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Contract and Exit Decisions in Finisher Hog Production

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Selected Paper prepared for presentation at the Agricultural & Applied Economics Association 2009 AAEA & ACCI Joint Annual Meeting, Milwaukee, WI, July 26-28, 2009.

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Abstract

Finisher hog production in North America has seen a shift toward larger production units and contract-organized production since circa 1990. Given the efficiency gains and conversion costs associated with contract production, growers may have to choose between long term commitment through investments and atrophy with intent to exit in the intermediate term. A model is developed to show that growers with any of three efficiency attributes (lower innate hazard of exit, variable costs, or fixed contract adoption costs) are not only more likely to contract but will also produce more and expend more on lowering business survival risks. Using the 2004 U.S. Agricultural Resource Management Survey for hogs, a recursive bivariate probit model is estimated in which exit is affected directly, and also indirectly through the contract decision. It is confirmed that contracting producers are less likely to exit. Greater specialization and regional effects are important in increasing the probability of contracting. More education, having non-farm income and older production facilities are significant in increasing the expected rate of exit. The findings suggest further exits by non-contract producers.

Keywords: agricultural industrialization, hog production, occupation choice, production contracts, recursive bivariate probit, relationship-specific investments, sector dynamics.

JEL classification: D23, Q12, J26, J43.

Introduction

Historically, farm exit has been a controversial policy matter arising from economic development in many countries. The general macro-level causes are clear enough and transcend commodities. Technical innovations have allowed substitution of physical assets for physical effort. There has also been increasing emphasis on human capital formation and growth in opportunities for more educated labor elsewhere in modern economies (Huffman and Evenson 2001; Gardner 2002; Federico 2005).

But the adjustments have been difficult, as they have often resulted in shattered hopes of continuity for family businesses, family ties, and community cohesion (Lobao and Meyer 2001). In part, agricultural commodity subsidies and other forms of protection from market forces can be seen as attempts to cope with or even avoid these adjustments. More direct structural policies have been used in the European Union, including farm retirement programs (Väre and Heshmati 2004). Other policies in the United States have had some influence on farm structure through subsidized loan opportunities, public R&D and education, although their effects are somewhat mixed for crop and livestock enterprises (Huffman and Evenson 2001).

Closer inspection of the farm exit decision reveals finer details. Kimhi and Lopez (1999) are among many that point to the importance of the typically joint decision on when to retire by the older generation and if to continue the business by the younger generation. Kimhi and Bollman (1999) for the Canadian Atlantic Provinces, Kimhi (2000) for Israel in the 1970s, Huffman and Evenson (2001) for the United States (for 1950-1982), and Breustedt and Glauben (2007) for early-member EU countries, identify part-time farming as a means of stabilizing a farm business and adjusting to economic change rather than preparation for eventual exit. Weiss (1999), with farm-level data for Austria during the 1980s, and Goetz and Debertin (2001), with county-level continental U.S. data over 1987-1997, find that the issue is not clear-cut.

Policy can affect the rate of exit. With reference to Finnish policies, Pietola, Väre, and

Lansink (2003) have confirmed that access to retirement benefits can be effective in promoting exit. Foltz (2004) shows that U.S. dairy price policies have reduced the rate of dairy farm exit in Connecticut over 1997-2001. Key and Roberts (2006) find that larger government payments, in the form of more base acres, have had a small but statistically significant effect in facilitating U.S. cash grain farm survival over 1982-1997. Subsidies and high prices have also slowed exit in Western European countries (Breustedt and Glauben 2007).

The survival struggle has been telling for U.S. hog producers in recent years. For most of the 20th Century, U.S. hog production had a stable structure that adapted incrementally. Production was small scale, especially in the Corn Belt where most hogs were grown. Typically, a hog enterprise complemented corn and soybean cropping in labor demand and on-farm feed use. Hogs were marketed at auction to the highest bidder where growers had no special relationship with any purchaser. Despite early warnings by some who surveyed the move toward tightly integrated poultry and egg sectors over 1930-1960, e.g., Thomas (1958), the system endured.

Since about 1990, however, the U.S. hog industry has seen major restructuring. The net rate of hog enterprise exits has outpaced those of grain farms and beef farms over the period 1992-97 (Hoppe and Korb 2006). According National Agricultural Statistics Service data (NASS 2008), the number of U.S. farms with hogs declined at an annual rate of 13.5% over 1992-97 and at an annual rate of 6.25% over 1997-2007. The declines were concentrated in farms with smaller inventory (< 2,000 head inventory), while the number of farms with larger inventory rose in the period 1992 and 2007. The percent of inventory held on farms with inventory size $\geq$2,000 has risen from 28.5% in 1992 to 81.5% in 2007.

While contract production has always had a place in agriculture, its significance in hog production has been growing in the United States and elsewhere (MacDonald and Korb 2006; Schultz, Spiller, and Theuvsen 2006; Boger 2001). Indeed full vertical integration similar to that in U.S. poultry production has been discerned by some (including Smithfield, the major packer)

as a very real possibility on the near horizon (Reimer 2006). The percent of hogs sold on the negotiated, or spot, market has declined from 62% in 1994 to 9.2% in 2008 (Grimes and Plain 2008).

In short, the U.S. hog industry has undergone a fundamental transformation between 1990 and 2007. Features of contracting that affect survival prospects include changes in risk exposures, business activities and investment requirements, as well as technology transfer. Not only do contracts secure markets for the contract duration, but they also often specify production practices and involve investments by both parties with low salvage value outside the relationship. While generating tension in the bargaining process, these relationship-specific investments can increase surplus through enhancing product revenue so that both parties can gain from the relationship. Formal analysis leans heavily toward efficiency motives for the shift toward hog contracting (Key and McBride 2003, 2007; Paul, Nehring, and Banker 2004; Paul *et al.* 2004), but has been less clear on what it is that enables contracts to be more efficient.[1]

Transactions costs and other possible efficiency motives for the adoption of contract governance forms have been overviewed in Hennessy and Lawrence (1999), Martinez (2002), and MacDonald *et al.* (2004). Coordination efficiencies concern product quality, search cost economies, and enhanced throughput in processing, among other items. Data are not generally available to identify what contributes to the efficiency gains. For this, there is a need for data from within the firm. Examples in other sectors where such data have proven useful include work on the organization of the trucking (Baker and Hubbard 2004) and valve-making sectors (Bartel, Ichniowski and Shaw 2004). In agriculture, farm-level survey data provide better opportunities to peer more closely at firm activities and motives for them.

[1] Other important dimensions to this fundamental transformation exist. For example, Roberts and Key (2005) argue that contract production threatens spot market production in another way. A decline of liquidity in spot markets may precipitate further exits from these markets as price discovery declines, growers face more risks and poorer quality market signals, and spot market support infrastructure decays.

Using 1998 and 2004 ARMS hog survey data, Key and McBride (2003, 2007) have concluded that unobservable variables drive both potential cost efficiency and the decision to contract. For given inputs and farm characteristics, they find that contracting can increase output productivity by about 20% (Key and McBride 2003). These efficiency gains include enhanced feed, labor and capital productivity. Contracting growers may also tend to be ones possessed of inherent characteristics associated with high productivity, so selection needs to be controlled for if the effects of contracting on cost efficiency are to be identified.

