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A Theory of Packer Self Production in the Swine Industry

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Abstract

An analytical model is developed to explain the increasing tendency of pork packers to produce their own hogs. Upstream integration is motivated by recent events including increasing hog buyer consolidation and a need for traceability, but is held in check since it lowers upstream managerial incentives to make non-contractible investments.

A Theory of Packer Self Production in the Swine Industry

The increasing tendency for packers to self produce their own hogs, instead of procure them from independent producers, has become a highly contentious issue in the U.S. pork sector (Ray; Iowa State Daily). This form of upstream integration is a step beyond arrangements in which a packer or integrator merely owns hogs and contracts their husbandry out to small independent producers. Over the past decade, two large entrants to the pork-packing business have elected to raise their own hogs instead of contract with independent producers (AMI). The industry's most prominent packer, Smithfield Foods Inc., identifies itself as "the largest hog producer and pork processor in the world," and currently owns 825,000 sows, more than 12 times the number it owned in 1994 (Freese). As of 1999 the 11 largest packers procured an average 18% of hogs from own production, a share that has since risen (Lawrence, Schroeder, and Hayenga, Table 1).

These changes – in conjunction with the fact that U.S. slaughter capacity is falling – have led some industry observers to question whether there is a future for small independent hog producers (Haggerty, Ray). Federal and state lawmakers are now considering a variety of policies to protect producers. A bill put before the 108th Congress would "make it unlawful for a packer to own, feed, or control livestock intended for slaughter" (1st session, S.27 and HR 719). Another proposal would require packers to procure at least 25% of hogs from spot markets (Carstensen). Several states already have anti-corporate farming laws that prohibit packer ownership of livestock. However, these laws are highly controversial, and are being severely tested. For example, in 1999 Iowa's ban prevented Smithfield from buying and raising its own hogs there, but a federal judge recently ruled that Iowa's policy is unconstitutional (Iowa State Daily).

To evaluate the likely impact of such policies and add precision to the debate over packer self production, this paper develops an analytical model of the industry's production and processing stages. The focus is on vertical integration (as opposed to the more general concept of vertical coordination) and centers on *packer* ownership and

husbandry of hogs, versus ownership and husbandry by independent upstream producers. The model is an adaptation of Grossman and Hart, who use the concepts of incomplete contracts and “relationship specific investments” (cost-saving and quality-enhancing investments that are more valuable in one business relationship than in alternatives) as determinants of optimal industry structure. The framework is adapted to the particular features of the swine industry using surveys, case studies, and statistics as a guide (e.g., Martinez; Lawrence and Grimes; Hennessy and Lawrence). While the focus is on pork, some of the insights carry over to related sectors such as beef.

The model’s starting point is the observation that while contracts can help coordinate the vertical stages of production, complete contracts that cover *all* contingencies are impossible to negotiate, write, interpret, and enforce. As a result, if a contractual relationship breaks down, ultimate control over the use and returns of an asset (e.g., hogs, equipment, buildings) lies with its *owner*. In such a setting, integration increases the acquiring firm’s incentive to make relationship-specific investments that maximize the returns from exchange.

While internalizing a transaction eliminates some problems associated with incomplete contracting, it also harms the incentives of the acquired firm’s manager. (In this paper the previously independent upstream producer becomes an upstream manager after integration.) Under integration, the upstream manager can be released, in which case he loses all contact with (and returns from) upstream assets. Since his investments then become worthless, his initial incentive to invest in human capital and effort is lower than under vertical separation. This works against the ability of integration to enhance efficiency in the vertical chain of production.

Using this approach, the paper makes a number of points about when and why we can expect to see packer self production of hogs. One finding is that even in an environment marked by incomplete contracts, opportunism, and an increasing need for packer-producer coordination, integration is not inevitable: it is often better for the

producer to be left as an independent entity. This is true even if the packer has such bargaining power that she can expropriate all *ex post* gains from trade with a producer.

While this bodes well for the future of small independent hog producers, other findings show that increased packer self-production may be the result of broad, unalterable trends affecting the pork sector as a whole. To the extent that evolving consumer preferences, new production technologies, and heightened concerns about food safety place increasing burden on packers, asymmetry in the relative importance of packer versus producer investments develops. As packer investments become more critical, the potential for opportunism on the part of the producer also increases unless the packer acquires the assets of the upstream producer.

Another explanation for the rise in upstream integration lies not in underinvestment on the part of packers, but on *producer* underinvestment arising from declining outside options for producers. Consider a scenario where the number of packers falls to just one within a well-defined hog-marketing region. Since the producer now has very limited outside options, and since there is always a chance that the relationship might fail, producer investment is lower than what maximizes the value of the relationship. The only way to increase investment levels, and thus the level of aggregate profits, is through upstream integration by the packer.

Another point is that heterogeneity in upstream producer management skill and size of operations is likely to lead to a *partially* integrated industry, all else the same. To the extent that relationship-specific investments of small or low-skill producers are unproductive relative to those of a packer, the former is likely to be bought out, while stronger producers retain their independence.

These cases are illustrated through numerical simulations of the conceptual model developed later in the paper. The following section very briefly examines alternative theories of vertical integration, and argues in favor of a property rights approach to examining structural change in the swine industry. Subsequent sections develop the

specialized version of the Grossman-Hart framework, and use it to investigate recent and anticipated events in the evolving pork sector. The final section concludes.

