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ORIGINAL PAPER

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Testing for the principal's monopsony power in agency contracts

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Abstract We develop a test for the presence of the monopsony power of the livestock integrator (principal) on the market for contract growers (agents) and estimate the model with the data on swine industry contract settlements. A natural test for the monopsony power of the principal would compare the estimated values of the marginal revenue products with the actual payments that agents receive for their services. The problem with implementing this approach comes from the fact that agents' abilities and actions are unobservable. Our approach is based on estimating the slope of the inverse supply function for grower input using generalized method of moments (GMM) estimators. The model specifies the relationships between the observable consequences and unobservable grower characteristics imposing the first order conditions for principal's profit maximization. The results show that the null hypothesis of no market power cannot be rejected.

Keywords Oligopsony · Principal–agent model · Production contracts

JEL Classification C33 · D43 · J41 · J43 · L13

1 Introduction

The estimation of market power has been and still is an important part of empirical industrial organization literature. Most of the attention has been directed toward the analysis of output markets (e.g. Appelbaum (1982), Bresnahan (1987)), but occasionally the specialized or localized nature of input markets warrants studying the monopsony/oligopsony issues as well (e.g. Murray (1995), Schroeter (1988)). In agriculture and food sectors, much of the empirical research in this area has tried to quantify the extent of packer/processor control in the livestock sectors, notably in the beef industry. Because of the high level of market concentration in this

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industry, there was concern that beef packing firms could be exercising market power in the purchase of finished cattle by keeping cattle prices below competitive levels. In addition to oligopsony issues, cattle producers have expressed concerns about packer-owned feedlots and captive supplies (Azzam and Anderson (1996)). The prevalent belief here is that, as captive supplies provide a substantial portion of packers' needs, the demand for cash market cattle declines and assuming that this decrease in demand is not accompanied by an adequate decrease in supply, the cash price will be negatively affected (Schroeder et al. (1993)).

In this paper the focus is on the pork industry. The issues of farm-level price formation in the swine sector are similar to the beef sector due to the declining importance of spot markets relative to the marketing contracts, company owned farms, and production contracts. Recent data indicates that only 13.5% of hogs sold during January 2003 were sold in negotiated cash markets, compared with 16.7% a year earlier, and 35.8% in 1999 (Grimes et al. (2003)). A significant and growing portion of the live hogs market is characterized by the production contracts between major hog companies (integrators) and independent growers. Hog production under contract in 2000 amounted to 42% of the total live production. The Southern Seaboard region, which includes North Carolina, the second largest hog production state in the U.S. after Iowa, is dominated by production contracts, with 87% of the total production volume being produced under contract (USDA–ERS (2001)). In addition to switching from cash markets to more advanced procurement arrangements for live hogs, over the past 20 years the pork industry has also witnessed a large increase in concentration. In 1980, top four firms controlled 33.6% of the slaughter and top eight firms 50.9%, whereas in 2000, leading four firms had 57.1% share of the packing and leading eight firms controlled 80.3% (USDA–GIPSA (2001)).

Given the current industry structure, the issue of whether integrators, when contracting for grower services, exhibit certain type of monopsony/oligopsony behavior becomes an interesting economic question that has not been studied in the literature so far. Basic economics texts usually describe monopsony as a situation where one firm has exclusive access to a labor market. Such situations are of course rare because competition thwarts monopsony driving the reservation wages of all potential employees up to the competitive wage. In the context of integrator-grower relations, there are at least three reasons that might explain the absence of perfectly competitive grower markets. First, different geographical areas are characterized by different levels of competition for growers. There are areas where companies have difficulties signing up enough growers but also areas where growers have no feasible opportunity to defect and seek a contract with another company. In areas with small number of integrators, a reasonably strong case can be made for the oligopsony type of behavior (Cournot and collusive models) on the market for grower services.

Second, contract specific investments that a grower has to undertake when signing the contract with the company may serve as a source of integrator's market power even in areas with multiple integrators offering contracts. Integrators between whom the potential grower is indifferent before signing the contract become "differentiated" once the contract is signed and a particular housing facility has been constructed and equipped according to integrator's specifications. The importance of this post-contractual differentiation depends on the length of the contract (either explicit or implicit). If the integrator can commit to compensation for the entire length of a grower's tenure (for the duration of the useful life of the facility), a competitive outcome will result. If the company cannot commit to compensation (which is almost always the case in the livestock contracts), the company enjoys monopsony power when contracts come up for renewal (see Black and Loewenstein (1991)).

Finally, production contracts in animal agriculture are plagued by moral hazard problems.[1] To cope with difficulties of ensuring grower effort, the larger an integrator becomes the more she must pay in efficiency wage premiums to elicit the adequate grower effort. The need for an increased compensation as an integrator signs up more growers means that integrators face an upward-sloping supply curve for grower services. In this case the monopsonistic behavior is produced by these rising monitoring (supervisory) costs. The result is that the wage must be below the marginal revenue product (MRP), where the difference goes to the increase in efficiency wages for inframarginal workers, and employment is reduced below the competitive (full information) level (see Rebitzer and Taylor (1995)).

