Do Production Contracts Raise Farm Productivity? An Instrumental Variables Approach

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Estimating how the use of production contracts affects farm productivity is difficult when unobservable factors are correlated with both the decision to contract and productivity. To account for potential selection bias, this study uses the local availability of production contracts as an instrument for whether a farm uses a contract in order to estimate the impact of contract use on total factor productivity. Results indicate that use of a production contract is associated with a large increase in productivity for feeder-to-finish hog farms in the United States. The instrumental variable method makes it credible to assert that the observed association is a causal relationship rather than simply a correlation.

Key Words: productivity, production contracts, instrumental variables, sample selection

Production contracts, in which the contractor exercises control over some production decisions and farmers are paid a fee for services rendered, are becoming increasingly common in the United States (MacDonald et al. 2004). In the U.S. hog industry, growth in use of production contracts has been particularly rapid: the share of all hog production under contract increased from about 5 percent in 1992, to about 40 percent in 1998, to 67 percent in 2004 (Key and McBride 2007). Production contracts offer several potential advantages over independent production that could explain their growing use: contracts can reduce information asymmetries between growers and processors, improve coordination and timing of product delivery, and lower income risk for growers. In addition to these benefits, production contracts could raise farm productivity by improving the quality of farm management decisions or speeding the transfer of technical information to growers (e.g., by requiring growers to attend training courses or follow integrator-provided procedures), improving growers' access to credit, and facilitating the adoption of more efficient technologies.

Using data from a 1998 survey, Key and McBride (2003) found that production contracts were associated with greater hog farm productivity. However, between 1998 and 2004 the number of hog farms in the United States fell from 113,830 to 69,500 (USDA, various issues), the average number of finished hogs removed per farm increased from 2,590 to 4,650, and the share of output under contract increased from 40 percent to 67 percent (Key and McBride 2007). Given these recent structural changes, it is reasonable to suppose that since 1998 a number of less efficient independent operations have exited, and that some independent operations have begun to contract (and therefore experienced a resulting increase in productivity), so that the productivity of the surviving independent operations increased. Hence, it is an open question whether production contracts continue to be associated with greater farm productivity, and if so, whether this effect has diminished. How contracts affect farm productivity will be an important factor influencing the future organizational decisions of farmers. Understanding how contracts affect productivity is important for evaluating legislative efforts to regulate contract production.

To measure the effect of contracting on farm productivity it is necessary to control for differences between those farmers who use contracts

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and those who produce independently. Farmers who contract might have larger operations, tend to be located in certain regions, be more credit-constrained, be more risk-averse, value autonomy less, or have less managerial or entrepreneurial ability—characteristics that could be positively or negatively correlated with farm productivity. Unfortunately, some factors correlated with the decision to contract and with farm productivity are not observable. Consequently, a simple regression of productivity on exogenous factors and a contract indicator could produce biased parameters. For example, if "management ability" is unobservable and negatively correlated with contracting but positively correlated with productivity, then an OLS regression would underestimate the effect of contracting on productivity.[1] The problem is one of self-selection—farmers with less management ability (and therefore lower productivity) would be more likely to contract, *ceteris paribus*.

Key and McBride (2003) used a full-information maximum likelihood (FIML) sample selection model to measure differences in farm productivity between contract and independent operations using a 1998 survey of hog farms. The authors found that contracting had a substantial positive effect on farm productivity. Paul, Nehring, and Banker (2004) used an input distance function approach to evaluate scale and technical efficiency of crop and livestock farms using a pseudo-panel data set. The authors found a small but statistically significant positive relationship between contracting and productivity. However, their approach did not control for sample selection bias, nor did it focus on a particular type of commodity farm or type of contract.

While FIML and two-step approaches to estimating sample selection models are frequently used in empirical work, these methods have limitations in practice (Puhani 2000). Problems may arise if many, or all, of the variables in the selection equation (the decision whether to contract) are included in the outcome equation (a measure of productivity). This can lead to a high degree of collinearity between the regressors in the outcome equation and the inverse Mills ratio, resulting in estimates that are sensitive to model specification (Little and Rubin 1987, Leung and Yu 1996). A high degree of censoring may also cause collinearity (Zuehlke and Zeman 1991). Another drawback to this approach is the sensitivity of the estimated coefficients to the distributional assumptions about the error terms of the selection and outcome equations (Little and Rubin 1987).