Alternative explanations for integration (*greatly shortened from full version of paper*)

The U.S. hog slaughter market has traditionally been extremely fragmented, with large numbers of producers selling to multiple downstream packers. In such an environment, spot markets are generally a very efficient means of transfer. To explain a move towards the other extreme, we must look to the literatures on vertical integration and the theory of the firm.

Coase was one of the first economists to study why some transactions between the vertical stages of production are coordinated within a firm, instead of through spot markets, contracts, or other means of transfer. His contributions form the basis of the extensive literature on transaction cost economics. Its central theme is that certain transactions between vertical stages are impossible to coordinate through spot markets and costly to coordinate through contracts, and are most efficiently coordinated *within* a firm. Transaction costs may be high since contracts can never adequately cover all possible states of the world, and thus are imperfect or “incomplete.” A contract between a downstream packer and upstream producer would ideally specify all factors affecting the type, quantity, quality, and price of hogs that are raised, including such issues as feed ratios, genetics, confinement conditions, and veterinary treatment. Yet the optimal specification of these factors may depend on many unforeseeable aspects, such as consumer demand for pork, changing feed and utilities costs, disease outbreaks, innovations in genetics, actions of competitors, new food safety regulations, and stricter environmental policies. Contracts are not comprehensive since it is difficult for people to *think* far into the future, it is difficult to *negotiate* about these plans, and finally, it is hard to *write* these plans so that a third party can interpret and enforce them in the event of a dispute (Hart).

Over time transaction cost theories have been enriched by concepts such as asset specificities, relationship-specific investments, and holdup, and these are important elements of the model in this paper. However, transaction cost models leave unanswered some important questions concerning the vertical boundaries of the firm. Why are the costs of an integrated firm less than those of vertically separated firms? What is the mechanism by which haggling and holdup are eliminated? Indeed, if it is so efficient to organize the vertical stages of production within a single firm, why does not the industry – indeed the entire economy – organize itself as a single huge firm with multiple upstream and downstream divisions? Questions such as this lead us to the property rights approach developed in the next section.

Property rights theory of the firm

Like transaction cost theories, Grossman and Hart's property rights framework begins with the idea that there are many aspects of performance over which a contract cannot satisfactorily negotiated, written, and enforced. These aspects may be observable by both parties, but not verifiable, such that a dispute could not be easily settled in court. For example, does the producer engage in timely and accurate record keeping? Is the ventilation system programmed to turn on at the right times, and if it fails, does the producer quickly get it repaired? Are the facilities properly cleaned and disinfected between animal changeovers? Does the packer follow through on producer efforts by garnering a reputation and tapping premium quality markets?

As a producer and packer coordinate their activities, investments become relationship-specific since an outside party may not be able to observe them or know how to capitalize on them. Yet relationship-specific investments (RSIs) give rise to quasi-rents (the difference between the investment's present use and its salvage value), and the risk that the other may try to expropriate this quasi-rent (i.e., "holdup" the other). To mitigate his exposure, a manager might substitute more general methods or make less effort. In other words, there is an incentive to underinvest in the relationship. Transaction cost

theories show that internalizing the transaction improves incentives for investments in human capital and effort.

Grossman and Hart point out that internalizing a transaction can create other types of costs. Vertical integration may not change governance, but it does change ownership, and the *residual rights of control*. This latter point matters because when contracts are incomplete, the holder of residual rights of control determines use of the asset.

Consider a packer and producer who are vertically separated, i.e., independently owned and managed. Their initial contract specifies how many hogs the producer supplies per day. If the derived demand for hogs suddenly increases (e.g., consumers lose confidence in a pork alternative such as beef, due to a disease outbreak in cattle), the packer must seek permission of the producer to increase output. Under imperfect contracting, the producer may threaten to make his operation and expertise unavailable for the uncontracted-for supply increase. To avoid such problems, the packer may integrate upstream. Then the producer is just a *manager* of the packer's upstream division, and at best can threaten to make his own labor unavailable. A problem for the packer, however, arises from the fact that there is always some chance the relationship breaks down. In this case, the packer keeps all upstream assets and the producer loses all investments. Assigning some probability to this possibility, the producer tends to underinvest in the relationship. Should producer investment be critical enough, the benefits of integration might be dominated.

Thus, there are harmful effects associated with the wrong allocation of residual rights. The choice of industry structure reflects a series of tradeoffs in which investment incentives are distributed according to their ability to maximize the value of exchange. The following section formalizes these ideas.

The model

The set-up draws from Hart's treatment, with alterations that reflect the pork sector and facilitate exposition. These include: more general treatment of *ex post* division of surplus,

specific functional forms,¹ consideration of investments that are not relationship-specific, and various restrictions on integration and investment productivity that are reflective of the industry. For example, while upstream integration is deemed possible, downstream integration by a producer is ruled out: individual hog producers are assumed too small to finance the purchase of a downstream packer's physical assets (the interest rate can be thought of as infinity in this case). The model as formulated here is also only relevant to investments in *human*, not *physical* capital, and considers only the incentives of the top managers of each firm.²

The analysis focuses on two of the industry's vertical stages: packers (processors), who buy live hogs from upstream producers (growers).³ We adopt the convention of calling upstream hog suppliers "producers" and refer to them with a " U ," which means "upstream." Downstream hog buyers are referred to as "packers," and sometimes identified with a " D ," which means "downstream." Producers are referred to with male pronouns, and packers are referred to with female pronouns. Downstream and upstream assets are denoted a_D and a_U , respectively. These are physical, non-human assets, including land, buildings, equipment, and other factors of production. Under *vertical separation* the packer owns a_D , and the producer owns a_U . Under upstream integration, the packer owns both a_D and a_U .