In this article we look at another part of the same story, namely contracts, exits and how they interact. We know that farm-level hog production occurs in an intensely competitive marketplace. The switch to contracting by any given grower generally provides substantial gains in unit production cost efficiency, but comes at an investment cost. If farm enterprises that choose not to contract are also, in general, innately less efficient then their prospects for persistence cannot be promising in a sector with a 6% annual rate of net exit. Are those choosing not to contract also reconciled to letting their business wither away toward low profitability and then termination?

Gillespie and Eidman (1998), Key (2005), and Davis and Gillespie (2007) suggest a less pessimistic possibility by estimating a positive non-pecuniary premium for autonomy. Independent production may preserve private utility that producers derive directly from having control over marketing and production decisions. An alternative explanation concerns the producers' "allocative ability", the ability to perceive changes in economic conditions and respond efficiently (Schultz 1975; Huffman 1977). Retaining independent production may offer better opportunities to exercise the skills associated with ability to allocate resources efficiently and respond efficiently to change in economic conditions. Independent producers also preserve bargaining strength that may become eroded as ties between contractor and contractee increase after signing a contract. Feeling that the era of non-contract production is passing, some may conclude that they would on-balance prefer autonomy even if it threatens survival. A better

understanding of determinants of exit requires information on what firms believe about their prospects and how they behave. If growers anticipate near-term exit then they may state this and they may reveal it in their contracting behavior.

This article provides three variants on a model of how exit expectations and contract decisions are made. These models explain how production scale and expenditures on protecting against business hazard risks can vary with the contract decision. They also explain how all these decisions enter the formation of expectations concerning the exit date. The models differ only in how innate farm cost efficiencies are represented. In one version, farms differ by their innate capacity to survive over time. In the other two, farms differ by unit cost efficiency and the fixed costs of switching to contract production. In all cases, it is shown that innately more productive farms tend to contract. These results provide theoretical underpinnings for the selection model approach taken and empirical results identified in Key and McBride (2003, 2007).

Our models suggest that contract production, high expectations that the enterprise will survive beyond any specified time horizon, and certain protective production decisions should be positively related to each other. As such our work can be placed in the larger literatures on industrialization and organizational economics. Hog contracts are, at least in some part, about extending downstream control over raw materials and recognizing the importance of process control. Packers seek to develop brand capital, invest in quality protecting assets, glean economies from efficient processing, and benefit when their raw materials are of good and consistent quality. There are technological complementarities in the manner of Milgrom and Roberts (1990). In short, access to downstream surplus has seeped upstream largely through contracts but only the more efficient growers have found it more profitable to sign on. The others do not see the benefits but face growing output price pressure, and so the profit wedge has widened between the more efficient and those at the margin.

We estimate a recursive bivariate probit model on 2004 ARMS hog survey data in order to

control for a variety of observed variables that could possibly explain the relations. Our results confirm that the decision to contract increases expected survival beyond any given time horizon. We also find that more education tends to reduce the extent of contracting while increasing the self-assessed probability of exit in ten years. Older production facilities have the same effects. More years in hog production is found to reduce the incentive to contract. Both producer age and participation in off-farm work increase the perceived probability of exit. When compared with the region dominated by North Carolina, other regions are less likely to contract and, by extension, more likely to exit. These results can all be rationalized by appealing to intuitive structure on grower cost attributes, skills and preferences. There follows a discussion of these results and what they convey about the forces forming the future structure of the hog sector. We conclude with suggestions on directions for further research.

Model

The intent of this section is to show how unobservable efficiency in hog management can induce a positive dependence between the contract decision and exit intentions. To demonstrate that the suggested relationship is robust, we will study three distinct ways for this capability effect to originate. Regardless of contracting choice, it can reduce the farm's failure risk, as represented by a hazard function. Also regardless of contracting choice, it can reduce the unit cost of production. It can also reduce the fixed cost of taking up the contract production business format.

At the present time, $t = 0$, a grower uncertain about enterprise survival makes three choices. One is whether to engage in contracting, and another is scale of production. The third choice involves a protective input that affects the survival rate. This input could maintain enterprise capacity to *a*) biosecure against a disease outbreak, *b*) manage odor or water emissions, or *c*) ensure financial liquidity. One view of this input is as an indicator choice variable for process control, including control of production processes, interactions with the natural environment, and

financial consequences.

For a non-contracting grower the one-time present value capital cost of producing q hogs per unit time is $C(q):\overline{\mathbb{R}}_+ \to \overline{\mathbb{R}}_+$, where $\overline{\mathbb{R}}_+$ is the set of closed positive reals. This cost function is held to be twice continuously differentiable, increasing and strictly convex. Absent the cost of a survival protection input, the net benefit per unit output per unit time is $\delta > 0$. Survival to time point $t \in \overline{\mathbb{R}}_+$ is given by

(1) $$S(t;z_1,x) = 1 - F(t;z_1,x),$$

where $F(t;z_1,x):\overline{\mathbb{R}}_+^3 \to \overline{\mathbb{R}}_+$ is the probability of failure to time t. Variable z_1 is an exogenous attribute concerning managerial ability that increases the business survival rate. Variable $x \in \overline{\mathbb{R}}_+$ represents expenditure per unit time on the protective input. More of it increases the survival rate, or $S_x(t;z_1,x) \geq 0$ where the subscript denotes differentiation. While the variable is continuous throughout our work, the analysis follows through when x is discrete so it might be viewed as an indicator to denote a discrete technology choice.

With $F_t(t;z_1,x) \equiv f(t;z_1,x)$ as the failure density function, the hazard rate is

(2) $$\lambda(t;z_1,x) = \frac{f(t;z_1,x)}{S(t;z_1,x)} = -\frac{d\,\mathrm{Ln}[S(t;z_1,x)]}{dt},$$

which is assumed to be constant with form

(3) $$\lambda(t;z_1,x) = h(y); \qquad y = \varphi z_1 + x;$$

where $\varphi > 0$ and $h_y(y) < 0$. An increase in either z_1 or x increases the survival probability for any given future time. In addition, it is assumed that $h_{yy}(y) > 0$ to reflect decreasing returns to the survival protection input. The linearity of aggregator y implies that input x is a perfect substitute for exogenous attribute z_1. For example, expenditures on reliable information, veterinary or other biosecurity inputs, or more regular manure lagoon patrols may substitute for unobservable

managerial ability. Integrate (2) to obtain a survival function of form $S(t;z_1,x)=e^{-h(y)t}$.

A second source of variation is attribute z_2, the negative of which enters as a variable cost in production under contract. This might regard input purchasing skills or feed conversion efficiency. It reduces unit cost in proportion to production, and so $z_2 q$ enters as a reduction in cost (or increase in benefit) per unit time in production. The third source of variation is a fixed cost associated with entering contract production. Fixed costs may be required to learn a new production paradigm, or to comply with animal welfare regulations needed to sell into markets the contractor has lined up.