In this study, we use the availability of contracting at the local level as an instrument for whether a farm uses a contract in order to estimate the impact of using a contract on total factor productivity. The availability of contracting (the prevalence of contracting in the county in which the farm is located) should influence the transaction costs associated with producing under contract relative to producing independently, and should therefore predict whether a farmer contracts. At the same time, there is no plausible reason to expect the availability of contracting to *directly* influence a farm's productivity. However, contract availability should increase the likelihood of contracting and might thereby increase productivity *indirectly* through the mechanisms described above. The instrumental variable method makes it credible to assert that the association between contracting and productivity is a causal relationship rather than simply a correlation.

The next section discusses some theoretical connections between the use of production contracts and farm productivity. The third section describes the two-stage instrumental variables approach. The fourth section describes the data and construction of the variables used in the analysis. The fifth section discusses the main results, the validity of the exclusion restriction, how the estimated effect varies by scale, and robustness of the results to alternative measures of productivity.

Theoretical Links

This paper is concerned with estimating the productivity effects of production contracts on-farm, but contracting could also affect productivity off-farm. For example, contracting might help ensure

[1] Many hog contracts provide management "services" to farmers in terms of specifying production methods, deciding what type of feed and feeder pigs to use, the timing of feedings, the type of equipment to use, etc. If contractors extract rents from growers for these management services, it is plausible that growers with weaker management skills would benefit more from a contract than would growers with stronger management skills. In addition, anecdotal evidence has suggested that "better" producers prefer independent to contract production (Rhodes 1995).

processors a steady flow of products, improve product traceability for health concerns, and help guarantee that certain methods of production are followed. Productivity gains for processors associated with these effects would not be measured by this analysis, because they would accrue downstream of the farm.

Production contracts might raise farm productivity by allowing production to achieve a more efficient scale (i.e., by increasing scale efficiency). Contracts can promote a larger scale of production through a variety of mechanisms (Key 2004). For example, contracts that reduce grower income risk may make lenders more willing to supply credit or might encourage risk-averse growers to take on more debt. In addition, because processors provide many inputs to production, a production contract reduces growers' financial requirements, which can allow for greater output given grower financial constraints. While contracting may increase scale, and hence scale efficiency, this paper does not attempt to measure this effect. Instead, this paper is concerned only with changes in efficiency resulting from contracts, holding the size of the operation constant. In other words, we ask whether farmers who use production contracts are more or less productive than independent growers, after controlling for farm size and other observable characteristics.

A possible reason for a positive effect on productivity is that production contracts generally reduce the financing requirements of growers, freeing up capital for investment in productive assets. With a typical production contract to finish hogs, a contractor provides a large share of the variable inputs—feed, feeder pigs, veterinary care, managerial assistance, and marketing services. Growers provide labor and "fixed inputs"—growing facilities, and equipment. Growers are paid a fee for raising the livestock, which may be based on animal weight gain, death loss, or feed productivity. Because contractors provide most of the variable inputs under a production contract, growers require far fewer financial resources to produce a given quantity of product. For example, the feed and other inputs supplied by a contractor under a production contract to finish hogs represent, on average, over 80 percent of the total costs of production (McBride and Key 2003). By relieving financing requirements, contracts may allow farmers to invest in superior production technologies (for a given farm size).

Production contracts have been shown to shift both output and input price risk to contractors and can also reduce some production risk for growers, depending on the contract's incentive structure (Knoeber and Thurman 1995, Martin 1997). By reducing risk, contracts may induce lenders to increase the amount they are willing to lend to farmers at a given rate, or to offer loans at a lower rate (Barry et al. 1997, Key 2004). Improved access to credit can allow growers to invest in more efficient technologies.

Production contracts may serve as a way to overcome information asymmetries—allowing processors to increase control over farm production methods so as to obtain greater product uniformity and improved product quality (Hennessy 1996, Martinez, Smith, and Zering 1998). While many of these benefits will accrue to the processor, greater product uniformity could allow the use of more efficient standardized equipment and thereby raise farm productivity. Contracts may also serve as a mechanism for transferring information to growers: contracts frequently require growers to attend training courses on hog production and to follow integrator-provided procedures, guidelines, and recommendations. This information transfer may improve farming practices and result in higher productivity. In addition, it is possible that the goods and services provided by the contractor—such as feed and especially the genetic quality of the animals—might be superior to those available to an independent producer, resulting in healthier animals and greater weight gain.