The importance of explicitly addressing the bargaining power of the contracting parties in a vertically integrated industry conduct models was first noticed by Azzam (1998). The assumption in that paper was that the price paid to contract growers is equal to the marginal cost of producing the captive supplies. Implicit in this assumption was that contract growers receive a price equivalent to the internal price that would be assigned to captive supplies if these were produced by the integrator (processor). However, Azzam (1998) realizes that the validity of this assumption depends on the market power of the integrator on the market for contract growers suggesting the need for incorporating in the industry conduct models a benchmark not only for processor's oligopoly power but also for the integrator/contractee bargaining power.[2]

In this paper we develop a methodology for testing the monopsony power of the principal on the market for agents' services. All of the discussed models (oligopsony, asset specificity, and efficiency wage) that might explain the behavior of integrators on the market for contract growers share common features with the classical monopsony (isolated firm) model in that: (a) individual firm labor supply is upward-sloping, (b) the firm sets its wage below the MRP, and (c) the resulting employment is below the optimal level.[3] Therefore, the easiest and the most natural way to test the monopsony power of the integrator would be to use the classical monopsony model. The main problem with using this model, which would ideally involve comparing the estimated values of the MRP with the actual payments that growers receive, comes from the fact that growers' abilities and actions (effort) are unobservable. We propose a method of estimating the slope of the inverse supply function for grower input using generalized method of moments (GMM) estimators. The model specifies the relationships between the observable consequences and

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[1] The measurement of the cost of moral hazard in swine production contracts has been attempted by Dubois and Vukina (2004).

[2] Notice, however, that in reality the price received by a contract grower and the internal price of captive supplies are never going to be the same even in the perfectly competitive setting. This is because the payment per unit of output that growers receive (settlement price) does not reflect the entire marginal cost of producing that output but rather represents the compensation for only those inputs and services that growers provide.

[3] However, these models are quite different in many other respects. For a good review the monopsony in the labor market literature see Boal and Ransom (1997).

unobservable grower characteristics imposing the first order conditions for principal's profit maximization. We estimate the model using the panel data from Martin (1997). The data set contains a sample of contract settlements for individual growers who contracted the finishing stage of hog production with an integrator in North Carolina in the 1985–1993 period. The results show that the null hypothesis of no market power cannot be rejected.

The paper is organized as follows. In the next section we present the stylized facts about the industry, describe the data set, and discuss the main features of the contracts that were in effect during the period covered by the data. In Section 3 we present a simple theoretical model. In Section 4 we introduce the econometric model. In Section 5 we discuss the details of the estimation procedure and present the empirical results. The final section concludes.

2 Stylized facts and data

Swine production in the United States is characterized by three organizational structures: a) independent producers, b) vertically integrated firms with company owned production facilities, and c) vertically integrated firms with production contracts with independent farmers. Kliebenstein and Lawrence (1995) characterize the pork industry as an industry in transition. The transition of the industry from the beef to the broiler model of production is occurring at different rates in different regions of the country. Old production areas (Iowa) are dominated by independent producers and tend to function with spot markets or marketing contracts. Newer production areas (North Carolina) are dominated by the vertically integrated firms who either use contract production or grow their hogs on company owned farms. This dichotomy creates problems as spot markets are getting thinner and risk seems to be shifting from those with contracts to those without them. Spot market prices may be depressed because of higher transaction costs, product variability and poor quality regardless of whether market power is exercised or not (Paarlberg et al. (1999)).

Hog contract production is dominated by the large national companies which run their businesses through smaller divisions or profit centers.[4] Each divisions does its own contracting with independent growers. A production contract is an agreement between an integrator company and a farmer (grower) that binds the farmer to specific production practices. Different stages of production of animals are typically covered by different contracts and farmers generally specialize in the production of animals under one contract. The most frequently observed contracts in the swine industry are single production stage contracts such as farrowing contracts, nursery contracts and especially finishing contracts. Some integrators offer contracts that combine several production stages under one contract. These are known as farrow-to-finish contracts or wean-to-finish contracts. All production contracts have two main components: one is the division of responsibility for providing inputs, and the other is the method used to determine grower

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[4] Over the years the industry has experienced many mergers and acquisitions such that many firms which existed during the period covered by this data set are no longer here today. The largest swine producer in the U.S. today is Smithfield Foods. Other big players are, for example, Tyson Foods and Premium Standard Farms.

compensation. Growers provide land, housing facilities, utilities (electricity and water) and labor and are also responsible for manure management and disposal of dead animals. An integrator company provides animals, feed, medications and services of field men. Typically, companies also own and operate feed mills and processing plants and provide transportation of feed and live animals. The integrator company also decides on the volume of production both in terms of the rotations of batches on a given farm and the density of animals inside the house.

Virtually all swine production contracts are settled based on one or some combination of the three compensation schemes. The first is a base plus bonus payment per pound of gain (live weight) transferred, where a bonus payment reflects some efficiency measure such as feed conversion. The second compensation method is a base payment per live animal transferred with bonuses for efficiency. Bonuses for reduced death loss and uniformity are also common. A third compensation method involves paying the grower on a per pig space, per year basis (National Pork Producer Council (2000)). Most of the production contracts also have a minimum guaranteed payment clause and a disaster payment clause, neither one of which would apply if a grower were grossly negligent of his production responsibilities. The most widely used compensation schemes for finishing contracts are from the first two groups. In both cases, the payment takes the form of a variable piece rate where the variation in individual piece rates depends on how efficiently did the grower use the integrator-supplied inputs.

The data set used in this study is an unbalanced panel from Martin (1997). It contains a sample of contract settlement data for individual growers who contracted the finishing stage of hog production with an integrator in North Carolina. The data set spans the period between December 1985 and April 1993, for a total of 802 observations. Each observation represent one contract realization, i.e., the payment received and the grower performance associated with one batch of animals delivered to the integrator's processing plant. There are 122 growers in the data set and the number of observations per grower ranges from 2 to 37.[5] The data set appears to be randomly extracted from the population of all contract settlements that occurred in that time period with no detectable systematic biases.

The size of the grow-out operation (the number of finishing houses) varies across growers between one and five houses. All houses under contract have approximately the same capacity. The median density of a house is 1,226 hogs per house and the mean density is 1,234 hogs per house. The contract coverage varies across farms and time. Sometimes one contract will cover multiple houses on a given farm, other times each house will be covered by a separate contract. In cases when multiple houses are covered by one contract, the grower payment is calculated by treating all houses as one unit. The coverage of the contract is determined by the timing of the placement and genetic composition of feeder pigs. The animals covered by the same contract have to be placed on a given farm at the same time and have to have similar genetic characteristics.[6] The average length of the production cycle is approximately 19 weeks. Counting one additional week for

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[5] The reasons for unequal number of observations across growers in not known. We confidently rule out the possibility that the facilities of those growers with only few observations in the data set were predominantly idle during that period.