There are two stages: 1 and 2. In stage 1, the productive assets of producers and packers (a_D and a_U) are already in place. We consider a packer who is the only buyer of hogs in a region, and thus a virtual monopsony (similar to Azzam). There are many price-taking upstream producers who are willing to supply the packer with hogs. We focus on a representative producer who, in contracting with the packer, receives his reservation payoff at stage 1. The packer expropriates the rest of the surplus generated through stage 1 contracting.

The producer and packer have the opportunity to enhance the productivity of their trade through relationship-specific investments, which are also made in stage 1. The investment is anything that changes the productivity of the assets, and can be thought of as

investments in human capital and effort. For example, consider the possibility of an equipment failure that threatens the production of hogs with certain characteristics. The problem can be resolved if the producer makes a good deal of effort to resolve the problem, perhaps by anticipating and getting training for the problem beforehand, and by staying after normal working hours on the day the problem occurs. However, the producer's incentive to respond depends on whether the producer is an independent owner/operator, versus just an employee of the packer's upstream division. In the latter case, the producer lacks residual rights of control, and has less incentive to resolve the problem to the best of his ability.

As discussed earlier, there is ambiguity regarding the details and circumstances of the input to be created. This precludes the writing of a complete contract that covers all contingencies, and the price paid by the packer to the upstream producer is not determined until stage 2. Upon resolving this, there is bargaining over the *ex post* division of surplus from trade. Now the packer's stage 1 bargaining advantage has been eroded, since there are just *two* parties to divide up the surplus arising from trade under relationship-specific investments. In the words of Williamson (1985), a "fundamental transformation" occurs in going from the stage 1 single packer / many producer environment, to the stage 2 one packer / one producer environment. The outcome of negotiations is an efficient operating decision: the firms will come to an arrangement that maximizes the gains from trade. The model is set up so that whenever investments are relationship-specific, there are *ex post* gains from trade, and the two parties find it optimal to do so. At the same time, the possibility that trade can break down due to imperfection of contracts is a key factor for agents as they select levels of relationship-specific investments.

Let Π_D be the downstream packer's *ex post* payoff, and i_D be the value of the packer's relationship-specific investment (RSI). Productivity of that investment under trade (T) with the producer is $D_T > 0$. Let r be packer revenue in the absence of investment and trade (i.e., spot markets are used), and let *overall* packer revenue under trade be uppercase R_T , with the following form: $R_T(i_D) = r + 2D_T(i_D)^{1/2}$. Let p be the

stage 2 equilibrium cost of procuring the input. The packer's *ex post* payoff less investment under trade is then:

$$\Pi_D - i_D = R_T(i_D) - p - i_D = r + 2D_T(i_D)^{1/2} - p - i_D.$$

Let Π_U be the upstream producer's *ex post* payoff, and i_U be the value of the producer's RSI. In turn, $U_T > 0$ determines the productivity of that investment under trade. c is producer costs in the absence of any trade or investment, and C_T is overall upstream producer costs under trade with the packer: $C_T(i_U) = c - 2U_T(i_U)^{1/2}$. Then, the upstream *ex post* payoff less investment under trade is:

$$\Pi_U - i_U = p - C_T(i_U) - i_U = p - c + 2U_T(i_U)^{1/2} - i_U$$

To have a benchmark against which to compared the second best environment described in earlier sections, we calculate the unobtainable **first best** choice of investments. This involves jointly selecting i_U and i_D to maximize the stage 1 net present value of their trading relationship, which is:

$$R_T(i_D) - i_D - C_T(i_U) - i_U = [r + 2D_T(i_D)^{1/2}] - i_D - [c - 2U_T(i_U)^{1/2}] - i_U.$$

Denote (i_D^{FB}, i_U^{FB}) as the unique first-best solution to the problem. (*FB* stands for First Best.) The two first order conditions are:

$$D_T(i_D^{FB})^{-1/2} - 1 = 0 \quad U_T(i_U^{FB})^{-1/2} - 1 = 0$$

Rearrangement yields the first best choice of investments:

$$i_D^{FB} = (D_T)^2 \quad i_U^{FB} = (U_T)^2$$

Total surplus from the relationship under this efficient outcome is:

$$S^{FB} = R_T(i_D^{FB}) - i_D^{FB} - C_T(i_U^{FB}) - i_U^{FB} = r - c + (D_T)^2 + (U_T)^2.$$

In the **second best** environment described earlier, contracts between packer and producer are incomplete, and stage 1 investments are chosen non-cooperatively. The stage 2 equilibrium price (p) is some deviation from a non-specific “generic” input price (\bar{p}) as given by the spot market. The *ex post* gains from trade are the difference between revenues and costs under trade ($R_T - C_T$), less the difference between revenues and costs when the relationship breaks down and there is no trade ($R_{NT} - C_{NT}$):

$$(R_T - C_T) - (R_{NT} - C_{NT}).$$

This equals the available quasi-rents (the value of assets under RSIs and trade, less the asset's next best alternative use). Let θ represent the downstream packer share of *ex post* gains from trade that result from the bargaining process. Upstream share is then $1-\theta$. (Under a Nash equilibrium $\theta = 1/2$.) The *ex post* payoffs can be calculated as:

$$\begin{aligned}\Pi_D &= R_T - p = [R_{NT} - \bar{p}] + \theta[(R_T - C_T) - (R_{NT} - C_{NT})] \\ \Pi_U &= p - C_T = [\bar{p} - C_{NT}] + (1-\theta)[(R_T - C_T) - (R_{NT} - C_{NT})].\end{aligned}$$