Contracts can also alter incentives for operators to apply effort. When growers share the product of their labor with a contractor, growers receive less reward for their effort than they would if they produced independently, and therefore they could have less incentive to work hard. However, incentive schemes that link grower fees to feed or reproductive efficiency, rate of weight gain, etc., can significantly mitigate incentive problems resulting from share contracts, and could even theoretically increase incentives to provide effort.

Finally, by requiring operators to surrender product ownership and control over the production process, production contracts generally reduce farmer autonomy (Gillespie, Davis, and Rahelizatovo 2004). Preferences for autonomy may correlate with factors such as entrepreneurial ability and management skills that affect productivity. Anecdotal evidence has suggested that "better" producers are less interested in the "quasi-employee" status associated with contract production (Rhodes 1995).

Empirical Approach

The empirical approach uses local (county-level) variation in contract availability as an instrument to identify the effect of contract use on farm productivity. In counties where contracts are more widely available, farms face lower transaction costs associated with obtaining and maintaining a contractual relationship. That is, in counties with greater contract availability, distances between contractors and growers are smaller, so the costs associated with search, information, and transportation are lower for farmers and contractors, making contracting relatively more profitable. It follows that farms in counties with greater contract availability should be more likely to contract, *ceteris paribus*. At the same time, it is reasonable to suppose that the county-level availability of contracts is exogenous to an individual farm and should have no direct effect on farm productivity (though contract availability could indirectly affect productivity by influencing the decision to contract). In other words, the local availability of contracts is not correlated with unobservable factors that influence farm productivity.

In the first stage, the availability of contracts ($AVAIL_i$) is used as an instrument for the use of a production contract ($CONT_i$), controlling for operator and operation characteristics ($\mathbf{X}_i$). State dummy variables ($\mathbf{STATE}_i$) are included to capture regional variation in technology, prices, and other factors:

$$(1) \quad CONT_i = \mathbf{X}_i^{'}\mathbf{a}_i + \mathbf{STATE}_i^{'}\mathbf{b}_i + c_i AVAIL_i + e_i .$$

As emphasized by Angrist and Krueger (2001), in two-stage least squares, consistency of the second-stage estimates does not depend on using the correct first-stage functional form (Kelejian 1971). That is, using a linear regression for the first-stage estimates generates consistent second-stage estimates even with a dummy dependent variable (the use of contracts, in this case). In fact, the linear model is generally preferred, as researchers risk specification error if they plug in fitted values from a logit, probit, or other nonlinear equation directly in the second step of a two-stage least squares procedure (Angrist and Krueger 2001, p. 80).

The second stage estimates the effect of contract use on farm productivity ($PROD_i$):

$$(2) \quad PROD_i = \mathbf{X}_i^{'}\alpha_i + \mathbf{STATE}_i^{'}\beta_i + \gamma_i CONT_i + e_i .$$

An instrumental variable two-stage least squares (IV-2SLS) procedure is used to estimate the model.

Data

Contract Availability

Data on the availability of contracting are from the 2002 U.S. Census of Agriculture. The National Agricultural Statistics Service, which conducts the Census of Agriculture every five years, attempts to survey every farm operator in the United States.[2] The Census questionnaire asked farmers how many head of hogs they had on December 31, 2002; how many head were sold or removed from the operation in 2002; the operation type (farrow to wean, farrow to feeder, farrow to finish, nursery, finish only); and organizational arrangement [independent grower, contractor or integrator, or contract grower (contractee)]. Respondents were also asked how many head of hogs and pigs they raised and delivered under a production contract. The Census classified hogs as produced under a "production contract" if (i) operators raised hogs that they did not own, (ii) the livestock owner (contractor) provided inputs such as feed, and (iii) the operation received a fee or percentage of the production for raising the livestock.

To reduce sample heterogeneity and to conform to the data used to measure farm productivity, we limit the analysis to "finish only" farms that produced at least 25 head of hogs or pigs as independent or contract growers. These farms are most similar to the "feeder-to-finish" operations

[2] More information about the Census is available at: http://www.nass.usda.gov/Census_of_Agriculture/index.asp.

surveyed in the USDA-ARMS, discussed below.[3] The sample used consists of 13,653 observations, representing 15,146 finish hog farms in 1,538 counties.[4]

We use the share of finish hog operations in a county that used a production contract as a measure of contract availability.[5] Table 1 presents the distribution of the share of contracts in the county for the Census sample. In 51.3 percent of the counties having finish hog operations, none of the finish hog operations used contracts. In contrast, all operations used a production contract in 8.7 percent of the counties. Counties having both independent and contract growers, though comprising only 40 percent of all counties, contained 85.1 percent of all finish hog operations, which produced 88.2 percent of all finish hog output.