[6] As a consequence, we occasionally encounter more than one observation per grower i in period t.

the necessary cleanup gives a maximum of 2.6 batches of finished hogs per house per year.

The particular finishing contract that generated the data is fairly representative for the industry as a whole. The contract requires that growers furnish fully equipped housing facilities and that they follow the management and husbandry practices specified by the integrator. The contract guarantees the grower a minimum of seven batches of feeder pigs and is automatically renewed unless cancelled in writing. The integrator provides the grower with feeder pigs, feed, medication, veterinary services and services of the field personnel. The quality of all inputs as well as the time of placement of feeder pigs and shipment of grown animals are exclusively under control of the integrator.

Compensation to grower i for her husbandry and housing facilities rental is paid on a per pound of gain basis with bonuses earned on a per head basis. The bonus is based on the difference between the individual grower's feed conversion, expressed as pounds of feed divided by pounds of gain F_i/q_i, and a standard feed conversion ratio ϕ. If the grower's ratio is above the standard, she receives no bonus and simply earns the base piece rate α multiplied by the total pounds gained q_i. If the grower's ratio is below the standard ratio, the difference is multiplied by a constant β to determine the per head bonus rate. The total bonus payment is then determined by multiplying the bonus rate by the number of pigs marketed, where the marketed pigs $(1-m_i)H_i$ are those feeder pigs that survived the fattening process. Algebraically, the exact formula for the total compensation is:

$$R_i = \alpha q_i + \max\left[0, \beta\left(\phi - \frac{F_i}{q_i}\right)(1 - m_i)H_i\right] \tag{1}$$

with m_i measuring the grower-specific mortality rate.

Over the period of the data set, some parameters of the payment mechanism (1) varied. First, there is a variation in the base piece rate having to do with the type of feeder pigs. In the event that commingled feeder pigs were placed with a grower α=0.0315, whereas in the event that integrator own nursery feeder pigs were placed with a grower α=0.0275.[7] Second, as a result of technological progress in nutrition and housing design, over the period of the data set the feed conversion standard was lowered from ϕ=3.50 to ϕ=3.35. However, after the lower feed conversion standard was introduced, the higher standard of 3.50 remained in effect for commingled pigs. As a result, three essentially different contracts were in effect during that time period: Type I (α=0.0315, ϕ=3.50), Type II (α=0.0275, ϕ=3.50) and Type III (α=0.0275, ϕ=3.35). The data summary statistics by contract type are presented in Table 1.

In addition to individual grower contract settlement data, the proposed methodology requires the integrator-level price data for the inputs and the output. However, such data is not available. Instead we use the regional market prices for feed, feeder pigs and finished hogs, also obtained from Martin (1997). The feed prices are quarterly figures for the Appalachian region, the feeder pig prices are monthly observations for North Carolina and the market prices for finished hogs

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[7] Commingled pigs are feeder pigs bought at an auction or from an outside source. Other feeder pigs come from the breeding stock controlled by the integrator hence are deemed to be of superior quality.

Table 1 Data summary

Contract type		Feeder pigs placed H_i (Heads)	Weight gain q_i (LB)	Mortality m_i (%)	Feed consumption F_i (LB)	Feed conversion F_i/q_i	Grower payment Ri ($)	Payment per house R_i/h_i ($)
I	Mean	2,592	417,473	6.65	1,271,490	3.03	20,178	9,756
	St. dev.	1,560	240,726	2.68	746,283	0.15	11,458	1,363
	Max	6,164	972,149	14.72	3,045,556	3.48	48,093	13,121
	Min	1,118	176,786	2.53	523,100	2.66	7,150	5,642
II	Mean	2,131	387,790	3.41	1,061,163	2.74	20,729	12,018
	St. dev.	1,113	202,412	1.37	556,596	0.12	10,919	1,120
	Max	6,132	1,119,755	9.34	3,188,183	3.09	63,651	14,735
	Min	1,204	201,279	0.82	513,360	2.43	9,470	8,574
III	Mean	1,945	357,052	3.85	970,235	2.72	17,372	11,033
	St. dev.	973	180,135	1.92	493,503	0.12	8,792	1,107
	Max	6,158	1,111,864	15.86	3,193,400	3.21	48,738	14,540
	Min	1,163	185,289	0.73	519,170	2.39	7,447	6,183
Total	Mean	2,078	374,386	3.97	1,033,731	2.76	18,886	11,268
	St. dev.	1,112	196,016	2.05	553,386	0.15	10,023	1,327
	Max	6,164	1,119,755	15.86	3,193,400	3.48	63,651	14,735
	Min	1,118	176,786	0.73	513,360	2.39	7,150	5,642

are monthly prices received by North Carolina farmers for barrows and gilts.[8] Also, the data on grower non-specific integrator's cost such as overhead, transportation, research in know-how, marketing, etc., is not available and hence is ignored. Therefore the net price that the integrator actually received for the product is smaller than the one used in the analysis and hence the magnitude of the marginal revenue product of grower services is somewhat exaggerated.

3 A simple model

To illustrate the basic idea, consider a risk-neutral swine producer who contracts the production of live hogs with n risk-averse growers of different observable abilities.[9] We define abilities as inherent or acquired skills resulting from experience, education, age etc., as well as other grower specific characteristics

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[8] The procedure to convert the quarterly prices into monthly figures and the exact matching of the monthly prices to contract settlement dates is explained in detail in Martin (1997).