Either of these can be solved for equilibrium stage 2 price of the input (p):

$$p = \bar{p} + (1-\theta)(R_T - R_{NT}) + \theta(C_T - C_{NT})$$

To derive the second-best choice of investments, p is plugged into the downstream and upstream *ex post* payoffs less investment costs:

$$\Pi_D - i_D = -\bar{p} + \theta R_T(i_D) - \theta C_T(i_U) + (1-\theta)R_{NT}(i_D) + \theta C_{NT}(i_U) - i_D \quad (1)$$

$$\Pi_U - i_U = \bar{p} + (1-\theta)R_T(i_D) - (1-\theta)C_T(i_U) - (1-\theta)R_{NT}(i_D) - \theta C_{NT}(i_U) - i_U. \quad (2)$$

In the second-best scenario, the downstream manager independently chooses i_D to maximize (1), and the upstream manager chooses i_U to maximize (2). The associated second-best first order conditions are:

$$\theta R'_T(i_D^{SB}) + (1-\theta)R'_{NT}(i_D^{SB}) - 1 = 0 \quad - (1-\theta)C'_T(i_U^{SB}) - \theta C'_{NT}(i_U^{SB}) - 1 = 0, \quad (3)$$

where *SB* stands for second best. Total surplus from trade under second-best choice of investments is then: $S^{SB} = R_T(i_D^{SB}) - C_T(i_U^{SB}) - i_D^{SB} - i_U^{SB}$. A second best scenario will be calculated for vertical separation (*VS*) and another for upstream integration (*UI*). (Hereafter, *SB* will be dropped and replaced with the specific case under consideration, *VS* or *UI*, to simplify notation.) The outcome with highest total surplus is optimal to both the producer and packer.

Vertical Separation

Under vertical separation the producer owns and operates the upstream asset, while the packer owns and operates the downstream asset. To calculate aggregate surplus (S^{VS}), we must identify revenues and costs under a no-trade situation, since the agents put weight on this non-cooperative outcome in choosing stage 1 investments. Let D_{NT}^{VS} represent

downstream investment productivity under vertical separation and no trade. When investments are relationship-specific, this is less than productivity under trade between the two partners (i.e., $D_{NT}^{VS} < D_T$). Then, under vertical separation and no trade, downstream revenue is $R_{NT}^{VS} = r + 2D_{NT}^{VS}(i_D)^{1/2}$.

Let U_{NT}^{VS} denote upstream investment productivity under vertical separation and no trade. When investments are relationship-specific, this is less than U_T . As before, c denotes upstream costs without any investments or trade. Then, upstream producer costs under no trade are: $C_{NT}^{VS} = c - 2U_{NT}^{VS}(i_U)^{1/2}$. Based on (3) and our chosen functional forms, the optimal (second best) choice of investments under vertical separation are:

$$i_D^{VS} = [\theta D_T + (1-\theta)D_{NT}^{VS}]^2 \quad i_U^{VS} = [(1-\theta)U_T + \theta U_{NT}^{VS}]^2$$

In terms of the productivity parameters and packer bargaining share, total surplus from the relationship under vertical separation is:

$$\begin{aligned} S^{VS} &= R(i_D^{VS}) - C(i_U^{VS}) - i_D^{VS} - i_U^{VS} \\ &= r - c + \theta(2-\theta)(D_T)^2 + (1-\theta)^2[2D_T D_{NT}^{VS} - (D_{NT}^{VS})^2] \\ &\quad + (1-\theta^2)(U_T)^2 + \theta^2 U_{NT}^{VS}(2U_T - U_{NT}^{VS}) \end{aligned} \quad (4)$$

Upstream integration

Under upstream integration, the packer integrates backwards and purchases the assets of the producer. The producer can either become a manager (i.e., there is “trade”), or is released, in which case his income is normalized to zero (there is “no trade”). Downstream revenue without trade is: $R_{NT}^{UI} = r + 2D_{NT}^{UI}(i_D)^{1/2}$, where productivity under no-trade and upstream integration (D_{NT}^{UI}) is higher than under the vertical separation case, but less than the case with trade ($D_{NT}^{VS} < D_{NT}^{UI} < D_T$). Upstream productivity in the absence of trade is zero ($U_{NT}^{UI} = 0$), which implies that upstream producer costs without any trade are simply: $C_{NT}^{UI} = c$.