Productivity

Data on farm productivity is drawn from the 2004 USDA Agricultural Resource Management Survey (ARMS) of the hog sector. To limit sample heterogeneity and to allow for a focus on contracts, we restrict the sample to feeder-to-finish hog operations (production contracts are much less common among farrow-to-finish operations, limiting our ability to make a comparison between independent and contract growers for this type of farm). There was a total of 478 feeder-to-finish hog operations surveyed in 2004, accounting for an estimated 16,245 operations, producing 169.8 million cwt. gain.[6]

We want to compare the productivity of similar farms that could feasibly produce under contract or independently. Because contract operations tend to be larger scale than independent operations, and to reduce the heterogeneity of the sample, we restrict our analysis to operations producing at least 3,000 cwt. gain (approximately equivalent to an inventory of 500 head[7]), resulting in a sample of 359 observations. Merging the ARMS and Census data, we drop one observation for which there is missing county-level data on contract availability, resulting in a final sample of

Table 1. Distribution of Share of "Finish Only" Hog Operations Using Production Contracts across Counties

Contract Availability (county contract share)	Frequency (number of counties)	Cumulative Percent (% of counties)
S = 0 (none contract)	789	51.3
0 < S ≤ 0.05	4	51.6
0.05 < S ≤ 0.10	15	52.5
0.10 < S ≤ 0.15	36	54.9
0.15 < S ≤ 0.20	59	58.7
0.20 < S ≤ 0.25	54	62.2
0.25 < S ≤ 0.30	34	64.4
0.30 < S ≤ 0.35	70	69.0
0.35 < S ≤ 0.40	49	72.2
0.40 < S ≤ 0.45	39	74.7
0.45 < S ≤ 0.50	97	81.0
0.50 < S ≤ 0.55	23	82.5
0.55 < S ≤ 0.60	37	84.9
0.60 < S ≤ 0.65	20	86.2
0.65 < S ≤ 0.70	28	88.0
0.70 < S ≤ 0.75	15	89.0
0.75 < S ≤ 0.80	12	89.8
0.80 < S ≤ 0.85	5	90.1
0.85 < S ≤ 0.90	8	90.6
0.90 < S ≤ 0.95	4	90.9
0.95 < S < 1	6	91.3
S = 1 (All contract)	134	100.0

Notes: "Contract share" is the share of "finish only" hog operations using a production contract in a county. All data are from the 2002 Census of Agriculture.

[3] Feeder-to-finish operations are those on which feeder pigs (weighing 30–80 pounds) are purchased/placed, finished, and then sold/removed for slaughter (weighing 200–260 pounds).

[4] Because some Census forms are not returned, an adjustment is made for the non-responses. This results in a discrepancy between the number of observations and the number of farms these observations represent. See http://www.nass.usda.gov/Census_of_Agriculture/index.asp for more details.

[5] An operation was considered to have used a production contract if it delivered any hogs or pigs under a production contract in 2002.

[6] The ARMS is a nationally representative survey of the hog sector. Weights are used to calibrate the sample frame to the national population. See http://www.ers.usda.gov/Briefing/ARMS/ for more details. For the productivity data, output is defined as "hog weight gain"—the weight added to purchased/placed hogs and existing hog inventory in the calendar year of the survey. Hog weight gain, unlike the alternative measure of output "number of head removed," accounts for changes in inventory and differences in weights of feeder and finished pigs between operations.

[7] Each head produced represents approximately 2 cwt. gain (250 pounds for a finished market hog minus 50 pounds for a feeder pig). Hence, output of 3,000 cwt. gain is approximately equivalent to 1,500 head sold per year. Assuming three hog cycles per year, and ignoring losses due to animal mortality, this implies an inventory of 500 head.

358 observations, representing 9,661 operations producing 160.6 million cwt. gain. The final sample represents 59.5 percent of all U.S. feeder-to-finish operations and 94.6 percent of all feeder-to-finish hog output.

Table 2 summarizes the variables used in the analysis. Total factor productivity is defined as total hog output (hundredweight gain) divided by total hog enterprise input costs. Input costs include costs for feed, labor (hired labor and an imputed value for own-labor), capital (the "capital recovery cost"—the estimated cost of replacing the existing capital equipment, such as barns, feeding equipment, etc.), and "other inputs" (expenditures on veterinary services, bedding, marketing, custom work, energy, and repairs). "Family proprietorship" is a dichotomous variable indicating the legal status of the farm business: a value of one indicates a sole (individual or family) proprietorship, and a zero indicates a legal partnership, family-held corporation, non-family corporation, or cooperative.