[9] For simplicity, we ignore the question whether the swine producer is an integrator or a fully vertically integrated company engaged in all stages of production and processing. Here we define an integrator as a firm that is engaged only in the production of finished hogs. The company buys feeder pigs and feed on an open market and sells live finished animals to the processing plant.

such as the size, location, and vintage of his barns and the age and quality of the installed equipment. The production technology can be described by the following relationship:

$$Q = Q(a_1, a_2, \ldots, a_n; x_1, x_2, \ldots, x_n; e_1, e_2, \ldots, e_n; Z; u_1, u_2, \ldots, u_n) \tag{2}$$

where a_i represents a vector of grower abilities, x_i is a vector of integrator-supplied production inputs (feed, animals, medication, etc.), e_i is a vector of grower-supplied production inputs (labor, electricity, water, etc.) usually called effort or action, Z is a vector of grower nonspecific inputs provided by the integrator (capital, management, overhead, etc.), u_i are i.i.d. production shocks with zero mean and finite variance σ^2, and $Q=\sum_i^n q_i(a_i, x_i, e_i, Z, u_i)$ is expressed in pounds of live weight gain.

Suppose further that all agents have the same utility function given by $U[R_i - C(e_i)]$, where R_i represents a payment to the agent and $C(e_i)$ is a strictly convex function of effort with $C'>0$, $C''>0$, and $C(0)=C'(0)=0$. We assume weak concavity of the utility function ($U'>0$, $U''\leq 0$) and set the reservation utility to zero. Both utility and costs are continuous and differentiable. The principal observes the outcome of the production process (output, feed utilization, etc.) but does not observe the level of effort exerted by the grower, hence there is a hidden action moral hazard problem. To attract prospective growers the integrator offers contracts based on the following compensation formula:

$$\widetilde{R}_i = \widetilde{\alpha}_i - \widetilde{\beta}_i[f_i(q_i, x_i) - \phi], \tag{3}$$

where $f_i(q_i, x_i)$ is some performance index, ϕ is a performance benchmark, and $\widetilde{\alpha}_i$ and $\widetilde{\beta}_i$ are contract parameters. A grower that accepts the contract maximizes his expected utility by choosing the vector of grower-supplied inputs (effort). The parameters of the affine payment function (3) are assumed fixed at the time the grower chooses his effort. Grower performance is assumed to stochastically depend on observable ability and unobservable effort such that $f_i(q_i, x_i) - \phi = a_i - e_i + u_i$. Under these circumstances, the agent problem is given by $\max\limits_{e_i} \int U[R_i - C(e_i)] f_u(u)du$ where f_u is the production shock density function. The sufficient first order condition for the agent's problem is given by $\int U'[R_i - C(e_i)]\left[\widetilde{\beta}_i - C'(e_i)\right] f_u(u)du = 0$ which implies the unique solution $\widetilde{\beta}_i = C'\left(e_i^*\right)$ or $e_i^* = C'^{-1}\left(\widetilde{\beta}_i\right)$, which indicates that all growers exert the same level of effort regardless of their ability as long as they operate under the same contract.[10]

In this framework, the integrator cost of producing live hogs will be determined by the abilities (skills) of the contract growers and by the level of other integrator-supplied production inputs. Since we postulate the integrators' monopsony power on the market for grower services, grower compensations are endogenously related to their abilities whereas other factor markets are assumed competitive. Therefore

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[10] This result holds for a wide class of payment mechanisms including simple piece-rates and piece-rate tournaments (for risk-neutral and -averse agents) as long as the stochastic production technology is additive (see Levy and Vukina (2004)). Of course, if ability affects the marginal cost of effort or the marginal return of effort, then agents of different ability would choose different levels of effort.

the integrator costs are defined as $C{=}\sum_i^n S_i(a_i)a_i{+}\sum_i^n w_x x_i{+}w_Z Z$, where $S_i(a_i)$ represents the inverse of grower *i's* ability supply function, and w_x and w_Z are other non-stochastic factor prices.[11] Assuming that the pork market is perfectly competitive, the integrator's expected profits are simply $\Pi = P\widetilde{Q} - C$, where P is the non-stochastic output price, and $\widetilde{Q}$ is the expected output obtained with all growers exerting the optimal level of effort as elicited by the payment scheme (3).

The integrator maximizes expected profits by selecting growers with certain abilities (characteristics) that will sign contracts and by choosing the level of other production inputs under her responsibility. The equilibrium level of ability is determined by the first order conditions for the expected profit maximum:

$$P\frac{\partial \widetilde{Q}}{\partial a_i} - \left(a_i\frac{\partial S_i}{\partial a_i} + S_i\right) = 0; \quad i = 1, 2, \ldots, n. \tag{4}$$

In equation (4), $P\frac{\partial \widetilde{Q}}{\partial a_i}$ is the marginal value product of ability and the expression in parentheses is marginal skills cost. Their intersection determines monopsony employment and monopsony wage. The monopsony and competitive outcomes are identical for this market if the supply function is perfectly elastic, i.e., $\frac{\partial S_i}{\partial a_i} = 0$, a situation described as zero monopsony power. The first order condition (4) can be rewritten as

$$\lambda_i \equiv \frac{\mathrm{MRP}_i - S_i}{S_i} = \eta_i^{-1} \tag{5}$$

where λ represents Pigou's measure of "exploitation", which is analogous to the Lerner index used to measure percentage departures from perfect competition in output markets (Boal and Ransom (1997)). Pigou's measure has the advantage of being computable from just the local elasticity of supply curve η, taking the value of zero in case the labor supply is perfectly elastic.

