

Vertical Integration in the Pork Industry

Jeffrey J. Reimer

Food System Research Group, University of Wisconsin – Madison

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Abstract

This article provides an economic explanation regarding why the share of U.S. pork raised on company-owned farms with hired management (integration) is increasing relative to production through independently owned-and-operated contract growers (contracting). The article develops a property rights model that shows how in certain circumstances production contracts do not transfer sufficient control over the use of production assets to intermediaries. On the other hand, integration removes certain grower incentives, with the result that production on company farms tends to be relatively costly. Practical examples of factors that influence the likelihood of full integration are emphasized.

Key words: contracts, economics of organization, integration, livestock, property rights

Vertical Integration in the Pork Industry

An increasing amount of U.S. hog production is controlled by a small number of very large pork producers. Examination of the “Pork Powerhouse” list published by *Successful Farming* magazine each October highlights the degree of integration taking place (Freese). While the top thirty Pork Powerhouses in 1994 owned 15% of all U.S. sows in full production, the top thirty in 2004 had 45% of the total, with the top three alone comprising 21%. In turn, many of these firms are also involved in processing. For example, the top three Pork Powerhouses are also the first, thirteenth, and seventh largest pork packers in the nation (Adhikari).

Many family farmers view large pork producers as a threat, and federal and state lawmakers are now considering a variety of policies that would limit the business practices of top-ranking firms. A bill before the 108th Congress would make it unlawful for a packer to own, feed, or control livestock intended for slaughter. 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 ownership and husbandry of hogs by large firms; yet, these laws are controversial and being severely tested in the courts.

Very large pork producers are commonly characterized as “contractors” or “integrators” who contract production of their hogs out to independent growers. Yet, it has become common for production to be carried out on company-owned farms with hired management, that is, *full integration*. For example, the third biggest U.S. pork producer, Seaboard, raises over 60% of the hogs processed at its Oklahoma plant on its own vertically integrated farms, including the breeding, farrowing, nursery, and finishing stages (Seaboard, p. 9). The second biggest U.S. producer, Premium Standard Farms, relies solely on company-owned farms for its Texas operation, and heavily on them for its Missouri and North Carolina operations (Premium Standard Farms). The biggest U.S. producer, Smithfield, raises 35% of the hogs produced from its breeding stock on company-owned farms with hired management, with the remainder contracted out to

independent growers (Smithfield Foods, 2004b). Overall, approximately 44% of hogs marketed by top pork producers are finished on their own farms (Rhodes, p. 109).

So while the above policy proposals are meant to shore up spot markets and help farmers who are not fully engaged in contract production, it appears that independent growers with contracts may also be in a precarious position. Will contract growers one day be superseded by very large pork producers who are fully integrated “from squeal to meal,” to borrow a phrase from Smithfield’s 2001 Annual Report (Smithfield Foods 2004a)?

The purpose of this article is to assess the likelihood of this scenario by examining a large pork producer’s decision to (a) contract out stages of production to independent growers with their own facilities (contracting), versus (b) carry out production on company-owned farms using a hired manager (integration). While large pork producers generally maintain some mixture of these two approaches we are interested in understanding recent trends and thus focus on scenarios where one tends to dominate. In examining this “make-or-buy” decision, the large pork producer is referred to as an *intermediary*. The intermediary is either a processor or markets directly to one; in either case there is a close connection to downstream markets.

The model is an adaptation of Grossman and Hart, who use the concept of non-contractible relationship-specific investments as determinants of optimal industry structure. Such investments do not concern the purchase of physical assets but correspond to investments in effort, human capital, and forward-thinking management that make existing assets more productive. When such investments are *relationship-specific* they are more productive in an exchange between two parties that have planned to work together than in an exchange between two parties that have no such relationship.

The Grossman and Hart framework is generalized and adapted to the particular features of the pork industry using surveys, statistics, and case studies as a guide (e.g., Hennessy and Lawrence; Lawrence, Schroeder, and Hayenga; Martinez; Vukina). While the focus is on pork, many insights apply to other commodities.

The model recognizes that many aspects of the exchange relationship can be handled successfully with contracts. In turn, it allows for certain incentive schemes that reward a grower for performing well, thereby taking care of some types of hidden-action problems.¹

However, there are other dimensions of effort, performance, and good management that are difficult to make part of contract incentives. Surveys of very large pork producers indicate that “loss of control” is the foremost drawback of contract production (e.g., Hennessy and Lawrence, table 2). In a rapidly evolving industry, certain important obligations may be impossible or costly to anticipate, negotiate over, and write about in a contract – and enforce if a dispute arises. This makes them *incomplete*, that is, they have gaps, missing provisions, and ambiguities that have to be remedied in an *ad hoc* manner, with the door to opportunism left open in these circumstances. Merely the threat of a dispute may in some cases lead to sub-optimal decision-making. In turn, some activities, such as animal waste management, may be too complex to specify in advance in an unambiguous manner (Vukina, p. 79). In short, contracting – as opposed to ownership – can in certain circumstances keep intermediaries from exercising their free will over the use of production assets: land, housing, lagoons, feed bins, and equipment.²

In such a setting, ultimate control over production assets lies with their owner; the person who owns the production facilities controls their use regarding those aspects not adequately covered by the contract. An intermediary who owns the assets has increased control, which in the context of our model, means increased incentive to make relationship-specific investments that maximize the returns from exchange.

Yet while integration eliminates some problems associated with contracting, it also replaces an independent owner-operator with a hired manager, which means that *residual rights of control* disappear at the grower stage. This mitigates the incentive to make

¹ No distinction is made between different types of production contracts, which include single-stage production contracts (farrowing, nursery, or finishing) and multi-stage production contracts (farrow-to-finish or wean-to-finish) (Vukina).