Table 2 also displays a comparison of means for contract and independent operations. The comparison shows that, on average, contract operations are significantly more productive than independent operations. However, contract operations are also significantly larger, and their operators have less experience farming, are less likely to have farming as a primary occupation, and are more likely to have only a high school degree. On average, contract operations are located in counties where 63.4 percent of finish hog farms contract; independent growers are located in counties where 35.5 percent of farms contract.

Data Limitations

Since contractors provide some of the inputs used in the production of hogs, care was taken to account for the separate contributions of the grower and contractor. The ARMS survey explicitly asked respondents for both the growers' and contractors' contribution for all the inputs, with a few exceptions. For paid labor, the survey asks for the contributions from the operator and partners, landlord, and contractor—so the total can be computed. However, for unpaid labor, only the grower's contribution is known. Consequently, if the contractor provides *unpaid* labor towards production activities performed by an independent operation (such as feed milling, hauling pigs, or management services), this would not be included in the labor variable, and labor productivity would appear higher for contract operations. However, because labor represents a small share of total costs, this is unlikely to have a large effect on the results of the total factor productivity estimates.

Because ARMS surveys growers and not contractors, it relies on growers' estimates of the value of the inputs provided by contractors. It seems plausible that, on average, growers' estimates of contractor costs would be unbiased estimates of actual costs. However, a problem could arise if growers consistently underestimate (or overestimate) contractor costs, in which case the productivity of contract operations would be over (under) estimated.

Results

Column 1 in Table 3 presents the estimated first-stage relationship between the availability of production contracts and the use of production contracts. Contract availability is significantly positively related to contract use at the 99 percent confidence level. The explanatory variables explain about 46 percent of the variation in contract use. The strong relationship means we do not confront problems associated with a weak instrument.

For comparison with the second-stage results, column 2 in Table 3 presents the simple linear regression of total factor productivity on the contract dummy variable and the explanatory variables. Contract use is positively and statistically significantly correlated with total factor productivity. Hog output is also correlated with productivity, implying increasing returns to scale. While no other operator or operation characteristics were statistically significant in the regression, 9 out of 17 state dummy variables were statistically significant (6 at the 99 percent level).

Column 3 in Table 3 presents the instrumental variable two-stage least squares results. The instrumental variable estimation yields a parameter value of 0.033, which is statistically significant at the 99 percent confidence level. In our sample, 62.1 percent of operations use production contracts, with an average total factor productivity of 0.039. The results imply that a 10 percent increase in the prevalence of contracting (to 68.3 percent of the population) would increase the average total factor productivity by about 5.2

Table 2. Descriptive Statistics and Test of Equality of Means for Independent and Contract Operations

	Mean			
Variables	All Farms	Independent	Contract	t-statistic
Total factor productivity	0.039	0.033	0.043	-5.26***
Hog production (cwt. gain)	16,621	11,565	19,708	-4.56***
Total assets ($1,000)	1,820	1,865	1,791	0.29
Family proprietorship	0.798	0.801	0.796	0.11
Operator age	48.878	48.64	49.02	-0.35
Operator hog farm experience	11.47	14.77	9.45	5.48***
Farming primary occupation	0.857	0.953	0.797	4.17***
Education: some high school	0.020	0.028	0.016	0.76
Education: completed high school	0.369	0.301	0.410	-2.07**
Education: some college	0.371	0.396	0.355	0.77
Education: completed college	0.240	0.275	0.219	1.2
Uses a production contract	0.621	0	1	-
Contract share	0.529	0.355	0.634	-11.69***
Observations	358	98	260	

Notes: All variables are from the 2004 USDA ARMS except "contract share," which is from the 2002 Census of Agriculture. Means are weighted to account for survey design. The t-statistics are for the test of the null hypothesis of equal means from a pooled sample. Total factor productivity is defined as total hog output (hundredweight gain) divided by total hog enterprise input costs. A "family proprietorship" refers to the legal status of the farm business and includes a sole proprietorship. Legal arrangements not considered a family proprietorship include legal partnerships, family-held corporations, non-family corporations, and cooperatives. "Contract share" is the share of "finish only" hog operations using a production contract in the county in which the operation is located. Significance level: * = 0.10, ** = 0.05, *** = 0.01.

percent, to 0.041. The estimates indicate that the productivity advantages associated with contracting persist despite substantial structural changes in the sector. In fact, the estimated effect found here is somewhat larger than that found by Key and McBride (2003), who used the 1998 data and a different methodology.