4 Econometric model

The problem with estimating Pigou's measure of exploitation comes from the fact that unlike an integrator who can observe grower characteristics (ability), an econometrician cannot. In our case the problem is exacerbated by the fact that we have no empirical data on grower supplied inputs, so effort variable is unobservable as well. The latter problem is solved by imposing a theoretical structure from which it follows that the equilibrium level of effort does not depend on individual grower characteristics, hence all growers exert the same level of effort regardless of their abilities. The link between the theoretical model and the data is established by realizing that the payment scheme in the theoretical model

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[11] Similar approach has been used by Scully (1974) to test for the monopsony power of major league baseball teams in the market for professional athletes.

(3) and the actual payment that generated the data (1) are the same as long as the contract parameters are defined such that

$$\begin{aligned}\widetilde{\alpha}_{it} = \alpha_{it}q_{it} = \alpha_{it}[\kappa_{it}(1-m_{it}) - \kappa_{0it}]H_{it} \\ \widetilde{\beta}_{it} = \beta(1-m_{it})H_{it}\end{aligned} \tag{6}$$

with the performance index being the feed conversion ratio $f_{it} = \frac{F_{it}}{q_{it}}$, κ_{it} being the weight of outgoing finished hogs, and κ_{0it} the weight of incoming feeder pigs.

Our approach is based on the generalized method of moments (GMM) by Hansen (1982). To derive moment conditions, we use the theoretical model developed earlier. To start, consider the integrator's expected profit maximization problem at time *t* that can be written as:

$$\begin{aligned}&\max_{H_{it},a_i} E(\Pi) \\ &= \sum_{i=1}^{n}\sum_{t=1}^{T} E\{P_t[q_{it}(H_{it},a_i)+\kappa_{0it}] - w_{Ht}H_{it} - w_{Ft}F_{it}(H_{it},a_i) - R_{it}(H_{it},a_i)\}\end{aligned} \tag{7}$$

where $P_t = p_t - w_{Zt}$ is the output price net of grower non-specific integrator's cost expressed on per pound of live pork basis, $q_{it}(\cdot) + \kappa_{0it} = \kappa_{it}$ is the total weight of finished hogs harvested from farm *i* at time *t*, w_{Ht} is the price of feeder pigs, w_{Ft} the price of feed at time *t*. Notice that live weight gain, feed utilization as well as mortality, which does not explicitly appear in the profit function but influences grower payment, are all functions of the number of feeder pigs that grower *i* receives and his ability.

Using the actual compensation formula from (1), for every $i = 1, 2, \ldots, n$, the first order necessary conditions for the expected profit maximization problem (7) equate the expected factor marginal value products with their expected marginal factor costs:[12]

$$E_{t-1}\left[(P_t-\alpha_{it})\frac{\partial q_{it}}{\partial a_i} - w_{Ft}\frac{\partial F_{it}}{\partial a_i} + \beta H_{it}\left(\phi - \frac{F_{it}}{q_{it}}\right)\frac{\partial m_i}{\partial a_i} + \beta H_{iT}(1-m_{it})\frac{\partial\left(F_{it}/q_{it}\right)}{\partial a_i}\right] = 0, \tag{8}$$

$$\begin{aligned}E_{t-1}\Bigg[(P_t-\alpha_{it})\frac{\partial q_{it}}{\partial H_{it}} - w_{Ft}\frac{\partial F_{it}}{\partial H_{it}} - w_{Ht} - \beta(1-m_{it})\left(\phi_{it} - \frac{F_{it}}{q_{it}}\right) \\ + \beta H_{it}\left(\phi_{it} - \frac{F_{it}}{q_{it}}\right)\frac{\partial m_{it}}{\partial H_{it}} + \beta H_{it}(1-m_{it})\frac{\partial\left(F_{it}/q_{it}\right)}{\partial H_{it}}\Bigg] = 0,\end{aligned} \tag{9}$$

or simply

$$E_{t-1}(\epsilon_{1it}) = 0, \quad E_{t-1}(\epsilon_{2it}) = 0, \tag{10}$$

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[12] We ignore the fact that the feed efficiency bonus is truncated at zero, which is rather harmless since all values of $\left(\phi - \frac{F_i}{q_i}\right)$ in the data set are strictly positive.

where ϵ_{1it} and ϵ_{2it} are the optimization errors, that is, the expressions inside the square brackets in equations (8) and (9), respectively. Then the first set of moment conditions follow from equation (10):

$$\sum_{t=1}^{T} E(\epsilon_{1it}) = 0, \quad \sum_{t=1}^{T} E(z_{it}\epsilon_{1it}) = 0, \quad \sum_{t=1}^{T} E(\epsilon_{2it}) = 0, \quad \sum_{t=1}^{T} E(z_{it}\epsilon_{2it}) = 0. \tag{11}$$

where z_{it} is an instrument that is uncorrelated with the optimization errors. The choice of such an instrument will be discussed shortly.

As seen from the payment scheme (1), the most critical variables influencing grower payments are weight gain q_{it}, feed conversion F_{it}/q_{it}, and mortality m_{it}. To construct the econometric model that will allow us to estimate the grower input (ability) supply function we exploit the fact that whatever the grower unobserved characteristics (ability) are, they impact all three performance variables in a particular way. This idea motivates modelling of the weight gain, feed conversion and mortality using the following system of equations:

$$\frac{q_{it}}{h_i} = \gamma_0 + \gamma_1 \frac{H_{it}}{h_i} + \gamma_2 a_i + \epsilon_{3it}, \tag{12}$$

$$\frac{F_{it}}{q_{it}} = \delta_0 + \delta_1 \frac{H_{it}}{h_i} + \delta_2 a_i + \epsilon_{4it}, \tag{13}$$

$$m_{it} = \mu_0 + \mu_1 \frac{H_{it}}{h_i} + \mu_2 a_i + \epsilon_{5it}, \tag{14}$$

where h_i measures the size of the grower facilities expressed as the number of finishing houses under contract.