² Note that all this occurs prior to any issue with agency costs that could potentially arise. The principal-agent literature emphasizes the costs of *observing* agents’ effort for tasks that are otherwise contractible. That theory has little to say about vertical asset ownership and the make-or-buy decision (Hart 1995, p. 20-21). Here we are concerned about the boundaries of firms and with the costs of *writing* a contract, specifically, the problem of specifying tasks in advance in an unambiguous manner.

investments in effort, human capital, and forward-thinking managerial decisions. As a result, production ends up being more costly under integration. Whether this effect outweighs the benefits of integration depends on the relative importance of grower versus intermediary investments in effort and human capital.

Using this general framework, the article makes a number of points about when and why we can expect to see integrated production by top-ranking pork producers. Factors that increase the likelihood of integrated production are distinguished from those that decrease it.

One finding is that even in an environment marked by increasing need for coordination in the vertical stages of production, integration is by no means inevitable: it is often better for the grower to be left as an independent entity. This holds even if the intermediary has such bargaining power that it can expropriate all the gains from trade with a grower.

Integration is more likely under two general sets of circumstances, however. The first follows from increased burdens on intermediaries, which may arise from recent changes in animal waste management and environmental liability, evolving consumer preferences, new production technologies, and heightened concerns about food safety. Ownership of production assets provides the intermediary with the necessary control and incentives required to maximize the gains from the relationship.

A second key explanation for the rise in integration lies not in under-investment on the part of intermediaries, but on *grower* underinvestment arising from declining outside options for growers. Consider a scenario where the number of intermediaries falls to one within a well-defined region. Since the grower now has very limited outside options, and since there is always a chance that the relationship might fail, grower 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 integration by the intermediary.

Below these arguments are developed in detail and illustrated through numerical simulations of the conceptual model. The remainder of the article is as follows. The following section examines the existence and sources of contractual incompleteness in the pork industry. The next section argues in favor of a property rights approach to examining

the large producer's integration decision, and contrasts this with related approaches such as transaction cost economics. Subsequent sections develop a property rights model and use it to investigate recent and anticipated events in the evolving pork sector.

Contractual Incompleteness

A “complete” contract would provide for each possible contingency in a clear and enforceable manner, including specification of how effort can be verified, and remedies for breach of contract. However, it has long been emphasized that transactions costs are large and pervasive, and as a result, no contract is ever truly complete (Coase; Klein, Crawford, and Alchian; Hart 1988, 1995). Williamson, for example, observes that contracts “can be very incomplete, the gaps to be filled in by the parties as the contingencies arise. Rather than contemplate all conceivable bridge crossings in advance, which is a very ambitious undertaking, only actual bridge-crossing choices are addressed as events unfold” (p. 20).

The incompleteness of contracts does not imply that they cannot handle most aspects of an exchange relationship. However, in a rapidly evolving industry most contracts will periodically have gaps, missing provisions, and ambiguities. Sometimes these matter, other times not. Hart (1995, p. 23) outlines three general reasons for contractual incompleteness. *First*, it is difficult to anticipate all contingencies regarding optimal actions. *Second*, even if all the contingencies can be identified, it can be hard to negotiate about the plans, since, for example, in an environment with rapid changes the parties may have little prior experience that can guide negotiations. A *third* problem is that even if the parties can plan and negotiate about the future, it may be hard to write clearly so that in the event of a dispute, a third party arbitrator can verify whether a commitment has been fulfilled. Even if each party can observe the other's actions, the contract may be costly to enforce.

It is worth elaborating more on the first and third difficulties in the context of the pork industry. Consider writing a contract that includes clauses regarding the disposal of swine waste, an increasingly important issue in this industry. The extent of pollution resulting

from animal waste is highly correlated with the composition of feed. Unfortunately, the optimal feed composition is a moving target, based on numerous, fluctuating, exogenous factors (Vukina). As a result, frequent contract renegotiations are likely to be necessary. In the words of Vukina, these would create “substantial transaction costs on both parties and are highly impractical” (p. 76) with the result that “the waste management job is probably too complex for all aspects to be contracted. Instead of offering rather complicated contracts, which growers can possibly game to their advantage, the integrators may be tempted to offer simple wage contracts” (p. 79).

Another example concerns rapid advances in genetics and the need for experimentation. Some production contracts have built-in impediments to change. Consider the following clause taken from the USDA Swine Contract Library: “*In the event packer requests producer to alter its current genetic line or develop or utilize a new genetic line, packer shall allow producer thirty months, which the parties agree is a reasonable and sufficient time, to make the transition.*” Long-term resistance to adjustments by the grower seems to be built into this contract. Yet consider recent efforts to produce leaner pork in response to changing consumer tastes. Ironically, these efforts have contributed to increased incidence of pale, soft, and exudative (PSE) pork (Marriott and Schilling). Thus the need for flexibility is paramount when experimenting with new genetic lines and products.

The following clause highlights a case in which changes in regulations may have been hard to anticipate: “*As result of the Country of Origin Labeling law passed by Congress in 2002, and the regulations that are to be issued by the USDA implementing the law, all hogs delivered to packer after specified date, must be exclusively born and raised in the United States.*” This is not likely from a production contract, but it highlights how circumstances can change rapidly, making a contract written before this announcement potentially out-of-date before its natural expiration.

It is also worth looking more at the third general reason for contractual incompleteness. Even if both parties can observe the other’s actions, an independent party, such as a court of law, may be unable to verify them. Williamson, for example,

emphasizes the “unenforceability of general clauses” (p. 63). Consider the following clauses from the USDA Swine Contract Library:

- *“Utilize nutrition programs that optimize the production of quality lean meat.”*
- *“Producer shall, if requested by packer, implement programs to improve the quality of the hogs and/or packer’s ability to sell pork products produced from the hogs.”*
- *“Producer must follow humane handling procedures at all times during the production, transportation and delivery of the hogs.”*
- *“Producer shall notify packer within 24 hours of any environmental violations.”*
- *“All trucks shall meet grower bio-security requirements.”*
- *“Electric prods used only within 20 feet of loading chutes.”*
- *“Hogs misted if temperature greater than 85 degrees.”*

Even with a performance-linked bonus scheme in place (based on factors such as feed conversion, death loss, or rate of gain), it is likely that contracts are incomplete over many of these issues. First, the very inclusion of these clauses hints that the bonus scheme alone is inadequate. Second, the general language of some of these clauses leaves room for the intermediary to maneuver, but for the grower as well since important aspects are left open to interpretation. One party’s definition of “humane” handling and “optimal” nutrition may differ from another’s, not to mention that of a third party. This ambiguity can at times leave the door open to opportunism. Third, some clauses are hard to verify simply because it may be one party’s word against another’s (e.g., notification after environmental mishaps).