It is interesting to note that the IV-2SLS estimate of the effect of contract use on productivity (column 3) is larger than the OLS estimate (column 2). This finding is consistent with the hypothesis that there are unobservable factors, such as "management ability," that are negatively correlated with the decision to contract and with productivity, which causes an OLS regression to underestimate the effect of contract use on productivity.

The instrumental variables estimate also indicates that the scale of production (logarithm of hog output) is statistically significantly correlated with total factor productivity. This result implies that a 10 percent increase in the scale of production results in about a 1 percent increase in productivity. Recent work has attributed much of the recent increases in factor productivity in the hog sector to growth in the scale of production and technical change (Key, McBride, and Mosheim 2008). The results of this analysis suggest that the recent growth in the use of contracts in the hog sector may also have contributed a substantial portion of the recent growth in productivity. However, it is not clear how much the effect of contracting on productivity can be attributed to technological differences between contract and independent operations. In other words, some of the effect of contracting would probably be attributed to technical progress in a standard decomposition of total factor productivity change.

Validity of the Exclusion Restriction

Next we explore the validity of the exclusion restriction: that the availability of contracting af-

Table 3. Instrumental Variable Estimates of Contract Use and Productivity

	Dependent Variable: Uses a Production Contract (1/0)	Dependent Variable: Total Factor Productivity	
	OLS (first-stage) (1)	OLS (2)	IV-2SLS (second-stage) (3)
Intercept	-0.488 (0.483)	-0.027 (0.024)	-0.026 (0.024)
Contract availability (share)	0.734*** (0.159)	--	--
Uses a production contract	--	0.011*** (0.0023)	0.033*** (0.011)
log (hog output)	0.127*** (0.031)	0.0073*** (0.0014)	0.0040** (0.0022)
log (total assets)	-0.073*** (0.027)	-0.0017 (0.0012)	-0.0001 (0.0016)
Individual proprietorship	0.051 (0.056)	-0.0005 (0.0024)	-0.0019 (0.0028)
Operator age	-0.005 (0.015)	0.0006 (0.0006)	0.0008 (0.0007)
Operator age squared	0.00009 (0.00014)	-0.000004 (0.000006)	-0.000007 (0.000007)
Operator experience	-0.011*** (0.002)	-0.0003*** (0.0001)	-0.0001 (0.0002)
Farming primary occupation	-0.134** (0.061)	0.0015 (0.0027)	0.0052 (0.0035)
Completed high school	0.305** (0.150)	0.0009 (0.0065)	-0.0064 (0.0081)
Some college	0.300** (0.151)	0.0012 (0.0066)	-0.0062 (0.0082)
Completed college	0.223 (0.152)	-0.0012 (0.0066)	-0.0070 (0.0079)
State fixed effects	yes	yes	yes
R-squared	0.46	0.34	0.27
Observations	358	358	358

Notes: "County contract share" is the share of "finish only" hog operations using a production contract in the county in which the operation is located. Significance level: * = 0.10, ** = 0.05, *** = 0.01.

fects farm productivity only through its effect on contract use. In other words, that the availability of contracting is not spuriously associated with other factors that independently determine farm productivity. The exclusion restriction could be violated if contractors tended to concentrate in counties with inherently more productive farms, so that contract availability was spuriously associated with farm productivity.[8] If differences in productivity across counties could not be con-

[8] The exclusion restriction implies that counties vary in the availability of contracting, but would provide similar environments in which to produce hogs (after controlling for observable characteristics). This might occur if contractors chose to locate in particular counties for reasons other than hog farm productivity. Of course, if contracts raise farm productivity, then once contractors have located in a particular

trolled for with the observable variables, then we would incorrectly attribute differences in productivity to contract use rather than to unobservable county-level factors.