There are three important econometric problems with estimating the parameters in equations (12), (13) and (14). First, the ability level a_i is not observed. Second, ϵ_{3it}, ϵ_{4it} and ϵ_{5it} can be correlated with H_{it} and a_i because H_{it} and a_i are simultaneously chosen by the integrator. Third, the correspondence between our theoretical model and the econometric model is not exact, leading to a possibility that the unobserved variable a_i may contain a time varying effort variable e_{it}. In our theoretical model grower effort impacted only one performance margin, i.e., the feed conversion ratio, so the mortality m_{it} and hence $\widetilde{\beta}_i$ were the same for all growers and consequently the equilibrium effort was constant across all growers. In our econometric model we allow the performance to vary across growers along all three margins (mortality m_{it}, weight gain q_{it}, and feed conversion $f_{it} = \frac{F_{it}}{q_{it}}$) and hence the constant effort result no longer strictly holds.[13]

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[13] We also allow the weight of the finished hogs (κ_{it}), and the number (H_{it}) and the weight of feeder pigs (κ_{0it}) to vary across growers and time, whereas in the theoretical model all those variables were constant across growers and time.

We circumvent the first two problems by imposing some identification conditions and using instrumental variables. Suppose that: (a) $E(a_i)=0$; (b) there is an instrument z_{it} such that $E(z_{it}a_i)\neq 0$; and (c) $E(z_{it}\epsilon_{1it})=E(z_{it}\epsilon_{2it})=\cdots=E(z_{it}\epsilon_{5it})=0$. Assumptions (a) and (b) are identification conditions. Because equations (12), (13) and (14) include constant terms, Assumption (a) is innocuous. Assumption (b) implies that γ_2, δ_2 and μ_2 are identified only up to scale, which effectively prevents us to obtain a unique estimate of the supply elasticity but is nevertheless sufficient for testing the null of no monopsony power as shown later.[14] Assumption (c) requires that the instrument be exogenous.

A good candidate for such an instrument is the contract type. This instrument is expected to be correlated with the ability level but should be uncorrelated with the optimization errors in equation (10) and the idiosyncratic shocks in equations (12)–(14). Recall that the data set contains three different payment schemes (contract types), determined by the quality of inputs supplied by the integrator to a grower's farm. In particular, for feeder pigs of inferior quality (commingled pigs) both the piece rate per pound of weight gain ($0.0315) and the feed conversion benchmark (3.50) are higher, i.e., more favorable to growers. For the superior quality input (integrator's own nursery feeder pigs), the piece rate is always lower ($0.0275) and the feed conversion benchmark is either lower (3.35) than for commingled pigs or the same (3.50).

Looking at those payment schemes it is impossible to uniquely order them in terms of their attractiveness to either high ability or low ability growers. For example, high ability growers may be attracted to contracts with high quality inputs even when the piece rate and the feed conversion benchmark are both lower because they know that they can perform really well with high quality inputs. It is also possible that high ability types may prefer low quality inputs because they know that they can salvage the low quality input and still make more money than in the other case if the differences in piece rate and feed conversion benchmark are sufficient large.[15] For this reason, in selecting the best instrument, we try all six possible rankings of contract types and we choose the ranking that produces the parameter estimates that are most consistent (in terms of their signs) with our theoretical model. Regardless of which ranking of contract types we choose, the instrument will be always uncorrelated with the optimization errors and idiosyncratic shocks because the type of contracts is chosen and remains fixed before the optimization errors and idiosyncratic shocks are realized.

Finally, in situations when the effort variable is not constant across growers, our a_i will be the sum of the ability variable and the time average of the effort variable, and the disturbance term will contain the effort variable's deviation from its time average. Because the systematic variation of the effort level is captured by its time

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[14] Notice that even if we can identify the parameters exactly, estimating the supply elasticity may require obtaining the forecasts of the latent ability variable a_i. Because the number of ability variables increases as the number of growers increases, any estimator of the ability variable will be inconsistent in short panel data like ours. This is a common problem in econometric models with fixed effects (see Wooldridge (2001) for example).

[15] Matching of variable quality inputs with growers of different abilities have been studied by Leegomonchai and Vukina (2005) in the context of dynamic (renewable) broiler production tournaments characterized by both moral hazard and adverse selection problems. They rule out the presence of the ratchet effect type of dynamic incentives that would be caused by matching of high ability types with low quality inputs due to the emergence of pooling equilibria where the growers mask their types to prevent being stuck with the low quality input in the next tournament.

average and the idiosyncratic variation of the effort level is probably uncorrelated to the predetermined contract type (i.e., chosen instrument), we expect that our GMM estimation procedure remains valid even if a_i contains the time varying effort variable. The interpretation of a_i in that case will be of course different.

Setting z_{it} to the particular ordering of contract types, we obtain the second set of moment conditions, that is for every t=1, 2, ..., T, we have:

$$E\left[q_{it}/h_i - \gamma_0 - \gamma_1 H_{it}/h_i\right] = 0, \tag{15}$$

$$E\left[z_{it}\left(q_{it}/h_i - \gamma_0 - \gamma_1 H_{it}/h_i\right) - \gamma_2\right] = 0, \tag{16}$$

$$E\left[\left(F_{it}/q_{it}\right) - \delta_0 - \delta_1 H_{it}/h_i\right] = 0, \tag{17}$$

$$E\left[z_{it}\left(\left(F_{it}/q_{it}\right) - \delta_0 - \delta_1 H_{it}/h_i\right) - \delta_2\right] = 0, \tag{18}$$

$$E[m_{it} - \mu_0 - \mu_1 H_{it}/h_i] = 0, \tag{19}$$

$$E[z_{it}(m_{it} - \mu_0 - \mu_1 H_{it}/h_i) - \mu_2] = 0. \tag{20}$$

Theoretically one can estimate $\theta_0=[\gamma_0\gamma_1\gamma_2\delta_0\delta_1\delta_2\mu_0\mu_1\mu_2]'$ from moment conditions (11) and (15)–(20).