Two other indications of contractual incompleteness are worth mentioning. First, grower contracts have been a source of much controversy in the last decade (Hamilton; Lewin-Solomons; Vukina, p. 72). One would not expect to see this proliferation of legal disputes unless there is some dimension of contractual incompleteness. The rise in disputes and increased calls for government oversight of contracts may be caused by the difficulties of writing contracts in a period of rapid change.

Second, evidence of contractual incompleteness is found in the many surveys of intermediaries to emerge in recent years. Hennessy and Lawrence, for example, report on

a survey of 99 large pork producers who identify the perceived advantages and disadvantages of contracting versus carrying out production in-house (table 2). Out of 10 drawbacks associated with contracting, “Loss of control” is cited far more than any other.

Contracting adds an additional layer between the intermediary and those who work directly with the intermediary’s hogs. Consider this clause from the Swine Contract Library: “*Grower will instruct and direct grower’s veterinarians and other employees to administer animal health care products only in accordance with label directions and instructions.*” This clause hints at some of the abuses that have occurred in the past, and is one example of how contracting can lead to loss of oversight and control.

Property Rights Theory

Incompleteness of contracts opens the door to a theory of ownership. When an unforeseen contingency or other aspect of incompleteness occurs, the owner has the right to decide how the asset should be used, that is, the owner has *residual rights of control*. An individual lacking residual rights of control will tend to make sub-optimal *relationship-specific investments*. As considered here, these are non-contractible investments in effort, human capital, and good management that: (a) increase the productivity of an asset, (b) have lower value when not associated with that specific asset, (c) are costly to make, and (d) are non-verifiable, which creates potential for disputes.

Consider an intermediary and grower who are separate entities. The contract includes a clause indicating that the grower must be willing to participate in the development and utilization of new genetic lines. Suppose that after introducing new genetic stock, some undesirable characteristics unexpectedly turn up (e.g., PSE problems in extra lean pork). Some amount of experimentation may be needed in this circumstance (Knoeber p. 279), and the contract may be vague on how to handle some of the complex issues that may arise. In addition, the grower may have too generous an amount of time to make the transition (earlier we saw this can be 30 months).

If the contract is vague on these things or there is some element of unenforceability, the grower – with whom the intermediary has significant relationship-specific investments

– may credibly threaten to make his operation and expertise unavailable for them in the short run. This does not have to be an open threat; it may just be a certain amount of hesitation or indifference to downstream concerns. In the least, contract production adds an extra layer of bureaucracy to deal with relative to an intermediary who is fully integrated in all stages of production. Anticipating such problems, a large pork producer may want to fully integrate, that is, carry out production on company-owned farms with hired management.

However, property rights theory also recognizes that there can be incompleteness in the contract between the integrated intermediary and the manager hired to run the production operation. Integration does not eliminate the costs of specifying contractual obligations in an unambiguous manner and therefore does not eliminate opportunism by the manager (Hart 1995, p. 27-28). If a hired manager should be released for some reason he loses whatever investments in effort, human capital, and forward-thinking management he has made to improve the productivity of the intermediary's physical assets. Assigning some probability to this possibility, the manager tends to underinvest relative to an independent owner-operator, and has correspondingly higher costs. Should his investment be critical enough, the intermediary may be better off under contracting.

Comparison to transaction cost economics: It is worth highlighting the differences between property rights theory (PRT) and transaction cost economics (TCE), which is also used to study the boundaries of the firm. Both approaches recognize that transaction costs are pervasive and large, and that gaps in contracts must be filled in as time passes. Like PRT, TCE has long emphasized that contractual problems may be particularly severe between an input supplier and a intermediary (Klein, Crawford, and Alchian; Williamson). In turn, both approaches relate the likelihood of integration back to relationship-specific investments among other aspects (Whinston).

One difference between the two approaches is that PRT focuses on ex ante investment distortions while TCE emphasizes additional transaction costs such as haggling and maladaptation costs (Whinston). Williamson (p. 21) observes that TCE “insists that contracting costs of all kinds be accorded parity,” and in this sense TCE is more general.

That said, PRT has been extended in a number of directions in recent years, including examination of bargaining inefficiencies caused by private information (Matouschek), to name just one example.

An important drawback of TCE's greater generality is that it is harder to formalize within a consistent analytic framework. In turn, since TCE is "largely verbal" (Whinston, p. 4) its assumptions are not always clear and it can give rise to contradictory outcomes (Gibbons, p. 6). PRT, by contrast, involves formal mathematical modeling and states all assumptions clearly.

Another drawback of TCE is that it assumes that opportunism is largely mitigated when the transaction is brought within the firm (Whinston, p. 4). As such, TCE does not have a unified theory of the costs and benefits of integration. By contrast, PRT explicitly recognizes that contractual incompleteness still exists in an integrated firm and leads to sub-optimal investments. This has been shown to be a very useful mechanism for understanding what underlies the notion of bureaucracy costs (Hart 1988).

It is also useful to distinguish PRT from TCE in the context of a specific study that examines contracting versus integration. Knoeber studies the broiler industry with a TCE approach and finds much less integration than TCE predicts (p. 277). To explain the existing structure Knoeber draws on institutional features outside the TCE framework, including the use of tournament bonus schemes and grower provision of production facilities (p. 281).