Based on (3) and our chosen functional forms, the optimal (second best) choice of investments under vertical separation are:

$$i_D^{UI} = [\theta D_T + (1-\theta)D_{NT}^{UI}]^2 \quad i_U^{UI} = [(1-\theta)U_T]^2$$

In terms of the productivity parameters and packer bargaining share, total surplus from the relationship under upstream integration is:

$$\begin{aligned} S^{UI} &= R(i_D^{UI}) - C(i_U^{UI}) - i_D^{UI} - i_U^{UI} \\ &= r - c + (1 - \theta^2)(U_T)^2 + \theta(2 - \theta)(D_T)^2 + (1 - \theta)^2(2D_T - D_{NT}^{UI})D_{NT}^{UI}. \end{aligned} \quad (5)$$

Using (4) and (5), it can be shown that vertical separation dominates integration ($S^{UI} < S^{VS}$) whenever:

$$(2D_T - D_{NT}^{UI})D_{NT}^{UI} - (2D_T - D_{NT}^{VS})D_{NT}^{VS} < (2U_T - U_{NT}^{VS})U_{NT}^{VS}. \quad (6)$$

This clarifies how the productivity parameters drive the outcome regarding optimal industry structure. We will occasionally refer back to (6) as we work through the cases below. Table 1 presents a summary of the above key results.

Numerical illustrations

Special cases of the model are used to represent how the pork sector has evolved over time. The cases are numerical to facilitate exposition, and build on the following baseline assumptions. In Cases 1 – 5, the gains from trade are split as in the Nash bargaining scenario, implying that packer share is $\theta = 0.50$. Packer value of output in the absence of investment and trade is arbitrarily chosen to be $r = 300$. Producer costs in the absence of investment and trade are chosen to be somewhat lower: $c = 200$ (these assumptions are largely inconsequential for subsequent results).

The remaining values concern investment productivity under different ownership structures (D_T , D_{NT}^{UI} , D_{NT}^{VS} , U_T , and U_{NT}^{VS}). These vary according to the case that is being considered, and are what drive the results. An important caveat is as follows. The use of numerical examples facilitates the exposition, but is not to be confused with statistical analysis. Although the outcomes are cardinal in nature, ultimately the results are treated as ordinal (i.e., results are evaluated only in terms of rank). In some cases the optimal industry structure may appear to have only a slight advantage over the alternative, but it is nevertheless considered the unique equilibrium outcome.

Case 1: Investments are not relationship specific

This baseline scenario represents the historical organization of the swine industry. Investments in human capital or effort can be made by producer or packer, and these influence the cost and quality of pork. However, there are very large numbers selling to large numbers of packers, and identities are not maintained. Thus these investments are not relationship-specific; any investment has *equal* value outside a given packer-producer combination. We can represent this in the model by equalizing packer and producer investment productivities:

$$D_T = D_{NT}^{UI} = D_{NT}^{VS} = U_T = U_{NT}^{VS}.$$

These values are arbitrarily assigned to be 4.

Based on the formulas of Table 1, the numerical results for Case 1 are presented in Table 2. Looking at the left data column, it is seen that packer investments under the two alternative industry structures (i_D^{VS} and i_D^{UI}) are first-best optimum (16). In turn, producer investment under vertical separation (i_U^{VS}) matches the first-best optimum (16). Producer investment under upstream integration (i_U^{UI}), however, is just 4. If the packer owns both downstream and upstream assets, the producer is now just a manager of the upstream division, and loses all investments in human capital and effort if he is released by the packer. Putting some weight on this possibility, his investments are sub-optimal. Loss of residual rights of control makes the producer's private return from investment less than the social return.

As a result, the highest second-best joint surplus is obtained under vertical separation (132) as opposed to upstream integration (128).⁴ When investments in effort and expertise work equally well with any trading partner, it is optimal (for all industry participants) to leave the producer as an independent owner/operator.

Thus, Case 1 offers an explanation as to why pork production has traditionally been carried out by spot markets. Spot markets and arm's length contracting perform better than integration in this setting.

Case 2: Investments are relationship specific

Recent studies document the increasing importance of asset specificities and relationship-specific investments in pork production and processing (e.g., Martinez; Hennessy and Lawrence). In this environment, producer-packer coordination can have major influences on meat quality and food safety, and may involve non-contractible investments in asset-specific skills that are not easily transferred to others. The packer may market products on the basis that certain practices are carried out in a timely and careful manner. Examples of such coordination may involve improvements in: (a) confinement conditions, including pig density, separation by age and gender, air temperature, circulation, dust, provision of rooting material; (b) timely inspection of hogs to ensure that sick and injured pigs receive immediate attention and teeth grinding is minimized; (c) treatment during transit of hogs to a slaughter facility (e.g., no use of electric goads); (d) accurate record-keeping; and (e) time spent at the slaughter facility, with no mixing of hogs from different groups.

As the importance of such coordination increases, investments have less value outside of a given producer-packer relationship. To capture this Case 2 assumes that:

$$D_T = 6, \quad D_{NT}^{UI} = 4, \quad D_{NT}^{VS} = 2, \quad U_T = 6, \quad U_{NT}^{VS} = 2.$$

Investments are “relationship-specific” since $D_T > D_{NT}^{UI} > D_{NT}^{VS}$, and since $U_T > U_{NT}^{VS}$. $D_T > D_{NT}^{UI}$ means that packer investments are more productive when she retains the producer’s expertise. $D_{NT}^{UI} > D_{NT}^{VS}$ signifies that packer investment productivity is higher when she has access to upstream as well as downstream assets (even though the producer is not retained). $U_T > U_{NT}^{VS}$ indicates that producer investment productivity under trade with a particular packer is greater than under alternatives.

Another key assumption is that producer investments are not more critical than packer investments, and vice-versa. Similarity in upstream and downstream investment importance is reflected through $D_T = U_T$ and $D_{NT}^{VS} = U_{NT}^{VS}$.