As seen from equation (7) we assumed that the monopsonist integrator maximizes the expected profit on a per grower basis. Hence, the ability supply function facing the integrator will be the horizontal summation of the individual growers' ability supply functions. Since the grower compensation in the integrator's profit function is assumed to be determined by $R_{it}\equiv a_i S_{it}(a_i)$, the slope of the individual grower's ability supply function is given by

$$\frac{\partial^2 R_{it}(a_i)}{\partial a_i^2} = 2\frac{\partial S_{it}(a_i)}{\partial a_i} + a_i \frac{\partial^2 S_{it}}{\partial a_i^2}. \tag{21}$$

From the perspective of the integrator, what matters is the expected total supply curve, and we estimate that by taking the average over all growers in the data set. The test for the monopsony power is based on testing whether the supply curve faced by the integrator is horizontal, which is the case whenever

$$\frac{\partial^2 R_{it}}{\partial a_i^2} = 2\beta H_{it}\delta_2\mu_2 \tag{22}$$

is zero under the null of no monopsony power. Testing the null boils down to testing that $\delta_2\mu_2=0$. Although δ_2 and μ_2 are identified only up to scale, which is precisely the reason we cannot estimate the supply elasticity, this restriction is testable provided $E(z_{it}a_i)\neq 0$. If the null of $\delta_2\mu_2=0$ is rejected against the alternative of $\delta_2\mu_2>0$, the integrator faces an upward sloping supply function for grower input signaling the presence of the monopsony power in the market for grower services.

5 Estimation and results

Because the largest number of time series observations per grower is 37 and the number of growers is only 122, stacking the moment conditions for each time period produces too many moment conditions relative to the sample size, which can result in the poor performance of GMM estimators (see Tauchen (1986) and Altonji and Segal (1996) for example). To reduce the number of moment conditions, following Hayashi et al. (1996), we will work with the sum of moment conditions over time:[16]

$$\sum_{t=1}^{T} E\left[q_{it}/h_i - \gamma_0 - \gamma_1 H_{it}/h_i\right] = 0, \tag{23}$$

$$\sum_{t=1}^{T} E\left[z_{it}\left(q_{it}/h_i - \gamma_0 - \gamma_1 H_{it}/h_i\right) - \gamma_2\right] = 0, \tag{24}$$

$$\sum_{t=1}^{T} E\left[\left(F_{it}/q_{it}\right) - \delta_0 - \delta_1 H_{it}/h_i\right] = 0, \tag{25}$$

$$\sum_{t=1}^{T} E\left[z_{it}\left(\left(F_{it}/q_{it}\right) - \delta_0 - \delta_1 H_{it}/h_i\right) - \delta_2\right] = 0, \tag{26}$$

$$\sum_{t=1}^{T} E[m_{it} - \mu_0 - \mu_1 H_{it}/h_i] = 0, \tag{27}$$

$$\sum_{t=1}^{T} E[z_{it}(m_{it} - \mu_0 - \mu_1 H_{it}/h_i) - \mu_2] = 0. \tag{28}$$

Using the optimal weighting matrix, the GMM estimation procedure allows contemporaneous correlations among the disturbance terms and optimally combines the moment conditions (11) derived from the first-order conditions and the moment conditions (23) – (28) derived from the technological relationships to estimate the parameters of interest. We tried different rankings of contracts as they would be perceived by high ability growers. The best results in terms of the theoretically anticipated signs of the parameters and the magnitude of the J test statistics of over-identifying restrictions were obtained by setting z_{it}=1 for the Type II contract, z_{it}=2 for the Type I contract, and z_{it}=3 for the Type III contract. This

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[16] Our dataset is unbalanced in that the number of time series observations per grower varies across growers. As long as the selection variable indicating whether or not data are available is strictly exogenous, the standard theory carries through; see Wooldridge (2001), pp. 552–556. For further discussion on the time aggregation of moment conditions see Hayashi et al. (1996), pp. 270–271.

means that from the perspective of high ability growers, the least attractive contract is Type II and the most attractive contract is Type III. This may sound counter-intuitive but it is not. A producer could find Type II contract less attractive then Type III contract despite the fact that Type II contract has the same base payment and higher feed conversion threshold than Type III. This is because Type II contract would require growing commingled pigs which are of inferior quality relative to integrator's own genetic stock, so the grower's overall performance may end-up being worse. In connection with the ranking of contracts we also imposed the restriction that $E(z_{it}a_i)=1$. This restriction does not affect the results for testing $\delta_2\mu_2=0$ provided that the contract type and the ability level are correlated. In addition, we imposed the constraint $\gamma_1=180$ because the average weight gain per animal q_{it}/H_{it} in the data set is 180. When it is not imposed, we experienced numerically unstable convergence that produced unreliable estimates with large values of the J test statistic.

The parameter estimates and test results resulting from the above choice of instruments are reported in the top panel of Table 2. As mentioned before, the magnitudes of individual coefficients are not meaningful as they are the results of imposing the identifying restriction $E(z_{it}a_i)=1$. However the signs and significance of the parameters are meaningful. Two out of three coefficients on grower ability have the expected signs. For example, the increase in grower input (i.e., higher ability) will increase the weight gain ($\gamma_2>0$) and decrease the feed conversion ratio ($\delta_2<0$). The sign of the ability coefficient in the mortality equation is counter-