These findings have relevance to the pork sector, but with the following caveats. As discussed above, tournaments and other such incentive schemes miss critical dimensions of effort and performance.³ This is especially important since the pork industry is in the midst of a major transformation. There is no indication that we have seen the last of: (i) integration, as seen by comparing recent Pork Powerhouse lists in *Successful Farming*; (ii)

³ Tournaments are much less common in the pork industry than in poultry. Tsoulouhas and Vukina link this to increased risk of bankruptcy associated with size differences of firms across the industries. Note that the idea of multiple dimensions of effort is similar in some ways to the multi-tasking problem of principal-agent theory. However, that theory focuses on the problem of worker effort being costly to observe and has little to say about the make-or-buy decision. The idea here is that some tasks are too costly to specify in advance in an unambiguous manner.

rapid advances in genetics, input technologies, and value-added branded products, and the associated experimentation, and (iii) dealing with complex emerging issues such as animal waste management and animal welfare concerns, to name just two examples. Thus contractual incompleteness is likely more pervasive in the pork industry than in the poultry industry at present. The latter industry is now reasonably mature and stable, having started to become vertically coordinated in the 1950s as feed manufacturers looked for guaranteed buyers of feed.⁴

Just as incentive schemes do not cover certain important dimensions of effort, grower provision of production assets does not eliminate the possibility for opportunism. Recall that large intermediaries cite “loss of control” as the leading drawback of contracting (Hennessy and Lawrence). Often a vehicle for opportunism is built into contracts, such as allowing growers a lengthy period to incorporate a new genetic line. A termination for hesitation on the part of the grower would technically be illegal in this case. In turn, intermediaries become “locked into” a grower as they make specific investments in the relationship. Human capital investments by the intermediary such as long range planning, specialized training, and learning-by-working-together are lost if the relationship is dissolved (Williamson p. 61-62). Even if an intermediary initially has a large number of potential growers with whom it can contract, the relationship becomes bilateral once specific investments are made.⁵ Furthermore, an intermediary may be locked into a grower through site specificity (building a facility next to those of a large grower), which also opens up the door to opportunism on the part of the grower.

PRT generally assumes that investments are observable but not verifiable, which is something not necessarily part of TCE.⁶ Consider Knoeber’s observation that a hired

⁴ For the record, note that the poultry industry has other differences, such as a different geographic concentration of production, a narrower genetic base, a shorter biological production cycle that allows for quicker genetic improvements, and differences in minimum efficient scale in production and processing (Ward). These too influence the contracting versus integration decision.

⁵ Shifting to alternative suppliers entails costs that are non-recoverable (Williamson p. 12, 211). In the words of Williamson (p. 61), upstream “rivals cannot be presumed to operate on a parity...once substantial investments in transaction-specific assets are put in place. Winners in such circumstances enjoy advantages over nonwinners, which is to say the parity is upset. Accordingly, what was a large numbers bidding condition at the outset is effectively transformed into one of bilateral supply thereafter.”

⁶ The non-verifiability assumption is not strictly required for the PRT approach (see, e.g., Hart 1995, p. 79).

manager working on a company-owned farm expends less effort on aspects such as maintenance than an independent owner-operator (p. 278, note 12). PRT provides an internal explanation of this by recognizing that a hired manager lacks residual control rights over production assets. In turn, even if the asset owner can *observe* the manager's low effort, it may be exceedingly difficult to quantify his performance such that it is verifiable. Knoeber (p. 281, note 18) observes that employees are not automatically punished for bad performance, but they may eventually be fired for consistently bad performance. A manager that is fired could sue for wrongful dismissal. If his low effort is non-verifiable the intermediary may have a difficult time defending against such a suit. Thus, the concepts of residual rights of control and non-verifiability can explain differences in effort between hired managers and independent owner-operators.⁷

The Model

The set-up draws from Hart's (1995) treatment, with a number of alterations made to reflect the particular structure of the pork sector and to facilitate exposition. These include: more general treatment of the gains from trade, incorporation of certain contractible investments in effort, specific diminishing marginal returns functional forms,⁸ consideration of non-contractible investments that are not relationship-specific, and restrictions on integration and investment productivity that reflect industry detail.

Intermediaries are denoted I , and growers are denoted G . Productive assets are in place from the outset.⁹ In both organizational structures the intermediary owns all

⁷ Non-verifiability also helps explain why profit- and cost-sharing agreements – which in theory could be more successful than simple bonus schemes for eliciting optimal levels of effort – are seldom used in practice (Hart 1995, p. 64, 79). Consider that an opportunistic party could overstate costs or understate profits to their benefit. One need not look far to see evidence of such opportunism in the livestock industry. In recent years there has been an increasing amount of litigation concerning the underweighing of animals and feed, and manipulation other types of quality, cost, and input information (Hamilton).

⁸ The results are robust to more general functional forms. For more on this issue and other possible specifications the reader is referred to Hart 1995, p. 37, and Whinston, p. 12.

⁹ Unlike the investments in effort and human capital discussed below, any investment in physical assets is considered perfectly contractible and fully recoverable if the relationship breaks down. This is a perfectly natural assumption and allows us to focus on the fundamental determinant of organization: human capital investments that make physical assets more productive, that is, “effort.”

downstream physical assets (such as a packing-processing facility) plus inputs for upstream production, including feed, medicine, and breeding stock and/or feeder pigs.

Under *contracting* the grower owns the production facilities, including land, access road, housing, feed bins, waste handling and disposal facilities (such as a lagoon), and other equipment. Under *integration*, these facilities are owned by the intermediary and the “grower” is a hired manager instead of an independent owner-operator. In both cases the grower has a contract from the intermediary; the scenarios differ solely in terms of production asset ownership and the residual rights of control.

There are multiple growers who can handle the stages of production for the intermediary’s hogs (this is the “large numbers” condition discussed in Williamson, p. 61). We focus on a representative grower who, in contracting with the intermediary, receives his reservation price (\bar{p}) regarding the basic elements of the contract. The intermediary expropriates the rest of this surplus (that is, the surplus unrelated to relationship-specific investments).