Case 2 results are in the second data column of Table 2. Looking near the bottom, second-best aggregate profits are higher under vertical separation ($S^{VS} = 164$) than under packer upstream integration ($S^{UI} = 162$). The problem with integration relative to

separation is understood through examination of packer and producer investments. Under separation they both invest 16, but under upstream integration, the producer has less incentive to invest (9). As an independent owner/operator, the producer keeps the hogs even if the relationship breaks down, and is therefore more willing to come up with cost-saving and quality-enhancing innovations. Integration eliminates the producer's residual rights of control, and lowers his incentive to invest. When the investments of both units are of comparable importance, vertical separation is ideal.

Case 3: Producers with unproductive investment

In the two cases so far, vertical separation has been ideal, regardless whether investments in human capital and effort are relationship-specific. Cases 3 – 5, on the other hand, introduce more detail from the swine industry and result in upstream integration being optimal. Case 3 begins with the observation that there is considerable heterogeneity in management style and size of operations among upstream producers. Such differences affect the degree to which upstream investments enhance the value of producer-packer exchange. In the context of our model, the RSIs of smaller and less sophisticated operations are likely to be less productive from the viewpoint of a packer. For example, certain producers are *less* willing and able than others to adopt and maximize the gain from new technologies. Likewise, producer investment in a 200-sow operation ultimately has a lower payoff from the perspective of a packer than a 5000-sow operation.

Case 3 alters Case 2 to reflect this possibility. The productivity of upstream investment under trade (U_T) is halved from 6 to 3 (Table 2). Since $U_T > U_{NT}^{VS}$ still holds, upstream investments are relationship-specific, as in Case 2. However, upstream investment is now *less* important to the relationship.

Going back to inequality (6), which shows the conditions under which vertical separation dominates integration, a decrease in U_T decreases the likelihood that vertical separation is optimal. The (negative) derivative of the right-hand side of (6) is:

$$-\frac{\partial[(2U_T - U_{NT}^{VS})U_{NT}^{VS}]}{\partial U_T} = -2U_{NT}^{VS} < 0 \quad \text{since } U_{NT}^{VS} > 0.$$

Since (6)'s right-hand-side value falls, upstream integration is now more likely.

Table 2 provides the numerical version of this result. Under either industry structure, Case 3 optimal upstream investments are lower than the corresponding values in Case 2. Upstream investment under vertical separation (i_U^{VS}) falls from 16 to 6, and upstream investment under integration (i_U^{UI}) falls from 9 to 2 (Table 2). Of these changes, the fall is largest under vertical separation. Looking at the total surplus from trade, integration edges out separation ($S^{UI} = 142 > S^{VS} = 141$).

Thus it can be worthwhile for a packer to buy out the assets of upstream producers who are otherwise unable to derive much traction from their efforts. To the extent that an upstream producer appears like the one in Case 3 (versus Case 2), it is less likely to survive as an independent firm. Given the degree of heterogeneity among U.S. hog producers, we might expect to see a *partially* integrated pork sector. For example, if half the industry's producers resemble the one in Case 2, and the other half reflects the smaller / less sophisticated producer in Case 3, then half of U.S. hogs will be raised by independent producers, and half will be self-produced by packers.

Case 4: Increasing burden on packer

The basic observation of Case 4 is that there are an increasing number of burdens borne by packers, and these burdens increase the importance of *packer* investment relative to producer investment. This point is made, for example, in Hennessy and Lawrence (p. 60-62). Producers are still recognized to play a key role in delivering low-cost high-quality products, and influencing food safety, environmental, and animal welfare outcomes. However, the packer may bear the brunt of the reputation and liability concerns. Packers are few in number, and closer to the retail market than producers (indeed, their branded products may be a household name). Packers transmit signals about preferences and costs between consumers and producers, and bear the brunt of quality and food safety concerns. Packing plants may be monitored by regulatory authorities, and packers must be responsive to the demands of export customers and their own brand managers.⁵

In this environment, packer investment in the relationship becomes the dominant determinant of producer-packer joint value. This is modeled in Case 4 by increasing the productivity of packer investments relative to Case 2 (the last case for which vertical separation was ideal). In particular, D_T is raised from 6 to 10.

Going back to inequality (6), which shows the conditions under which vertical separation dominates integration ($S^{UI} < S^{VS}$), an increase in D_T increases the left-hand side of (6):

$$\frac{\partial[(2D_T - D_{NT}^{UI})D_{NT}^{UI} - (2D_T - D_{NT}^{VS})D_{NT}^{VS}]}{\partial D_T} = 2D_{NT}^{UI} - 2D_{NT}^{VS} > 0 \quad \text{since } D_{NT}^{UI} > D_{NT}^{VS}.$$

As packer RSI productivity grows, upstream integration is more likely.

This is borne out in the numerical analysis of Table 2. Here, second-best aggregate profits are higher under integration ($S^{UI} = 218$) than under vertical separation ($S^{VS} = 216$). As before, this result is driven by investments. Under vertical separation, packer and producer optimal investments are 36 and 16, respectively. Yet with integration, the packer is willing to invest 49, and the high D_T makes the most of this investment. The packer will not invest this much under vertical separation due to the possibility of non-cooperation on the part of the producer. If the packer is to attain optimal levels of investment, it must acquire the upstream assets.