One way to control for factors affecting farm productivity that might be correlated with contract availability is to control for the number of farms in a county. It is plausible that hog farms tend to concentrate in areas possessing characteristics that would enhance farm productivity, such as being close to cheap inputs (feed or labor), or being agriculturally, geologically, and climatically well-suited to manure disposal. If contractors locate in counties in which hog farms are concentrated, this could bias our estimates if the number of farms in a county is not controlled for. In fact, contract operations are significantly more likely to operate in counties with more hog producers (contract operations have an average of 68.9 hog farms in the counties in which they are located, versus an average of 42.5 hog farms in the counties in which independent operations are located). Second-stage IV-2SLS estimates are presented in column 1 of Table 4, where the number of finish hog farms in the county are included as controls in both the first and second stages. Results indicate that the number of hog farms is not significantly related to farm-level productivity, and the inclusion of this variable has little effect on the estimate of the effect of contract use on productivity.

Another approach to control for factors affecting farm productivity that might be correlated with contract availability is to increase the homogeneity of the sample by considering only those counties where some hog farms used contracts and some produced independently. That is, to discard those counties where no farms contracted and where all farms contracted. There are 302 operations in such counties. Second-stage estimates for this sub-sample are presented in column 2 of Table 4. The estimated effect of contract use on productivity is somewhat smaller for this sub-sample, but the effect remains statistically significant at the 99 percent level.

Finally, to increase the homogeneity of counties even further we consider only those counties where there were both contract and independent operations and where there were a substantial number of hog farms. Selecting counties that had at least 10 operations (choosing a minimum of 5 or 20 operations produced similar results) results in a sub-sample of 249 operations. Results are shown in column 3. Estimates of the effect of contract use on productivity fall between estimates from model (1) and (2), which provides further evidence for the robustness of the findings.

region and more farms in that region contract, average farm productivity in that region will be higher.

Scale and Alternative Measures of Productivity

Table 5 illustrates how the estimated relationship between contracting and productivity varies with farm size. The table compares the mean total factor productivity for independent and contract operations distinguished by their scale of production. On average, "small" (300–9,000 cwt. gain) and "medium" (9,000–18,000 cwt. gain) contract operations were statistically significantly more productive than their independent counterparts, while there was no statistically significant difference between "large" operations (18,000+ cwt. gain). The right-hand column in Table 5 presents the results of the two-stage least squares regression, which was separately estimated for each size category. The regressions, which control for state fixed effects and other operator and operation characteristics, indicate that contracting had a significant effect for operations in all three size categories. The magnitude of the effect did not vary substantially across scale categories.

Table 6 presents estimates of the model for all farms using alternative measures of factor productivity—all in terms of output (cwt. gain) per unit of input. We consider two measures of feed—value in dollars and hundredweight—and two measures of labor—value in dollars and hours. Both feed and labor are difficult inputs to measure using the survey instrument, as contract operations often are not aware of the composition or value of their feed, and own-labor is not priced in the market. When contract growers did not know the feed value, it was estimated by USDA's National Agricultural Statistics Service based on reported quantities. For labor, the price of hired labor is observed, and the value of own-labor was imputed using a regression that estimated the operator's opportunity cost based on operator and household characteristics. Both the quantity and value approaches have their merits: the quantities

Table 4. Second-Stage IV-2SLS Estimates of Contract Use and Productivity

	All Counties (1)	Counties Where 0 < Contract Share < 1 (2)	Counties Where 0 < Contract Share < 1, and at Least 10 Hog Farms (3)
Intercept	-0.028	-0.032	-0.035
	(0.023)	(0.025)	(0.029)
Uses a production contract	0.032***	0.024***	0.028***
	(0.010)	(0.009)	(0.010)
log (hog output)	0.004**	0.0051**	0.0045*
	(0.0022)	(0.0022)	(0.0024)
log (total assets)	-0.0002	-0.0006	0.0000
	(0.0015)	(0.0016)	(0.0019)
Individual proprietorship	-0.0019	-0.0012	-0.0016
	(0.0028)	(0.0029)	(0.0033)
Operator age	0.0008	0.0007	0.0008
	(0.0007)	(0.0008)	(0.0009)
Operator age squared	-0.000007	-0.000005	-0.000006
	(0.000007)	(0.000007)	(0.000009)
Operator experience	-0.0001	-0.0002	-0.0002
	(0.0002)	(0.0002)	(0.0002)
Farming primary occupation	0.0055	0.0051	0.0059
	(0.0035)	(0.0036)	(0.0042)
Completed high school	-0.0060	-0.0016	-0.0031
	(0.0080)	(0.0080)	(0.0099)
Some college	-0.0058	-0.0012	-0.0020
	(0.0081)	(0.0081)	(0.0099)
Completed college	-0.0065	-0.0026	-0.0036
	(0.0078)	(0.0078)	(0.0098)
Number of hog farms	0.000015	0.000016	0.000015
	(0.000021)	(0.000022)	(0.000025)
State fixed effects	yes	yes	yes
R-squared	0.28	0.29	0.27
Observations	358	302	249

Note: "Number of hog farms" is the number of "finish only" hog operations in the county in which the operation is located, from the 2002 Census of Agriculture. Significance level: * = 0.10, ** = 0.05, *** = 0.01.

may be more accurately measured than the values, but the values control for the quality of the input. A drawback with the value measure is that it incorporates regional price variation that may not reflect quality.