The grower and intermediary have the opportunity to enhance the productivity of their trade through investments. These are non-cooperative due to the possibility that the relationship may falter under contractual incompleteness. The investments are anything that change the productivity of physical assets, and can be thought of as non-contractible investments in effort, human capital, and forward-thinking management. In general the investments have some degree of productivity even if trade between two parties breaks down.

To formalize this set-up, let c be costs in the absence of any extra effort or relationship-specific investments by the grower. (For simplicity, and without loss in generality, only one unit of input is considered in all that follows.) The grower can make contractible investments in effort (e_G) that can be thought of as improving the feed conversion ratio or similar performance-based bonus scheme. This reduces costs by this diminishing marginal returns functional form: $2\beta(e_G)^{1/2}$, where $\beta > 0$ is an unknown parameter. The grower can also make important non-contractible investments (i_G) that have the effect of reducing costs. The reduction is: $2G_T(i_G)^{1/2}$, where $G_T > 0$ determines

the productivity of the investment under trade (T). This productivity level can be thought to reflect the marginal importance of an agent's investment. C_T is overall grower costs under trade with the intermediary:

$$(1) \quad C_T(e_G, i_G) = c - 2\beta(e_G)^{1/2} - 2G_T(i_G)^{1/2}.$$

When the relationship breaks down and there is no trade (NT) we replace G_T with G_{NT} , and costs become:

$$(2) \quad C_{NT}(e_G, i_G) = c - 2\beta(e_G)^{1/2} - 2G_{NT}(i_G)^{1/2},$$

where $G_{NT} \leq G_T$. The investment is weakly less productive under no trade because an outside party is less likely to appreciate and be able to capitalize on the grower's investments.

Now consider the intermediary. Let r be intermediary revenue in the absence of any investments in effort and human capital, and i_I be the amount of investment. The positive benefit to intermediary revenue is: $2I_T(i_I)^{1/2}$, where $I_T > 0$ is productivity of that investment under trade with the grower. Overall intermediary revenue under trade is then:

$$(3) \quad R_T(i_I) = r + 2I_T(i_I)^{1/2}.$$

When there is no trade (NT) the specification is:

$$(4) \quad R_{NT}(i_I) = r + 2I_{NT}(i_I)^{1/2}.$$

where $I_{NT} \leq I_T$. The investment is weakly more productive under trade within the relationship because the two parties have planned to work together.

The gains from trade within the relationship are: $(R_T - C_T) - (R_{NT} - C_{NT})$, that is, the difference between revenues and costs under trade between the two parties, less the difference between revenues and costs under no relationship. These gains are costlessly bargained over in a process independent of ownership structure. θ is the intermediary's share of the gains from trade, and $1 - \theta$ is the grower's share. In the standard Nash bargaining process these gains are split 50:50, such that $\theta = \frac{1}{2}$ (this follows from Williamson's fundamental transformation, p. 61). If the intermediary expropriates all the gains from trade then $\theta = 1$.

Let p represent the equilibrium transfer price for the input. The grower's post-contractual payoff is then the transfer price less costs ($\Pi_G = p - C_T$). Analogously, the

intermediary's post-contractual payoff is revenue less the transfer price ($\Pi_I = R_T - p$). Let \bar{p} be the reservation price of the grower in the preliminary stage, that is, before relationship-specific investments or other types of effort are made. The payoffs (net of investments in effort) can be rewritten as:

$$(5) \quad \Pi_G = p - C_T = \bar{p} - C_{NT} + (1 - \theta)[(R_T - C_T) - (R_{NT} - C_{NT})]$$

$$(6) \quad \Pi_I = R_T - p = R_{NT} - \bar{p} + \theta[(R_T - C_T) - (R_{NT} - C_{NT})].$$

Equation (5) says that grower payoffs are reservation price less costs under no investment and trade ($\bar{p} - C_{NT}$) plus the grower's share of the gains from trade. Equation (6) says that intermediary payoffs are revenue under no investment and trade less reservation price ($R_{NT} - \bar{p}$) plus the intermediary's share of the gains from trade. Equation (5) or (6) can be solved to get the equilibrium transfer price (p):

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

To derive optimal grower and intermediary investments, p is plugged into grower and intermediary payoffs (Π_G and Π_I) less all investment and effort costs:

$$(7) \quad \Pi_G - e_G - i_G = \bar{p} + (1 - \theta)R_T(i_I) - (1 - \theta)C_T(e_G, i_G) - (1 - \theta)R_{NT}(i_I) - \theta C_{NT}(e_G, i_G) - e_G - i_G$$

$$(8) \quad \Pi_I - i_I = -\bar{p} + \theta R_T(i_I) - \theta C_T(e_G, i_G) + (1 - \theta)R_{NT}(i_I) + \theta C_{NT}(e_G, i_G) - i_I.$$

As discussed above, the parties can contract over e_G . So for this investment alone, the parties are able to fully cooperate, and (7) and (8) are maximized jointly, not individually. The optimal level of e_G is chosen by the grower, wherein the objective function is the sum of (7) and (8):

$$(9) \quad \Pi_G + \Pi_I - e_G - i_G - i_I = R_T(i_I) - C_T(e_G, i_G) - e_G - i_G - i_I.$$

Observe that when effort is perfectly contractible, no weight is put on the possibility of the relationship breaking down (C_{NT} and R_{NT}). The grower chooses e_G to maximize (9). Using (1), the first order condition is:

$$(10) \quad -C'_T(e_G, i_G) - 1 = \beta(e_G)^{-1/2} - 1 = 0$$

Rearrangement yields the optimal contractible grower effort: $e_G = \beta^2$.