Net benefit per unit time the firm survives is $(\delta - x + z_2)q$, where of course no optimal x will ever exceed $\delta + z_2$. With continuous time discount rate r, the non-contracting firm's expected present value is

$$
\begin{aligned}
&V^{nc}(z_1,z_2)=\max_{(x,q)}\int_{t=0}^{\infty}(\delta - x + z_2)qe^{-rt}e^{-h(y)t}dt - C(q) = \max_{(x,q)}\pi(\delta,x,q;z_1,z_2);\\
&\pi(\delta,x,q;z_1,z_2)=\Phi(\delta,x;z_1,z_2)q - C(q); \qquad \Phi(\delta,x;z_1,z_2)=\frac{\delta - x + z_2}{r + h(\varphi z_1 + x)};
\end{aligned}
\tag{4}
$$

with attribute-conditioned optimization vector $(x^{nc}(z_1,z_2), q^{nc}(z_1,z_2))$.

Turning to the contracting grower, (s)he accrues benefit per hog per unit time of θ, $\theta > 0$, in addition to δ. This may be due to sharing some of the surplus from improved contract inputs, better information flows to the contractor concerning the quality and consistency of hog genetics, better information on production practices, improved access to veterinary services, transactions cost efficiencies in procuring hogs, or technical efficiencies in scheduling hog slaughter (General Accounting Office 1999). Or it may be a premium offered to assist in inducing productive types to contract. But this gain comes at the expense of a one-time investment cost of z_3 per hog where this cost may be required to support transactions cost efficiencies and contract stipulated production practices.

So the contracting farm's value is given by

$$
\begin{aligned}
&V^c(z_1,z_2,z_3,\theta) = \max_{(x,q)} \int_{t=0}^{\infty} (\delta+\theta-x+z_2) q e^{-rt} e^{-h(y)t} dt - C(q) - z_3 \\
&= \max_{(x,q)} \pi(\delta+\theta,x,q;z_1,z_2,z_3); \\
&\pi(\delta+\theta,x,q;z_1,z_2,z_3) = \Phi(\delta+\theta,x,q;z_1,z_2)q - C(q) - z_3; \\
&\Phi(\delta+\theta,x,q;z_1,z_2) = \frac{\delta+\theta-x+z_2}{r+h(\varphi z_1+x)};
\end{aligned}
\tag{5}
$$

with attribute-conditioned optimization vector $(x^c(z_1,z_2,\theta), q^c(z_1,z_2,\theta))$. Heterogeneity source z_3 enters only through the decision to contract or not. The attributes follow the joint distribution $G(z_1,z_2,z_3): Z \to [0,1]$ where $Z = [0,\hat{z}_1]\times[0,\hat{z}_2]\times[0,\hat{z}_3]$ and, for convenience we assume the distribution has a density function. Notice that each z_i is assumed to have lower support value 0. This is at no loss of generality as an alternative lower support value can be subsumed into $h(\cdot)$ for z_1, or δ for z_2. In the case of z_3, the marginal density can be assumed to be zero over the relevant range.

The proof of Proposition 1 to follow demonstrates that contracting growers live in a set $U(z_1,z_2,z_3)$ that satisfies the following monotonicity condition, labeled M: $(z_1',z_2',z_3') \in U(z_1,z_2,z_3)$ implies $(z_1'',z_2'',z_3'') \in U(z_1,z_2,z_3)$ for all (z_1'',z_2'',z_3'') satisfying $z_1'' \geq z_1', z_2'' \geq z_2', z_3'' \leq z_3'$. Notice the reversal in direction for fixed contracting cost z_3. The following is demonstrated in supplemental materials available upon request.

Proposition 1. When compared with non-contracting growers, contracting growers *i*) live in a set satisfying the monotonicity condition M; *ii*) produce more; and *iii*) have a lower probability of quitting by any arbitrarily chosen time $T \in [0,\infty)$.

Since z_1, z_2, and z_3 may not be entirely observable, one interpretation of part *i*) is as a rationalization of the selection model approach taken in Key and McBride (2003) to control for productivity-related contract selection bias. A noteworthy feature of managerial heterogeneities

z_1 and z_2, but not z_3, is that they do not arise from the contract decision *per se*. Rather the higher return on contracting, or $\theta > 0$, means growers with higher z_1 or z_2 find contracting to be comparatively more remunerative. This is because, even when not under contract, these growers produce more when in production and/or have a lower business hazard risk. The act of contracting further increases their incentive to produce and also to protect their business. So the relatively prosperous are best positioned to gain from opportunities to contract. A further observation is in order, and is shown in supplementary materials:

Remark 1. For any given vector of grower attribute values (z_1, z_2, z_3), a contracting farm *i*) uses more of the protective input, or $x^c(z_1, z_2, \theta) \geq x^{nc}(z_1, z_2)$, *ii*) exhibits a lower hazard rate, or $h[y^c(z_1, z_2, \theta)] \leq h[y^{nc}(z_1, z_2)]$, and *iii*) produces more, or $q^c(z_1, z_2, \theta) \geq q^{nc}(z_1, z_2)$.

So the model suggests that contracting leads to larger scale and greater control over processes. These features of agricultural industrialization have been noted since at least Urban (1991) and Drabenstott (1994). Given the three ways in which we have allowed growers to differ, the theoretical impact of contracting on expected enterprise survival would appear to be robust.

Data and Empirical Framework

We apply our theoretical model to U.S. feeder pig-to-finish hog operations. We investigate the determinants of exit and contracting decisions in those operations with a focus on the impact of operation and operator's characteristics. Data used are from the USDA's 2004 ARMS Phase III, Hogs Production Practices and Costs and Returns Report. Covering a cross-section of U.S. hog operations, the survey collects information on farm operators and farm financial characteristics as well as on production practices and facilities (Key and McBride 2007). Hog farms were chosen from a list of farm operations maintained by USDA's National Agricultural Statistics Services (NASS). Survey data had 1,198 responses from 19 states.

Phase III of the survey for hogs asked two questions the responses relevant to studying how contracting and exit intentions interact. One, question 3 in Section N, was 'Under what type of production arrangement was hogs produced on this operation in 2004?' where the respondent could choose among four types [production contract, independent, cooperative, more than one type]. We assigned 1 to the first response and 0 to the other three responses, giving our contracting data. The other, question 5 in that section, was 'How many more years do you expect this operation will be producing hogs?' This gives our survival indicator data.

As there are broad differences in production techniques among different types of hog operations, we limit our study to feeder pig-to-finish hog operations. Feeder pig-to-finish hog operations were defined to be those on which 75% of feeder pigs were obtained from outside the operation and then finished to a slaughter weight of 225-300 pounds; more than 75% of the value of hogs and pigs left through market hog sales or contract removals. This group of operations has experienced rapid growth, increasing from 19% of total hog operations in 1998 to 40% of total hog operations in 2004. In the meantime, the share of hogs produced under contract in this group of operations has increased from 22% in 1998 to 73% in 2004 (Key and McBride 2007).

We deleted all observations with missing values (12%), leaving a total of 420 observations. Variables used are presented in table 1; summary statistics of all variables are presented in table 2. Apart from providing labels and explanations, table 1 assigns types to variables as one among *Endogenous*, entering the *Exit* equation only, entering the *Contract* equation only, or entering *Both*. As sampling weights were used to account for the survey design, survey population means instead of sample means are reported in table 2.

