0.864	0.000	Years in hog business	0.001	0.766
lnx1	0.619	0.000	Total farm assets	0.002	0.291
lnx2	0.173	0.044	Southern State	0.223	0.005
lnx3	0.366	0.000	Western State	0.170	0.007
lnx4	0.066	0.374	Northern State	-0.055	0.271
lnx1lnx1	-0.004	0.911	Eastern State	0.013	0.914
lnx2lnx2	-0.120	0.028			
lnx3lnx3	0.010	0.829	Sigma	0.356	0.000
lnx4lnx4	-0.017	0.686	Rho	-0.211	0.321
lnx1lnx2	-0.020	0.786			
lnx1lnx3	-0.003	0.961			
lnx1lnx4	0.040	0.531			
lnx2lnx3	0.116	0.125			
lnx2lnx4	0.062	0.432			
lnx3lnx4	-0.036	0.662			

Notes: Table presents maximum likelihood parameter estimates for sample selection model. Dependent variable in the selection equation: uses a production contract=1, otherwise=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. Log likelihood function=-371.44.