The parties cannot cooperate on non-contractible investments, so i_G is independently chosen to maximize (7) and i_I to maximize (8). The associated first order conditions are:

$$(11) \quad -(1-\theta)C'_T(e_G, i_G^{SB}) - \theta C'_{NT}(e_G, i_G^{SB}) - 1 = 0 \quad \theta R'_T(i_I^{SB}) + (1-\theta)R'_{NT}(i_I^{SB}) - 1 = 0,$$

where SB stands for *second best*. Total surplus is: $S^{SB} = R_T(i_I^{SB}) - C_T(e_G, i_G^{SB}) - e_G - i_G^{SB} - i_I^{SB}$. Hereafter, SB will be dropped and replaced with the specific case under consideration: contracting (CON) or integration (INT). The outcome with highest total surplus (S^{CON} or S^{INT}) is optimal to both the grower and intermediary.

To calculate total surplus under **contracting**, costs under no trade (2) and revenue under no trade (4) need to be specified in slightly more precise terms. In (2) G_{NT} takes on the specific value G_{NT}^{CON} , which denotes grower investment productivity under contracting and no trade. Similarly, in (4) I_{NT} takes on the specific value I_{NT}^{CON} , which denotes intermediary investment productivity under contracting and no trade. Based on these specific versions of (2) and (4), and given (1), (3), and (11), investments under contracting are:

$$i_G^{CON} = [(1-\theta)G_T + \theta G_{NT}^{CON}]^2 \quad i_I^{CON} = [\theta I_T + (1-\theta)I_{NT}^{CON}]^2.$$

Observe that each party takes into account the fact that it only gets a share of the surplus from its investment, and puts weight on the possibility that trade may not occur. Total surplus under contracting is:

$$(12) \quad S^{CON} = R_T(i_I^{CON}) - C_T(e_G, i_G^{CON}) - e_G - i_I^{CON} - i_G^{CON} \\ = r - c + \beta^2 + \theta(2-\theta)(I_T)^2 + (1-\theta)^2[2I_T I_{NT}^{CON} - (I_{NT}^{CON})^2] \\ + (1-\theta^2)(G_T)^2 + \theta^2 G_{NT}^{CON} (2G_T - G_{NT}^{CON}).$$

Note that investments are relationship-specific if G_{NT}^{CON} is strictly less than G_T , and D_{NT}^{CON} is strictly less than I_T .

To calculate total surplus under **integration**, costs under no trade (2) and revenue under no trade (4) again need to be specified in slightly more precise terms. In (2), G_{NT}^{INT} is zero by default because if his contract is terminated, the hired manager loses all non-contractible investments; he has no residual rights of control. In (4), I_{NT} takes on the specific value I_{NT}^{INT} , which denotes intermediary investment productivity under integration and no trade. Now, based on these specific versions of (2) and (4), and in conjunction with (1), (3), and (11), investments under integration are:

$$i_G^{INT} = [(1-\theta)G_T]^2 \quad i_I^{INT} = [\theta I_T + (1-\theta)I_{NT}^{INT}]^2.$$

Total surplus from the relationship under integration is:

$$(13) \quad S^{INT} = R_T(i_I^{INT}) - C_T(e_G, i_G^{INT}) - e_G - i_G^{INT} - i_I^{INT} \\ = r - c + \beta^2 + (1 - \theta^2)(G_T)^2 + \theta(2 - \theta)(I_T)^2 + (1 - \theta)^2(2I_T - I_{NT}^{INT})I_{NT}^{INT}.$$

Note that investments are relationship-specific if I_{NT}^{INT} is strictly less than I_T . This signifies that productivity of investment is higher when the intermediary retains a particular grower's expertise. In turn, productivity under no-trade and integration (I_{NT}^{INT}) is weakly greater than under contracting (I_{NT}^{CON}) because ownership of the production assets increases the likelihood that the intermediary will see a return on its investment.

Using (12) and (13), it can be shown that contracting dominates integration ($S^{INT} < S^{CON}$) whenever:

$$(14) \quad (2I_T - I_{NT}^{INT})I_{NT}^{INT} - (2I_T - I_{NT}^{CON})I_{NT}^{CON} < (2G_T - G_{NT}^{CON})G_{NT}^{CON}.$$

Note that this is a sufficient but not necessary condition under the way the model has been developed. Optimal industry structure is clearly a function of the importance (productivity) of intermediary investment relative to grower investment.

We now have a framework for evaluating the tendency to integrate versus contract under different assumptions about the importance of grower versus intermediary investment. It will also be useful to compare the above second-best levels of investment to those that would arise in a **first best** environment, that is, one in which tasks can be specified comprehensively in advance in an unambiguous manner. In this unobtainable first-best world, all investments are perfectly contractible, and the two parties cooperate and jointly select i_G and i_I to maximize (9) above. Using (1) and (3), the first order conditions can be shown to be: $I_T(i_I^{FB})^{-1/2} - 1 = G_T(i_G^{FB})^{-1/2} - 1 = 0$, where *FB* stands for *first best*. Rearrangement yields the first best choice of investments: $i_I^{FB} = (I_T)^2$ and $i_G^{FB} = (G_T)^2$. Total surplus from the relationship under this efficient outcome is:

$$S^{FB} = R_T(i_I^{FB}) - C_T(e_G, i_G^{FB}) - e_G - i_G^{FB} - i_I^{FB} = r - c + \beta^2 + (I_T)^2 + (G_T)^2.$$

Table 1 summarizes the key results from above and gives the formula for $S^{CON} - S^{INT}$, a convenient expression for determining optimal asset ownership in each case.

The Tendency to Integrate

Special cases of the model are used to represent how the pork sector has evolved over time. Although comparative statics with (14) could adequately convey many of the results, we also introduce numerical examples to facilitate the exposition. Unless otherwise indicated the gains from trade are split as in the Nash bargaining scenario, implying that intermediary share is $\theta = 1/2$. Intermediary value of output in the absence of investment and trade is arbitrarily set at $r = 300$. Grower costs in the absence of investment and trade are chosen somewhat lower: $c = 200$ (these specific numerical values are inconsequential for the results of interest). Investment importance under different ownership structures (I_T , I_{NT}^{INT} , I_{NT}^{CON} , G_T , and G_{NT}^{CON}) vary according to the case being considered, and are what drive the results.