Of the 420 hog operations in the data set, 275 (65%) were producing hogs under contract and 227 (54%) were expecting to exit within the next 10 years (i.e., $T = 10$). The dependent variables for the exit and contracting equations are respectively: $y_1 = 1$ if the hog operation was expecting to exit in the next 10 years and 0 otherwise, and $y_2 = 1$ if the hog operation was under production

contract and 0 if otherwise (i.e., hog production on the operation was independent). Without conditioning on relevant attributes, the mean of the exit indicator for contracting farms is 0.462 while it is 0.687 for independent producers. The raw responses suggest a strong interaction between the two.

Among independent variables, the size of the hog operations is categorized into four groups: Size 1 with less than 500 hogs through Size 4 with over 5,000 hogs. The dummy variable for each size group (*Size1*, *Size2*, *Size3*, and *Size4*) is equal to 1 if the operation has the corresponding number of hogs and 0 otherwise. And we divided the hog operation locations into five geographical regions: *East* (including North Carolina), *South*, *North*, *West*, and *Midwest* (including Iowa). Contracting was least common in the *West* and most common in the *East*. Dummy variables for these regions are set equal 1 if the operation is located in the corresponding region and 0 otherwise.

Another explanatory variable, *VPHog*, is used to indicate specialization and is defined as the proportion of value from hog production in a farm's total value of production. On average, contracted operations had larger values of this variable than did independent operations. The variable *Facilities Age* indicates the average age of the hog operation's facilities/buildings since last remodeled. And *Years* measures years of the operation in the business of producing hogs. *Off-farm* has value 1 if the operator and/or spouse worked off-farm for wages or a salary in 2004. *Education* and *Age* denote the education level and age of the hog farm operator, respectively. Operators who expected to exit in the next ten years tended to be more educated and older than those who did not.

To investigate the impacts of operator and operation's characteristics on exit expectations and the contracting decision, we set up a recursive bivariate probit model (Heckman 1978; Maddala 1983; Rhine, Greene and Toussaint-Comeau 2006), in which one of the binary dependent

variables (the contracting decision) is an endogeneous regressor in the other equation (exit equation). The bivariate recursive probit model for our analysis is set up as follows:

$$
(6)\quad
\begin{aligned}
&\text{Exit}: && y_1^* = \beta' X_1 + \gamma y_2 + \varepsilon_1, && y_1 = \begin{cases} 1 & \text{if } y_1^* > 0, \\ 0 & \text{otherwise;} \end{cases} \\
&\text{Contract}: && y_2^* = \alpha' X_2 + \varepsilon_2, && y_2 = \begin{cases} 1 & \text{if } y_2^* > 0, \\ 0 & \text{otherwise;} \end{cases}
\end{aligned}
$$

with estimates $\hat{\beta}$, $\hat{\gamma}$, and $\hat{\alpha}$. Here, y_1^* and y_2^* are the latent variables for exit intentions and the contract decision, respectively, while β' and α' are transpose vectors for regression parameters to be estimated. The recursive specification is in the manner of Greene (1998). Thus, contracting is held to affect exit expectations but exit expectations are not conditioned on contracting. We think this is reasonable as the contract decision is likely to be more discretionary than the exit decision, where the latter may be due to on-going health status, or want of a successor.[2]

Data matrix X_1, the set of all exogenous variables on the right-hand side of the first equation, includes operator's age, off-farm work, operator's education level, facilities age, and hog operation's size (see table 1). Data matrix X_2, the set of all exogenous variables on the right-hand side of the second equation, includes years the hog operation has been in the business, operation's level of specialization in hog production, operation's location, operator's education level, facilities age, and operation's size.

The reasoning behind this type of variable assignment is that *Education*, *Facilities Age* and *Size* are likely to be important in both decisions. A production contract may be viewed as a substitute for certain types of education, while education also determines off-farm retirement preferences and off-farm employment options. Smaller operations with older fixed capital are generally unlikely to be attractive partners for integrators, and also face relatively larger

[2] A square model with y_1 also as an explanatory variable in the contract equation is not well-posed, and cannot be estimated (Maddala 1983).

investments in order to increase the probability of survival beyond any given threshold.

Years in the hog business has been included in the *Contract* equation as it is intended to capture inertia in organizational form. The specialization variable *VPHog* is placed in the *Contract* equation as it identifies a need for revenue stability, but we see no strong link with exit incentives. Given historical geographical patterns in contracting, geographic indicators are more appropriately placed in the *Contract* equation. Operator *Age* has been placed in the *Exit* equation as it is likely to have a direct influence on exit expectations through bringing the labor force retirement decision closer. Engaging in *Off-farm* work is also likely to have a direct influence on exit, because it provides direct evidence of outside employment options and higher returns from off-farm work. While size is endogenous in our theoretical model and, in reality, we have controlled for it as an exogenous variable. This is because including it in a joint estimation with the *Exit* and *Contract* equations is too ambitious to hope for meaningful results given the complexities of estimating the bivariate probit in itself.

As for the connections with the heterogeneity vector (z_1, z_2, z_3), the heterogeneous component of fixed costs of contracting, z_3, is likely to depend on geographic location, extent of specialization, and operator years in the hog business. These we have modeled as entering the *Contract* equation, and not entering the *Exit* equation. This fixed cost component, z_3, should also depend on facilities age in both equations. The heterogeneous component of unit production costs, $-z_2$, whether in a contract or not, depends on the extent of specialization. The specialization variable, *VPHog*, is included in the *Contract* equation only. The unit production costs might also depend on facilities age and on education, and both of these variables are included in both the *Contract* and *Exit* equations. Hazard rate heterogeneity z_1 should also depend on the facilities age and education variables.

The error terms ε_1 and ε_2 are assumed to be bivariate normal, located and scaled to satisfy

$$(7)\qquad \begin{aligned} &E[\varepsilon_1 \mid X_1, X_2] = E[\varepsilon_2 \mid X_1, X_2] = 0; \quad \mathrm{Var}[\varepsilon_1 \mid X_1, X_2] = \mathrm{Var}[\varepsilon_2 \mid X_1, X_2] = 1; \\ &\mathrm{Corr}[\varepsilon_1, \varepsilon_2 \mid X_1, X_2] = \rho. \end{aligned}$$

This specification is as in Greene (2003), and the model was estimated by maximum likelihood methods. The probability terms that enter the log-likelihood are

$$(8)\qquad \begin{aligned} &\Pr(y_1 = 1, y_2 = 1) = \Phi_2\left(\beta X_1 + \gamma, \alpha X_2, \rho\right), \\ &\Pr(y_1 = 1, y_2 = 0) = \Phi_2\left(\beta X_1, -\alpha X_2, -\rho\right), \\ &\Pr(y_1 = 0, y_2 = 1) = \Phi_2\left(-\beta X_1 - \gamma, \alpha X_2, -\rho\right), \\ &\Pr(y_1 = 0, y_2 = 0) = \Phi_2\left(-\beta X_1, -\alpha X_2, \rho\right), \end{aligned}$$

where $\Phi_2(\cdot)$ denotes the cumulative distribution function of the bivariate normal distribution.