Case 5: Fewer downstream hog buyers

This case provides a distinct rationale for integration based on the trend towards packer horizontal consolidation and closure of existing packing plants. Suppose that a producer has traditionally been able to sell hogs to more than one packer in his locality. Investments are relationship-specific, so if trade does not occur within a relationship, the investment is less productive when the producer sells to alternative packers. Yet since these alternatives know the producer and his management style/expertise, the productivity loss is minimal. Specifically, U_{NT}^{VS} is less than U_T , but not to a great extent. So far this setting is consistent with Case 2.

Now suppose the number of packers falls to one. This may be due to horizontal consolidation (to exercise market power or spread the fixed costs of new safety provisions) or due to closure of outdated facilities. The producer can still sell to an unknown packer located far outside his area, but there is a cost. The productivity of investment falls off greatly in this case: U_{NT}^{VS} declines to zero. This may occur because the distance traveled is far, and the extra time in transit and storage harms animal well-being. Such stress can have a major impact on meat quality. The alternative, unknown packer may also have no understanding of the producer's expertise and management style. Producer investments are misread and unexploited, and the packer processes the hogs into undifferentiated low-quality products.

In the context of equation (6), the decrease in U_{NT}^{VS} causes the right-hand side of the inequality to fall:

$$-\frac{\partial[2U_T U_{NT}^{VS} - (U_{NT}^{VS})^2]}{\partial U_{NT}^{VS}} = -2U_T + 2U_{NT}^{VS} < 0 \quad \text{since } U_T > U_{NT}^{VS},$$

and integration becomes more likely. In our numerical illustration (bottom section of Table 2), Case 5 second-best aggregate profits are higher under integration ($S^{UI} = 162$) than vertical separation ($S^{VS} = 159$). Examination of optimal investments reveals that the producer's incentive to invest under vertical separation falls to 9 from 16 in Case 2. All other investments are the same as in Case 2. Upstream investment is now no better under vertical separation than under integration. Since the packer is always willing to invest more under integration (since it gains access to both sets of assets and all residual rights of control), integration becomes the optimal industry structure.

Case 6: Packer derives all surplus from relationship

Case 6 revisits Cases 1 – 5 with an altered assumption about the *ex post* division of surplus. Until now, the “fundamental transformation” associated with relationship-specific investments has ensured that *ex post* gains from trade are split 50:50. Case 6, in contrast, assumes that the packer has 100% of *ex post* bargaining power, and expropriates

all gains from trade. This reflects the overwhelming power a near-monopsony may hold when dealing with small producers.

In the context of the model, assigning all bargaining power to the producer implies that $\theta = 1$ instead of $\frac{1}{2}$. With $\theta = 1$, the packer has no concern about holdup, and her investment is equal to the first best investment, irrespective of industry structure:

$$i_D^{VS} = i_D^{UI} = i_D^{FB} \text{ when } \theta = 1.$$

This is true regardless of which productivity assumptions from Cases 1 – 5 are adopted. Second-best producer investments, on the other hand, are affected dramatically. This is especially so in the case of *upstream integration*, in which case it drops to zero:

$$i_U^{UI} = [(1 - \theta)U_T]^2 = 0 \text{ for } \theta = 1.$$

It is not generally zero under *vertical separation*, however, since the producer can count on a reasonably productive outside option if trade with the packer does not take place. Only in Case 5, wherein $U_{NT}^{UI} = 0$ is upstream investment actually zero.

The fact that second-best producer investment is typically highest under vertical separation makes it optimal when $\theta = 1$, in Cases 1 – 4 ($S^{VS} > S^{UI}$). When Case 5 is revisited with $\theta = 1$, however, upstream investment turns out to be zero under *both* industry structures. In this setting, vertical separation and integration yield an equivalent level of overall surplus ($S^{VS} = S^{UI}$).

Thus, if the packer can extract all the surplus from a relationship (both *ex ante* and *ex post*) vertical separation is likely to prevail, at least under the assumptions of our model. Under vertical separation, the upstream producer is willing to invest because there is always the possibility that trade may break down, in which case the producer sells his hogs to someone else. When the packer owns the upstream assets and expropriates all *ex post* surplus, however, the producer's incentive to make a relationship-specific investment completely subsides. This is important enough that the packer is better off letting the producer remain an independent owner/operator.

Conclusions

Debate on the reasons for packer self production in the swine industry is intense, but theoretical models of the underlying economic forces are only just emerging in the literature. The model of this paper is a tool for understanding the trend towards packer upstream integration based on Grossman and Hart's property rights theory of the firm.

One point is that the evolving need for producers and packers to coordinate their cost-saving and quality-enhancing investments does not imply that upstream integration is inevitable. In becoming the manager of a packer's upstream division as a result of integration, a hog producer's residual rights of control over upstream assets are eliminated, and he has reduced incentive to make investments in human capital and effort.

A second point is that increasing burdens on packers (owing to forces including more sophisticated consumer demands and the need for traceability in the food system) create asymmetries in packer versus producer investment productivity, and are a force for upstream integration. In this case, integration increases the packer's assurance of receiving a return on relationship-specific investments.

A distinct source of integration is horizontal consolidation among packers. As the outside options of producers deteriorate, the productivity of relationship-specific investment falls to zero should a relationship break down. As a result, producers invest in effort and human capital no more than they would under upstream integration. Since the latter gives the downstream packer full residual rights of control, upstream integration becomes optimal in this case.