Case 1: General Types of Investments

In this baseline scenario, non-contractible investments in effort can be made by grower or intermediary, and these influence profitability in the supply chain. However, these investments are not relationship-specific; any investment has *equal* value outside a given intermediary-grower combination. This is represented in the model by equalizing intermediary and grower investment productivities:

$$I_T = I_{NT}^{INT} = I_{NT}^{CON} = G_T = G_{NT}^{CON}.$$

For our numerical example, these values are arbitrarily assigned to be 4. Case 1 results are presented in table 1. Looking at the left data column, it is seen that intermediary investments under the two alternative industry structures (i_i^{CON} and i_i^{INT}) are first-best optimum (16). In turn, grower investment under contracting (i_G^{CON}) matches the first-best optimum (16). Grower investment under integration (i_G^{INT}), however, is just 4. If the intermediary owns both downstream and upstream assets, the “grower” is just a hired manager, and loses all investments in human capital and effort if he is released by the intermediary. Putting some weight on this possibility, his investments are sub-optimal. Lack of residual control rights makes the grower’s private return from investment less than the social return. As a result, joint surplus is highest under contracting ($S^{CON} > S^{INT}$).

Thus when investments in effort and expertise are not relationship-specific, all else the same, production is optimally contracted out to an independent grower. Use of company-owned farms with a hired manager harms grower incentives without providing a gain elsewhere for the intermediary.

Case 2: Investments are Relationship-Specific

Recent studies document the increasing importance of relationship-specific investments in pork production and processing (e.g., Hennessy and Lawrence; Martinez). In this environment, upstream-downstream coordination can have considerable influences on meat quality and safety, and may involve non-contractible investments in asset-specific skills that are not easily transferred to others. The intermediary may improve the productivity of its downstream assets by researching new export markets for pork products, and training the grower to perfect the husbandry of new genetic lines developed for these markets. The grower may improve the productivity of production assets through better record-keeping, seeking advanced training, and being sensitive to those aspects of the operation that can potentially enhance the profitability of downstream products. For example, both parties may coordinate on better treatment during transit of hogs to a slaughter facility (e.g., no use of electric prods), and while at the slaughter facility (e.g., shortened stays and no mixing of hogs from different groups).

To recognize that these costly, observable, and non-verifiable investments have less value outside a given relationship, Case 2 specifies that:

$$I_T = 6, \quad I_{NT}^{INT} = 4, \quad I_{NT}^{CON} = 2, \quad G_T = 6, \quad G_{NT}^{CON} = 2.$$

Investments are “relationship-specific” since $I_T > I_{NT}^{INT} > I_{NT}^{CON}$ and since $G_T > G_{NT}^{CON}$. $I_T > I_{NT}^{INT}$ signifies that intermediary investments are more productive when it retains this particular grower’s expertise and experience. $I_{NT}^{INT} > I_{NT}^{CON}$ signifies that intermediary investment productivity is higher when it has access to all productive assets. $G_T > G_{NT}^{CON}$ signifies that grower investment productivity under trade with a particular intermediary is greater than under alternatives.

Another key assumption is that grower investments are not more critical than intermediary investments, and vice-versa. This symmetry in marginal investment importance is reflected through $I_T = G_T$ and $I_{NT}^{CON} = G_{NT}^{CON}$.

Case 2 results are presented in table 1. Looking near the bottom, second-best aggregate profits are higher under contracting ($S^{CON} > S^{INT}$). The problem with integration is understood through examination of intermediary and grower investments. Under contracting they both invest 16, but under integration, the grower invests less (9). Integration eliminates the grower's residual rights of control and thus his incentive to increase effort. While the intermediary does invest more under integration (25), diminishing marginal returns mean that this gain counts for less than the decrease on the grower side.

Thus this case illustrates that even with relationship-specific investments, traditional contract production can be optimal. One need not look far in the real world to find examples of growers and intermediaries who have a very close working relationship but nonetheless remain separate entities.

Case 3: Increasing Burdens on Intermediary

In the two cases so far, contracting has been ideal, regardless whether investments are relationship-specific. Cases 3 and 4, on the other hand, show how other aspects of the pork industry can increase the likelihood of integration for some intermediaries. In these cases, the intermediary optimally owns the production assets and uses hired management.

The basic observation of Case 3 is that there are an increasing number of burdens borne by intermediaries, and these increase the importance of intermediary investment relative to grower's. This point is made, for example, in Hennessy and Lawrence (p. 60-62). Growers are still recognized to play a key role in delivering low-cost high-quality products, and influencing food safety, environmental, and other outcomes. However, the intermediary bears the brunt of reputation and liability concerns.

Consider that intermediaries are fewer in number, and closer to the retail market than growers. Some large pork producers that are also packers are aggressively developing

value-added and branded pork products, and may need to be responsive to the demands of brand managers and customers in new export markets. In turn, intermediaries are increasingly likely to share responsibility for swine waste management (Vukina, p. 68). Indeed, some industry observers argue that the owner of the pigs (the intermediary) should be responsible for the waste and nuisances created by production as opposed to merely the owner of production facilities (or no one at all) (Grannis and Seidl, p. 21). In turn, intermediaries confront growing food safety concerns. While food safety has improved in many dimensions (e.g., lower disease rates for three of the four major pathogens associated with meat products), this is an increasing area of concern, with recalls of meat products sometimes linked back to intermediary-owned animals raised on contract farms.¹⁰ Bogetoft and Olesen, for example, demonstrate how greater integration in the upstream stages of production can reduce the incidence of Salmonella.

These type of developments are modeled in Case 3 by increasing the productivity (importance) of intermediary investments relative to Case 2. Going back to inequality (14), which shows the conditions under which contracting dominates integration ($S^{INT} < S^{CON}$), an increase in I_T increases the left-hand side of (14):

$$\frac{\partial[(2I_T - I_{NT}^{INT})I_{NT}^{INT} - (2I_T - I_{NT}^{CON})I_{NT}^{CON}]}{\partial I_T} = 2I_{NT}^{INT} - 2I_{NT}^{CON} > 0 \quad \text{since } I_{NT}^{INT} > I_{NT}^{CON}.$$

As intermediary investment importance grows, integration is more likely.