Estimation

The estimation results are reported in table 3. To measure goodness of fit, we calculated McFadden's likelihood ratio index, $LRI = 1 - \frac{\mathrm{Ln}(L)}{\mathrm{Ln}(L_0)}$, where $\mathrm{Ln}(L)$ is the likelihood ratio of the unrestricted model and $\mathrm{Ln}(L_0)$ is that where all slopes in the model are restricted to have value zero. This index is bounded between zero and 1 and analogous to the R^2 in a conventional regression. The *LRI* for our model is 0.320. The model correctly predicts 294 of 420, or 70%, of expected exit status by year 10; and 330 of 420, or 78.6%, of contracting decisions.

As shown in table 3, all parameter estimates are significant except *Size2* in the contract equation. The coefficient on *Contract* in the *Exit* equation is -0.204 and is statistically significant ($\alpha = 0.01$). This result supports Proposition 1, part *iii*), that contract producers should express a lower probability of exit over any given time horizon. Noteworthy too are *a*) the positive relation between size and contract, *b*) the negative direct relation between size and exit expectations, and *c*) the negative indirect relation between size and exit expectations through the *Contract* indicator in the *Exit* equation. Point *a*) supports Proposition 1, part *ii*). Together, points *a*) through *c*) support part *iii*) as well because they confirm that size, longevity, and contracting come as a

mutually re-enforcing package.

The other terms generally support Proposition 1, part *i*). Consider *Facilities Age*. Both directly and indirectly, older facilities increase the exit probability. These facilities likely have higher unit costs, and so are likely not in the set of producer characteristics for which contracting is optimal. The *Education* variable is an exception in that it is not consistent with this reading of part *i*). To some extent, this is because Proposition 1 deals only with the supply side whereas education also has demand side effects. But also, the role of education is multifaceted and, with the available data, we measure only general education and not occupation-specific education. We defer further discussion on education until a later juncture.

The estimated value of correlation between the two structural disturbances, ρ, is 0.142 with a *t* statistic of 4.38 (table 3). Both the Wald statistic for the hypothesis $\rho = 0$ and likelihood ratio statistic for the same hypothesis (where the log likelihood with $\rho = 0$ is $\mathrm{Ln}(L_{\rho=0})$ and that with unrestricted ρ is $\mathrm{Ln}(L)$) also support the conclusion that the null hypothesis $\rho = 0$ should be rejected (table 3).

Average Marginal Effects

The absolute scale of the coefficients in a binary choice model gives a distorted picture of the response of the dependent variable to a change in one of the stimuli because the model is actually of a probability. Therefore, it is customary to estimate the marginal effects of the explanatory variables on the probability of observing a certain outcome. Understanding how hog producers respond to marginal changes of some features is important to an analysis of the recent structural changes in the hog industry. However, little is known about how marginal changes in particular hog producer and operation characteristics can alter hog producer's contracting decisions and exit expectations.

The calculation of marginal effects depends on whether the explanatory variable in question is binary or continuous. In addition, the explanatory variables that appear in the contract equation can have two effects on exit expectations. They can have a direct effect if they appear in the *Exit* equation. They can also have an indirect effect through changing the probability of contracting. The marginal effect of a change in a variable is the sum of these effects. Greene (1998) has shown how to calculate marginal effects in a recursive bivariate probit model for the special case in which $\rho = 0$ is assumed. In the recursive bivariate probit model with the presence of correlation, our case given the table 3 tests, the calculation of the marginal effects is more complicated. The method we propose to calculate marginal effects for the bivariate probit model with $\rho \neq 0$ improves and corrects that used in earlier studies (e.g., Christofides, Stengos and Swidinsky 1997; Christofides, Hardin and Swidinsky 2000). We have placed the more involved steps of our analytical derivations for marginal effects and their standard errors for a recursive bivariate probit model with the presence of correlation in supplementary materials for interested readers.

Consider first the exit variable y_1. Using (8), the conditional mean is;

$$\begin{aligned} E[y_1 \mid X_1, X_2] &= \Pr(y_2 = 1) E[y_1 \mid X_1, X_2, y_2 = 1] + \Pr(y_2 = 0) E[y_1 \mid X_1, X_2, y_2 = 0] \\ &= \Pr(y_1 = 1, y_2 = 1) + \Pr(y_1 = 1, y_2 = 0) = \Phi_2\left(\beta' X_1 + \gamma, \alpha' X_2; \rho\right) + \Phi_2\left(\beta' X_1, -\alpha' X_2; -\rho\right). \end{aligned} \tag{9}$$

As a variable in the exit equation may also appear in the contracting equation, the marginal effect of a change in a variable in the exit equation will be the sum of the direct effect (the effect of a change in that variable on the probability that $y_1 = 1$ given the value of y_2) and the indirect effect (the effect of the variable on the probability that $y_2 = 1$, which, in turn, affects the probability that $y_1 = 1$). Thus, for y_1, the marginal effect of a continuous explanatory variable, u, which might appear in X_1 and/or X_2, is

$$\frac{dE[y_1 \mid X_1, X_2]}{du} =$$

$$(10) \quad \underbrace{\left\{\phi\left(\beta' X_1 + \gamma\right)\Phi\left[\frac{\alpha' X_2 - \rho(\beta' X_1 + \gamma)}{\sqrt{1-\rho^2}}\right] + \phi\left(\beta' X_1\right)\Phi\left[\frac{\rho\beta' X_1 - \alpha' X_2}{\sqrt{1-\rho^2}}\right]\right\}\beta_u}_{\text{direct effect}}$$

$$+\underbrace{\left\{\phi\left(\alpha' X_2\right)\Phi\left[\frac{\beta' X_1 + \gamma - \rho\alpha' X_2}{\sqrt{1-\rho^2}}\right] - \phi\left(-\alpha' X_2\right)\Phi\left[\frac{\beta' X_1 - \rho\alpha' X_2}{\sqrt{1-\rho^2}}\right]\right\}\alpha_u}_{\text{indirect effect}}.$$

where the first part of the equation is the direct effect and the second part, the indirect effect. Here, $\phi(\cdot)$ is the standard normal density function with distribution $\Phi(\cdot)$ while β_u and α_u are the coefficients on variable u in the two equations. Depending on the variable in question, one of β_u or α_u may have value zero.

For a binary variable $m \in \{0,1\}$, which might appear in X_1 and/or X_2, the marginal effect is

$$E[y_1 \mid X_1, X_2, m=1] - E[y_1 \mid X_1, X_2, m=0] =$$

$$\underbrace{\left\{\begin{array}{l}\left[\Phi_2\left(\beta'_{\backslash m} X_{1\backslash m} + \beta_m + \gamma, \alpha'_{\backslash m} X_{2\backslash m} + \alpha_m, \rho\right) + \Phi_2\left(\beta'_{\backslash m} X_{1\backslash m} + \beta_m, -\alpha'_{\backslash m} X_{2\backslash m} - \alpha_m, -\rho\right)\right] \\ -\Phi_2\left(\beta'_{\backslash m} X_{1\backslash m} + \gamma, \alpha'_{\backslash m} X_{2\backslash m} + \alpha_m, \rho\right) - \Phi_2\left(\beta'_{\backslash m} X_{1\backslash m}, -\alpha'_{\backslash m} X_{2\backslash m} - \alpha_m, -\rho\right)\end{array}\right\}}_{\text{direct effect}}$$