Table 2 Parameter estimates and tests

Instrument 1: $z_{it}=1$ for Type II, $z_{it}=2$ for Type I, $z_{it}=3$ for Type III		
Observations=802	Estimate	*t*-statistics
γ_0	975	(1.604)
γ_2	1,270	(4.894)
δ_0	−4.920	(35.152)
δ_1	−0.002	(−12.941)
δ_2	−0.019	(−2.878)
μ_0	−3,566	(−2.762)
μ_1	3.500	(2.778)
μ_2	1.636	(0.043)
J test	5.469	
t test ($\delta_2\mu_2=0$)	−0.043	
Instrument 2: $z_{it}=1$ for Type I, $z_{it}=2$ for Type III, $z_{it}=3$ for Type II		
γ_0	1,942	(3.485)
γ_2	1,409	(4.754)
δ_0	−5.938	(115.955)
δ_1	−0.003	(−35.813)
δ_2	−0.020	(−3.137)
μ_0	6,118	(12.699)
μ_1	−5.887	(−13.390)
μ_2	1.001	(0.063)
J test	5.638	
t test ($\delta_2\mu_2=0$)	−0.065	

intuitive, however, μ_2 is not statistically significant. All coefficients associated with the density variable H_{it}/h_i are statistically significant but δ_1 has an unexpected (negative) sign, saying that the increase in placement density would decrease the feed conversion ratio. Even if the magnitudes of individual coefficients are not meaningful, their comparison make sense. Looking at the estimates of the ability coefficients one can see that the marginal ability effect is much larger in the weight gain equation than in the feed conversion equation meaning that the ability matters more for producing more weight gain than for reducing feed conversion ratio.

In the second to last row, we report Hansen's (1982) *J* test statistic of over-identifying restrictions, which is asymptotically distributed as a χ^2 random variable with degrees of freedom two. The *J* test fails to reject the moment conditions (11) and (23) – (28) at the 5% significance level. These results suggest that the model is a reasonable description of the data. Finally, the last row shows the *t* test statistic for testing $\delta_2\mu_2=0$. The *t* test statistic was computed by using the delta method. The *t* test fails to reject the null of no monopsony power.

To check whether the derived conclusions are robust with respect to the choice of instruments, in the bottom panel of Table 2 we present the results of an alternative specification of instruments based on some a priori meaningful ranking of contracts. Here we set $z_{it}=1$ for the Type I contract, $z_{it}=2$ for the Type III contract, and $z_{it}=3$ for the Type II contract.[17] This ranking is based on the average grower payment per house reported in the far right column of Table 1. The average grower payment per house should be highly correlated with the rate of return on the invested capital and therefore should reflect the attractiveness of various contract types. However, the problem is that the ordering of contracts from the perspective of an average grower may not correspond to the ordering of contracts from the perspective of the high ability growers. Since the true grower ability is unobservable, the true ordering cannot be independently verified. As seen by the presented results, the parameter estimates show a couple of signs reversals but, same as before, the *t* test statistic fails to reject the null of no monopsony power.

6 Conclusions

The main problem with econometric estimation of the degree of market power of a principal on the market for agents' services in the livestock sector comes from the fact that most potentially obtainable data sets on contract settlements would contain only information about integrators' actions, whereas the data on growers' characteristics and grower supplied inputs are almost never available. To solve this problem we proposed an econometric model where we treated grower ability and effort as an unobservable joint production input. In exchange for supplying that input contract growers receive compensation that varies depending on how efficiently they used the integrator supplied inputs. Integrators design the compensation mechanisms with an objective to attract the pool of growers with abilities that match their needs. To make the problem tractable we assumed that the integrator can observe the grower types, and that all growers, regardless of their abilities (type), exert the same level of effort. Within this framework, we were able

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[17] All other specifications produced worse results either in terms of higher *J* statistics, or wrong signs of the estimated coefficients, or both.

to test the null hypothesis of no monopsony power of the integrator on the market for contract growers.

Our econometric model specifies three performance indexes (live gain, feed conversion, and mortality) as being impacted by the unobservable grower characteristics. These three technological relationships are tied to the first order conditions for the integrator's profit maximization. The model is estimated with GMM using the data on individual contract settlements between individual contract growers and one swine integrator company in North Carolina. During the period covered by the data we found no statistically significant presence of the integrator's monopsony power on the market for contract grower services. The obtained result is somewhat surprising yet still reasonable. All what it says is that integrators can hire the entire pool of desired ability growers without paying increasingly higher compensations to higher ability growers.

Given the fact that the individual contract settlement data comes from only one company, the estimated supply elasticity is reflective of the supply function for grower services faced by this particular firm and may not be representative of the entire industry contracting practices. On the other hand, one can argue that within a geographic region where growers can freely move among integrators, in equilibrium all contracts have to be welfare equivalent, so this particular contract should be no better and no worse than any other contract attracting similar pools of growers. Therefore, we believe that the obtained results are fairly representative for North Carolina and almost surely not representative for the rest of the country. This is also true because the data set is 10 years old, during which period the industry underwent substantial organizational changes. However, most of those changes occurred in the industry's cradle, the Midwest, whereas in North Carolina the industry has always been organized via production contracts, and the contracts used then are very similar to the contract used today. Obtaining more and newer data on contract settlements would improve and extend the reliability of the estimates.

The most important drawback of this approach is the fact that we are not able to generate the forecasted values for the ability variable nor were we able to estimate the supply elasticity exactly. The practical consequence of this is the inability of the model to say anything beyond testing for the presence of the monopsony power. Concretely, had our results rejected the null of no monopsony power, in favor of accepting the alternative hypothesis, we would not be able to say anything about the sources of this market power. For example, as stated in the introduction, in the context of integrator-grower relations, the sources of monopsony power could either be a classical oligopoly, asset specificity, or supervisory costs. In this respect our model would be completely silent, as we would not be able to say which one of the competing theories is conformable with the observed data. Notice, however, that the problem is more difficult than it first appears. The reason is that all three competing theories, in addition to predicting an upward sloping supply function, predict underemployment and a wedge between the MRP and the wage rate. These problems present themselves as a promising area for future research.

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