A further finding is that the weaker investment productivity of upstream producers with small operations and lower management expertise can also act as a force for upstream integration. All else the same, heterogeneity in producer size and management skills may result in a *partially* integrated industry in which small hog operations are bought out by packers, and strong hog operations are left as independent.

Another point is that as the bargaining power of packers grows, upstream integration turns out to be less likely, all else the same. As packers expropriate more and

more of the surplus generated through a relationship with a producer, the producer's incentive to make cost-saving and quality-enhancing investments declines.

Some of these results may not be novel to readers familiar with the property rights theory of the firm, but they have yet to emerge as clearly understood facets in the literature on vertical integration in the livestock industry. The results can also play a role in highlighting the limitations of relying too heavily on traditional price, quantity, and cost data when making inferences about the evolving structure of the livestock industry. The underlying forces identified in this paper are difficult if not impossible to quantify, and even if they somehow can be, such data are unlikely to be publicly available.

The model can be extended in a number of ways to address other important issues, such as how lower-level worker incentives are affected by changes in ownership. The model could incorporate multiple packers and producers, integrators, and a retail sector to better depict the mechanisms by which changes in ownership affect optimal industry structure. In turn, it may be useful to look at more than just *ex ante* investment inefficiencies, such as bargaining inefficiencies related to the existence of private information.

Table 1. Investment and the gains from trade: Summary of analytical results

Optimal downstream (packer) investment

Vertical Separation	$i_D^{VS} = [\theta D_T + (1-\theta)D_{NT}^{VS}]^2$
Upstream Integration	$i_D^{UI} = [\theta D_T + (1-\theta)D_{NT}^{UI}]^2$
<i>First Best (Efficient)</i>	$i_D^{FB} = (D_T)^2$

Optimal upstream (producer) investment

Vertical Separation	$i_U^{VS} = [(1-\theta)U_T + \theta U_{NT}^{VS}]^2$
Upstream Integration	$i_U^{UI} = [(1-\theta)U_T]^2$
<i>First Best (Efficient)</i>	$i_U^{FB} = (U_T)^2$

Total surplus from trade

Vertical Separation	$S^{VS} = r - c + \theta(2-\theta)(D_T)^2 + (1-\theta)^2[2D_T D_{NT}^{VS} - (D_{NT}^{VS})^2] + (1-\theta^2)(U_T)^2 + \theta^2 U_{NT}^{VS}(2U_T - U_{NT}^{VS})$
Upstream Integration	$S^{UI} = r - c + (1-\theta^2)(U_T)^2 + \theta(2-\theta)(D_T)^2 + (1-\theta)^2(2D_T - D_{NT}^{UI})D_{NT}^{UI}$
<i>First Best (Efficient)</i>	$S^{FB} = r - c + (D_T)^2 + (U_T)^2$

Vertical separation dominates integration ($S^{UI} < S^{VS}$)

$$(2D_T - D_{NT}^{UI})D_{NT}^{UI} - (2D_T - D_{NT}^{VS})D_{NT}^{VS} < (2U_T - U_{NT}^{VS})U_{NT}^{VS}$$

Note: “First best” scenarios are for reference purposes only; they are unobtainable under the assumptions of the model.

Table 2. Investment and total surplus: Numerical results for Cases 1 – 5

	Case 1	Case 2	Case 3	Case 4	Case 5
Productivity of downstream (packer) investment					
D_T	4	6	6	10	6
D_{NT}^{UI}	4	4	4	4	4
D_{NT}^{VS}	4	2	2	2	2
Productivity of upstream (producer) investment					
U_T	4	6	3	6	6
U_{NT}^{VS}	4	2	2	2	0
Optimal downstream (packer) investment					
Separation (i_D^{VS})	16	16	16	36	16
Integration (i_D^{UI})	16	25	25	49	25
<i>First Best</i> (i_D^{FB})	16	36	36	100	36
Optimal upstream (producer) investment					
Separation (i_U^{VS})	16	16	6	16	9
Integration (i_U^{UI})	4	9	2	9	9
<i>First Best</i> (i_U^{FB})	16	36	9	36	36
Total surplus from trade					
Separation (S^{VS})	132	164	141	216	159
Integration (S^{UI})	128	162	142	218	162
<i>First Best</i> (S^{FB})	132	172	145	236	172

Notes: Bold font corresponds to optimal industry structure. Productivity values are synthetic and for illustrative purposes only. “First best” scenarios are unobtainable; they are for reference purposes only. Surplus from trade is divided as in the Nash bargaining solution ($\theta = \frac{1}{2}$).

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¹ Functional forms are inspired by Church and Ware's treatment, and embody diminishing returns to investment.

² Hart and Moore extend the analysis to other workers within the firm. This is less important for the pork sector since hog producers are often owned and operated by the same individual.

³ A richer depiction of the production and marketing system might allow for and distinguish among other possible participants, e.g., integrators, cooperatives, purebred producers, feeder pig producers, farrow-to-finish producers, hog finishers, order buyers and dealers, and so forth. Our focus on a small independent "producer" and single large "packer" keeps the analysis tractable, and gets to the heart of issues.

⁴ Vertical separation yields same results as the (unobtainable) efficient outcome.

⁵ In Smithfield's 2001 annual report, the president of the firm's largest processing subsidiary, Lewis Little, discusses upstream integration in the context of food safety and reputational issues. Self production of hogs makes it "a relatively easy matter for us to tell our customers where the hogs were raised for their products, what they were fed at each step along the way, and when and where they were processed."