$$(11) \quad +\underbrace{\left\{\begin{array}{l}\left[\Phi_2\left(\beta'_{\backslash m} X_{1\backslash m} + \gamma, \alpha'_{\backslash m} X_{2|m} + \alpha_m, \rho\right) + \Phi_2\left(\beta'_{\backslash m} X_{1\backslash m}, -\alpha'_{\backslash m} X_{2\backslash m} - \alpha_m, -\rho\right)\right] \\ -\Phi_2\left(\beta'_{\backslash m} X_{1\backslash m} + \gamma, \alpha'_{\backslash m} X_{2\backslash m}, \rho\right) - \Phi_2\left(\beta'_{\backslash m} X_{1\backslash m}, -\alpha'_{\backslash m} X_{2\backslash m}, -\rho\right)\end{array}\right\}}_{\text{indirect effect}}$$

$$= \Phi_2\left(\beta'_{\backslash m} X_{1\backslash m} + \beta_m + \gamma, \alpha'_{\backslash m} X_{2\backslash m} + \alpha_m, \rho\right) + \Phi_2\left(\beta'_{\backslash m} X_{1\backslash m} + \beta_m, -\alpha'_{\backslash m} X_{2\backslash m} - \alpha_m, -\rho\right)$$

$$-\Phi_2\left(\beta'_{\backslash m} X_{1\backslash m} + \gamma, \alpha'_{\backslash m} X_{2\backslash m}, \rho\right) - \Phi_2\left(\beta'_{\backslash m} X_{1\backslash m}, -\alpha'_{|m} X_{2\backslash m}, -\rho\right),$$

where $X_{i\backslash m}, i \in \{1,2\}$, is a variable vector obtained by removing binary variable m from X_i, while $\alpha_{\backslash m}$ and $\beta_{\backslash m}$ are the associated parameter vectors.

For the endogenous binary variable y_2, the expected marginal effect on exit is $\Gamma(y_1 \mid X_1, X_2)$ $= E[y_1 \mid X_1, X_2, y_2 = 1] - E[y_1 \mid X_1, X_2, y_2 = 0]$ where

(12) $$\Gamma(y_1 \mid X_1, X_2; \rho) = \frac{\Phi_2\left(\beta' X_1 + \gamma, \alpha' X_2; \rho\right)}{\Phi\left(\alpha' X_2\right)} - \frac{\Phi_2\left(\beta' X_1, -\alpha' X_2; -\rho\right)}{\Phi\left(-\alpha' X_2\right)}.$$

In all cases, standard errors are computed using the delta method described by Greene (1998). Write $\vartheta \in \mathbb{R}^S$ with representative entry ϑ_s as the parameter vector formed from joining the parameters in β, α, and γ. Let $\delta_k(\vartheta, \text{data})$ be the estimated marginal effect for the *k*th variable. An estimate of the asymptotic variance for the estimated marginal effect is

(13) $$\text{Asy.Var.}\left(\hat{\delta}_k\right) = \sum_{i=1}^{S} \sum_{j=1}^{S} \frac{\partial \delta_k(\hat{\beta}, \hat{\alpha}, \hat{\gamma}, \text{data})}{\partial \vartheta_i} \text{Asy.Cov.}\left(\vartheta_i, \vartheta_j\right) \frac{\partial \delta_k(\hat{\beta}, \hat{\alpha}, \hat{\gamma}, \text{data})}{\partial \vartheta_j},$$

where $\text{Asy.Cov.}(\hat{\vartheta}_i, \vartheta_j)$ is the estimated asymptotic covariance of the estimates in the recursive bivariate probit model. Interested readers are referred to supplemental materials for more details. Substituting into the above expression for $\text{Asy.Var.}(\hat{\delta}_k)$, we can calculate the asymptotic variance for the estimated marginal effect. The square root gives the estimated standard error for the estimator.

The *Contract* equation in (6) has conditional mean as $E[y_2 \mid X_1, X_2] = \Phi\left(\alpha' X_2\right)$ while the recursive structure ensures the marginal effect of some continuous variable u is simply

(14) $$\frac{dE[y_2 \mid X_1, X_2]}{du} = \phi\left(\alpha' X_2\right)\alpha_u,$$

and the marginal effect of some binary variable is

(15) $$E[y_2 \mid X_2, m = 1] - E[y_2 \mid X_2, m = 0] = \Phi\left(\alpha'_{\backslash m} X_{2\backslash m} + \alpha_m\right) - \Phi\left(\alpha'_{\backslash m} X_{2\backslash m}\right).$$

Standard errors for marginal effects are also calculated using the delta method, described above.

The estimation results for marginal effects are averaged across all observations. The averages, together with their standard errors, are reported in table 4 for the *Exit* equation and in table 5 for the *Contract* equation. The parameter estimate for the recursive bivariate probit model in table 3 identified the marginal impact of contracting on exit probability in 10 years as -0.204, while the

average marginal result of contracting on exit decision turns out to be positive. As we shall explain, this is because of the existence of positive correlation across unexplained variation in the two equations. Correlation coefficient ρ measures the correlation between the errors, where $\rho > 0$ suggests a positive correlation between the outcomes after the influence of the included factors has been accounted for (Greene 2003). The estimated marginal effect shows that the presence of contracting raises the probability of exit by about 0.02. Were $\rho = 0$ imposed then the presence of contracting would decrease the probability of exit by about 0.065.

The results also show that a one year increase in operator's age raises the probability of exit by 0.01. And off-farm work by the operator or spouse raises the probability of exit by 0.08, equivalent to an eight year age increase. Besides direct effects on the exit decision, operator's education level, facilities age, and the operation size also exert indirect effects through the contracting decision. For these variables, both the direct and indirect effects are consistent in sign and the direct effects account for most of the total effects.

When compared with *Size2* (500-1999 inventory), the two larger size categories each have about 0.27 greater self-assessed probability of being in business in ten years. Based on stated producer intentions, this result suggests that the hog industry will follow historical patterns of continued consolidation of hog production and having larger farms account for an increasing share of total output.

Both production scale and specialization have strong positive effects on the likelihood of contracting (table 5). *Size4* operations have a ten percent higher probability of being under contract when compared with *Size2* operations. And a one percent increase in the proportion of farm revenue that comes from hog production raises the probability of contracting by 0.36 percent. Having controlled for other factors, large, specialized farms are most likely to contract. Operations with older facilities are more likely to go out of the business in the next ten years. A one year increase in facilities age increases the probability of exit by 0.3 percent. Together with

scale and specialization effects, this suggests that many growers are legacy growers, rationalizing their production decisions on existing assets and disinclined to make further investments.

When compared with completing High School only, completing a Four Year Degree increases the probability of exit within ten years by 14 percent and decreases the probability of contracting by 3.6 percent. The effect of education on contracting and exit may be subtle. Production contracts involve a transfer of many management decisions off-farm, typically including the choice of genetic inputs, feed rations, and marketing. Although efficiencies may be gleaned from this transfer in control, growers who choose to contract may do so because rewards for specialization remain for their provision of other skills, including day-to-day animal husbandry. Production under contract may involve less demand for higher levels of general education, but perhaps higher demand for production skills that could be learned on the job (Lazear 2004). Huffman and Evenson (2001) find some evidence that the cumulative effect of public R&D and education led to a small reduction in specialization in the livestock sector (about 8%) during the 1950-1982 period. Also, Hennessy and Rehman (2007) find Higher Education reduces the probability of entering farming full-time.