The table shows that, on average, contract operations have statistically significantly greater factor productivity than independent operations for most inputs. However, the two-stage least squares regression results indicate a strong association only between contracting and feed productivity—with a weakly significant association with capital productivity. Feed costs represent an average of 66 percent of the total costs of production (compared with 10, 15, and 9 percent for labor, capital, and other inputs, respectively). Greater feed productivity could reflect a number of technological advantages—including improved feed or feeding techniques, or better genetic stock.

Table 5. Total Factor Productivity by Farm Size Category

Farm Size Category	Mean Independent [N]	Mean Contract [N]	t-stat	Estimated 2SLS Coefficient (std. err.)
Small (3,000 ≤ cwt. gain < 9,000)	0.0281	0.0368	-3.51***	0.032*
	[43]	[71]		(0.018)
Medium (9,000 ≤ cwt. gain < 18,000)	0.0333	0.0407	-2.06**	0.037**
	[36]	[75]		(0.015)
Large (18,000 ≤ cwt. gain)	0.0381	0.0434	-1.46	0.034**
	[19]	[114]		(0.015)

Note: The t-statistics is for the test of the null hypothesis of equal means from a pooled sample. Significance level: * = 0.10, ** = 0.05, *** = 0.01.

Table 6. Total and Partial Factor Productivity

Productivity Measure	Mean Independent	Mean Contract	t-stat	2SLS Coefficient (std. err.)
TFP (cwt. hog gain/$ total inputs)	0.032	0.041	-5.26***	0.033***
				0.011
Feed (cwt. hog gain/$ feed)	0.052	0.071	-3.51***	0.098***
				0.032
Feed2 (cwt. hog gain/cwt. feed)	0.567	0.831	-1.25	1.85**
				0.85
Labor (cwt. hog gain/$ labor)	0.381	0.654	-6.41***	0.329
				0.214
Labor2 (cwt. hog gain/hrs. labor)	6.61	11.26	-6.24***	5.75
				3.63
Capital (cwt. hog gain/$ capital)	0.247	0.303	-4.05***	0.168*
				0.095
Other (cwt. hog gain/$ other inputs)	0.542	0.563	-0.17	-0.071
				0.184
N	98	260		358

Note: The t-statistics are for the test of the null hypothesis of equal means from a pooled sample. Significance level: * = 0.10, ** = 0.05, *** = 0.01.

Conclusion

This study addresses a major methodological problem associated with estimating the effect of using a production contract on farm productivity: the potential sample selection bias resulting from the fact that the decision to contract is made simultaneously with other factors affecting productivity, and that many of these factors are unobservable. Using the availability of contracts at the county level as an instrument variable for the decision to contract, we find that using a production contract has a large effect on total factor productivity for feeder-to-finish hog farms. Contract use was a statistically and economically significant determinant of farm productivity in several different model specifications. Results suggest that contracts improve productivity primarily by raising the quantity of output produced per unit of feed. Contracts might allow farmers to attain greater feed productivity by improving access to better quality feed, by enhancing the flow of information about optimal feed rations or timing, or by providing growers with feeder pigs with improved genetic characteristics.

The last two decades have seen a substantial growth in the use of production contracts in the hog sector, and there has been rapid growth in total factor productivity. While increases in the scale of production and technical change have contributed to this productivity growth, the results of this analysis suggest that the increase in the use of contracts may have also played a role. The fact that contracts appear to continue to provide an advantage in terms of total factor productivity suggests that the trend towards greater contract use will continue.

The implications of this research are potentially important from a public policy perspective: policies that restrict contracting may impose costs in terms of lower farm productivity. However, this analysis did not consider non-market costs of production such as odor or water pollution, or negative producer welfare effects in terms of loss of grower autonomy. Hence, it is not possible to conclude from this study what the overall impact of policies to restrict contracting would be on producers or society.

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