Some general comments on the interactions between education and training, technology, and organizational structure are perhaps in order. De-skilling is the process in which skilled labor is replaced by a technological innovation. The idea has long been applied in the study of industrial labor with regard to rent transfer and redundancies. More recently, it has been applied to franchising, where concerns have been expressed that entry-level jobs neither require nor foster the development of high skill levels. Cappelli and Hamori (2008) used United States data to argue that the situation is more involved. While franchise routines may substitute for schooling, franchise labor is generally provided with more on-job training.

These perspectives are consistent with one interpretation of education input cost efficiencies from production contracts. Confined production and genetic uniformity as well as innovations in

record keeping and analysis are likely to be substitutes for general animal husbandry skills. Contracting is one, but not necessarily the only, way of unbundling production skills into a centralized set for which scale economies can be gleaned by multiplying over production units and another set that remains decentralized. Incentives for feed conversion efficiency and for pigs per litter can then be used to encourage development of these remaining decentralized skills. This would explain why more educated growers are less inclined to contract. On the demand side, operators with stronger general education are likely better positioned to find alternative employment. For them, jobs outside production agriculture are likely to be less physically demanding and may reward skills that no longer carry a premium within hog production. This would explain why educated growers are more likely to foresee exit, even having controlled for the contract decision.

Region dummy variables, years in the hog business, and degree of operation specialization had only indirect effects on the exit decision through the endogenous contracting variable. When comparing to hog farms in *East*, those in *South*, *North*, *West*, and *Midwest* were self-identified as more likely to go out of business in the next ten years. Relative to *East*, being in *Midwest* or *North* increased the self-assessed exit probability by just short of two percent, while being in *South* or *West* increased it by about three percent. The effect on the probability of contracting was much larger, but (by construction) the pattern was the same. *Midwest* and *North* had contract probabilities about 27 percent lower than *East* whereas *South* and *West* had probabilities about 50 percent lower. The forecasted geographical shift in hog production is consistent with that observed between 1992 and 2004 (Key and McBride 2007).

Contract and Exit

Some comments are in order concerning (12) above, together with the table 3 estimate of the Contract effect in the Exit equation (-0.204 and statistically significant) and the table 4 estimated

total marginal effect of contract in the Exit equation (+0.021 and statistically significant). There may appear to be a contradiction in these estimates. There is not.

To confirm why, notice that table 3 also provides the estimate $\hat{\rho} = \text{Corr}[\varepsilon_1, \varepsilon_2 \mid X_1, X_2] = 0.142$, which is also significant. Slepian's inequality (Tong 1980) for two random variables states that for (η_1, η_2) a pair of bivariate normally distributed random variables with correlation ρ then $d\Pr[\eta_1 \le a_1, \eta_2 \le a_2; \rho]/d\rho \ge 0$ for any couple (a_1, a_2). Since the denominators in (12) are marginal distributions and are unaffected by a change in ρ, we need only consider the effect of a change in ρ on the numerators. The inequality clearly implies that $d\Phi_2(\beta' X_1 + \gamma, \alpha' X_2; \rho)/d\rho \ge 0$. In addition, $d\Phi_2(\beta X_1, -\alpha' X_2; -\rho)/d\rho \le 0$ so that $d\Gamma(y_1 \mid X_1, X_2; \rho)/d\rho \ge 0$ and the expected marginal effect is increasing in the correlation between error terms. Of course when $\rho = 0$ then

$$\text{(16)} \qquad \Gamma(y_1 \mid X_1, X_2; 0) = \Phi\left(\beta' X_1 + \gamma\right) - \Phi\left(\beta' X_1\right) \begin{cases} \ge 0 & \text{if } \gamma \ge 0; \\ < 0 & \text{if } \gamma < 0. \end{cases}$$

Together, the above imply three scenarios

Proposition 2. When *i*) $\gamma < 0$ and $\rho \le 0$, then $\Gamma(y_1 \mid X_1, X_2; \rho) \le 0$; *ii*) $\gamma \ge 0$ and $\rho \ge 0$, then $\Gamma(y_1 \mid X_1, X_2; \rho) \ge 0$; *iii*) $\gamma\rho < 0$ then no sign can be identified without further information.

Our case is *iii*), and so no sign on (12) can be identified. Available evidence identifies a negative effect of contracting on exit. But unexplained variations are positively correlated. What might be missing from the specification that could explain the positive correlation between ε_1 and ε_2 in (7)? A possibility is that those who take up contracting have a different set of values. Contract production stripped of diversity in tasks as well as much of the human interaction and management control associated with independent production may be viewed as less pleasant, and not what one would wish to do in one's old age. Or, although the growers see larger profits with contracting, those who contract may eye more favorably the prospect of retirement. Another

possibility is that many who have entered contracts have been forced to take stock of industry trends and have provided more realistic responses to the question on exit intentions.

Conclusions

Through a formal model we have argued that hog grower types who are disposed to entering a production contract should be less likely to exit production in the near horizon. This is likely to be true whether grower heterogeneities arise due to differences in fixed costs of contracting, differences in cost efficiencies that do not depend on the contracting decision, or differences in the hazard rate that do not depend on the contracting decision. A recursive bivariate probit model on USDA ARMS data confirms the negative impact that the act of contracting should have on probability of exit, even after controlling for scale of production.

One implication of our findings is that the share of independent production in total production has likely not stabilized in the United States. The remaining independent producers are likely to either enter contract production or exit in the longer run. Of course, the inference needs to be qualified because the hog production environment has changed dramatically in at least two ways since the 2004 survey was completed. One is feed costs. Another regards the regulatory environment, consumer preferences and how the two interact. As of 2008, substantially higher feed prices apply. In light of the large feed economies associated with contracting that were identified in work by Key and McBride (2003), tight margins due to higher feed prices are likely to pressure independent growers into either exiting the sector or entering contracts.

Growing demand for niche products, including organic foods, free-range animals and meat produced with low use of antibiotics, might provide some prospects in growth for independent producers, who are generally smaller producers (see table 2). But while the emphasis may differ in these production niches, future growth in these sectors of the market may well involve production contracts. This is because both consumers and retailers want assurances that the

production practices are as advertized. Downstream firms may impose practices and inspection regimes through production contracts.

Non-market pressures are also being directed towards large-scale, contract-based, integrated animal production. For example, the Pew Commission report (Pew Commission 2008) on Industrial Farm Animal Production has recommended that "If enforcing existing antitrust laws are not effective in restoring competition, further legislative remedies should be considered, such as more transparency in price reporting and limiting the ability of integrators to control the supply of animals for slaughter." Several states have legislation in place that limit the use of contract ownership. Although legislation emerging from social pressure will come too late to stem the shift to contract production, increasing regulation for environmental, animal welfare, food safety, zoonotic disease, and other concerns will involve more specialized human capital or regulatory costs. Increased control of production processes may be best dealt with in production contract format where compliance costs, perhaps including use of technology transfer specialists, could be spread out over higher volumes.

An important feature of hog production markets that has received inadequate attention is heterogeneity on the organization and scale of production enterprises across high income countries. The Danish hog sector has succeeded within a cooperative structure, but it is strongly vertically integrated (Hobbs 2001). Growth and exit patterns in the United States suggest that contract production is more cost efficient than independent production, and also may better provide the quality of hogs the mass retail trade demands. Work such as Key and McBride (2003) have identified where many of the cost efficiencies arise. Our work has clarified the origins of some labor cost efficiencies. But details on how organizational form affects other efficiencies at the production process level remain to be established.

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Table 1. Description of Variables

Variable	Type	Explanation
Exit	Endogenous	1 if answer to question "How many more years do you expect this operation will be producing hogs?" is 10 or less
Production Contract	Endogenous	1 if under production contract, 0 otherwise. Operations on which hogs were produced for a cooperative or for more than one type of production arrangement were excluded
Age	Exit	Years old
Off-farm	Exit	1 if operator and/or spouse worked off-farm for wages/salary in 2004, including any off-farm business proprietorship, 0 otherwise
Years	Contract	Years operation has been in the hog production business
VPHog	Contract	Value of hog production over total farm value of production
East	Contract	North Carolina, Virginia, Pennsylvania
South	Contract	Arkansas, Georgia, Kentucky, Missouri
North	Contract	Michigan, Minnesota, Wisconsin, South Dakota
West	Contract	Colorado, Kansas, Nebraska, Oklahoma
Midwest	Contract	Iowa, Illinois, Indiana, Ohio
Education	Both	1 if less than High School Diploma, 2 if High School Diploma only, 3 if Some College, 4 if completed Four Year Degree, 5 if Graduate School
Facilities Age	Both	Average age of hog operation's facilities/buildings since last remodeling
Size1	Both	Maximum hog inventory during 2004 was less than 500
Size2	Both	Maximum hog inventory during 2004 in range 500-1,999
Size3	Both	Maximum hog inventory during 2004 in range 2,000-4,999
Size4	Both	Maximum hog inventory during 2004 was 5,000 or more

Table 2. Descriptive Statistics for Feeder Pig-to-Finish Hog Operations, 2004[a]

Producer type	All (420 Obs.)	Independent (145 Obs.)	Contract (275 Obs.)	Exit (227 Obs.)	No Exit (193 Obs.)
Variable					
Exit	0.572	0.687	0.462	1	0
	(0.04)	(0.060)	(0.044)	(0)	(0)
Production Contract	0.510	0	1	0.412	0.641
	(0.043)	(0)	(0)	(0.056)	(0.054)
Age	50.4	51.3	49.6	52.8	47.1
	(0.659)	(1.010)	(0.790)	(0.781)	(0.909)
Off-farm	0.346	0.254	0.433	0.381	0.298
	(0.038)	(0.056)	(0.044)	(0.056)	(0.052)
Years	13.1	17.1	9.3	14.7	11.1
	(0.946)	(1.636)	(0.64)	(1.467)	(0.766)
VPHog	0.605	0.436	0.766	0.519	0.719
	(0.033)	(0.044)	(0.021)	(0.047)	(0.031)
East	0.117	0.008	0.221	0.078	0.169
	(0.016)	(0.004)	(0.029)	(0.015)	(0.030)
South	0.028	0.035	0.021	0.036	0.017
	(0.008)	(0.014)	(0.010)	(0.013)	(0.009)
North	0.232	0.249	0.215	0.219	0.250
	(0.042)	(0.074)	(0.042)	(0.062)	(0.054)
West	0.163	0.287	0.044	0.231	0.071
	(0.041)	(0.075)	(0.014)	(0.066)	(0.023)
Midwest	0.457	0.417	0.496	0.431	0.492
	(0.041)	(0.066)	(0.044)	(0.058)	(0.053)
Education	2.90	3.05	2.75	3.00	2.77
	(0.097)	(0.174)	(0.070)	(0.151)	(0.085)
Facilities Age	12.4	14.3	10.6	14.1	10.2
	(0.674)	(1.204)	(0.606)	(0.980)	(0.872)
Size1	0.261	0.414	0.114	0.400	0.075
	(0.050)	(0.080)	(0.039)	(0.060)	(0.044)
Size2	0.349	0.389	0.311	0.407	0.271
	(0.036)	(0.064)	(0.040)	(0.056)	(0.048)
Size3	0.262	0.153	0.367	0.140	0.426
	(0.030)	(0.036)	(0.041)	(0.027)	(0.051)
Size4	0.127	0.043	0.208	0.053	0.227
	(0.021)	(0.019)	(0.035)	(0.016)	(0.042)

[a] Standard errors are in parentheses.

Table 3. Maximum Likelihood Estimates of Parameters of Bivariate Recursive Probit Model

Parameter	Estimate	*t* Value	Approx Pr > |*t*|
Exit equation			
Intercept	-1.432	-16.03	<0.001
Contract[1]	-0.204	-4.21	<0.001
Age	0.034	26.78	<0.001
Off-farm	0.260	9.84	<0.001
Education	0.221	15.88	<0.001
Facilities age	0.009	6.09	<0.001
Size2	-0.597	-16.74	<0.001
Size3	-1.443	-33.35	<0.001
Size4	-1.579	-29.41	<0.001
Contract equation			
Intercept	1.205	14.75	<0.001
Years	-0.051	-36.16	<0.001
VPHog	1.514	29.10	<0.001
South	-1.937	-20.22	<0.001
North	-1.222	-20.11	<0.001
West	-2.326	-34.01	<0.001
Midwest	-1.119	-19.33	<0.001
Education	-0.075	-4.96	<0.001
Facilities age	-0.012	-7.61	<0.001
Size2	0.031	0.83	0.404
Size3	0.211	4.84	<0.0001
Size4	0.446	8.41	<0.001
ρ	0.142	4.38	<0.001
Ln(L)	-13814		
Ln($L_{\rho=0}$)	-13823		
Ln(L_0)	-20317		

H0: $\rho = 0$	Statistic value	95% Critical value
Wald Test	19.15	3.84
Likelihood Ratio	18.00	3.84

Table 4. Estimated Marginal Effects in Exit Equation

	Direct Effect	Indirect Effect	Total Effect	t-value
Contract	0.0215		0.0215	30.71
Age	0.0108		0.0108	21.60
Off-farm	0.0825		0.0825	9.71
Education	0.0694	0.0011	0.0705	15.67
Facilities age	0.0028	0.0002	0.0030	6.00
Size2	-0.1639	-0.0004	-0.1643	-20.28
Size3	-0.4320	-0.0031	-0.4351	-43.51
Size4	-0.4329	-0.0066	-0.4395	-30.95
Years		0.0008	0.0008	30.19
VPHog		-0.0232	-0.0232	-15.47
South		0.0295	0.0295	26.82
North		0.0187	0.0187	20.78
West		0.0354	0.0354	59.00
Midwest		0.0168	0.0168	18.67

Table 5. Estimated Marginal Effects in Contract Equation

	Total effect	t-value
Years	-0.012	-30.67
VPHog	0.359	35.75
South	-0.451	-75.21
North	-0.288	-103.05
West	-0.546	-64.67
Midwest	-0.258	-69.76
Education	-0.018	-4.76
Facilities age	-0.003	-7.39
Size2	0.007	61.22
Size3	0.050	57.79
Size4	0.104	46.24