This result can be expressed in numerical form by raising I_T from 6 to a higher value such as 10. Integration yields higher second-best aggregate profits than contracting ($S^{CON} < S^{INT}$, bottom of table 1). As before, this result is driven by investments. Under contracting, grower and intermediary investments are 16 and 36, respectively. Yet with integration, the intermediary is willing to invest 49, which is more than the 25 it invested in Case 2. The intermediary will not risk investing as much under contracting since some weight is put on the possibility that the relationship might break down due to contractual

¹⁰ On this issue, one intermediary, Smithfield, observes that integration 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” (Smithfield Foods 2004a).

To prevent the spread of disease, Premium Standard Farms requires employees at its fully integrated Texas facilities to shower at the central administration office, then don company-supplied work clothes before driving to the grow/finish complex (Premium Standard Farms).

incompleteness. Under this asymmetry of investment importance, if the intermediary is to attain optimal levels of investment, it is better off to own the production assets.

Case 4: Fewer Intermediaries

A distinct reason why an intermediary may find it worthwhile to carry out full-fledged upstream production is related to increasing concentration among intermediaries. Consider that an independent grower may have traditionally been able to contract with more than one intermediary in his locality. Investments are relationship-specific, so if trade does not occur within a relationship, the investment will be less productive when the grower sells to alternative intermediaries. Yet since these alternatives know the grower and his management style/expertise (perhaps they have contracted with the grower before or know him through reputation), the productivity loss is minimal. Specifically, G_{NT}^{CON} is less than G_T , but not to a great extent. So far this setting is consistent with Case 2.

Now suppose the number of intermediaries falls to one, perhaps because of a merger or acquisition. The grower can still sell to an unknown intermediary located far outside his area, but there is a cost. The productivity of investment falls off greatly in this case: G_{NT}^{CON} declines to zero. This may occur because the distance traveled is far, and the extra time in transit and storage stresses the animals and reduces the quality of processed products. The alternative, unknown intermediary may also have no understanding of the grower's expertise and management style. Grower investments may be misread and unexploited, and hogs might be processed into undifferentiated low-quality products.

In the context of inequality (14), the decrease in G_{NT}^{CON} causes the right-hand side of the inequality to fall:

$$-\frac{\partial[2G_T G_{NT}^{CON} - (G_{NT}^{CON})^2]}{\partial G_{NT}^{CON}} = -2G_T + 2G_{NT}^{CON} < 0 \quad \text{since } G_T > G_{NT}^{CON}.$$

This means integration is more likely. In our numerical example, Case 4 aggregate profits are higher under integration than contracting ($S^{CON} < S^{INT}$, bottom of table 1). This is because the grower's incentive to invest under contracting (i_G^{CON}) falls to 9 (from 16 in Case 2), while all other investments are as in Case 2. Grower investment is now no better

under contracting than under integration. Even though contracting provides the grower with residual rights of control, they do him no good. Since the intermediary is always willing to invest more under integration (since it gains residual rights of control), integration is more likely as grower outside options disappear.

This example provides one reason why some large new producers develop fully integrated production and processing operations when they move into areas that previously had no hog production (e.g., in recent years, certain areas of Texas, Oklahoma, and Utah). The hog breeding, growing, and finishing operations of these intermediaries are not intended and may not be able (because of distance) to supply an alternative intermediary if the initial relationship sours. The lack of a viable outside option for the production division implies that G_{NT}^{CON} is zero, which – as we just saw – makes integration the optimal arrangement, *ceterus paribus*.¹¹

Case 5: Intermediary Expropriates All Gains from Trade

Case 5 revisits Cases 1–4 with an altered assumption about the division of surplus. Until now, it has been assumed that bargaining is such that gains from trade are split 50:50, as in the Nash bargaining solution. This is the standard approach of related studies and is quite reasonable under the fundamental transformation described earlier. There is, however, currently much interest in the possibility that an intermediary may exhibit overwhelming bargaining power when dealing with growers. It is conceivable that an intermediary could have 100% of bargaining power over the gains from relationship-specific investments and all other surplus arising from the relationship.

To capture this in the model, Case 5 drops the Nash bargaining solution and assigns all bargaining power to the intermediary. Now that $\theta = 1$ instead of $\frac{1}{2}$, intermediary investment levels obtain the first best optimum irrespective of industry structure:

$$i_I^{CON} = i_I^{INT} = i_I^{FB} = (I_T)^2 \text{ when } \theta = 1.$$

¹¹ This explanation complements others that also surely have relevance. An anonymous reviewer points out that these integrated operations are typically large state-of-the-art facilities built from scratch in one place to exploit economies of scale in transport, feed mixing and delivery, and waste management. The operations are constructed according to strict company standards regarding parcel size, the size of the house, and the type of the equipment.

This is true regardless of which productivity assumptions from Cases 1–4 are adopted (see table 1). Second-best grower investments, by contrast, are unambiguously lower. This is especially so in the case of *integration*, in which case it drops to zero:

$$i_G^{INT} = [(1-\theta)G_T]^2 = 0 \quad \text{for } \theta = 1.$$

It is not generally zero under *contracting*, however, since the grower can count on a reasonably productive outside option if trade with the intermediary does not take place. Only in Case 4, wherein $G_{NT}^{INT} = 0$, is i_G^{CON} driven down all the way to zero.

The fact that second-best grower investment is highest under contracting makes this industry structure clearly optimal when $\theta = 1$, in Cases 1–3 ($S^{CON} > S^{INT}$). When Case 4 is revisited with $\theta = 1$, however, grower investment is zero under both industry structures, and contracting and integration are equivalent ($S^{CON} = S^{INT}$). So in this extreme case, when the intermediary has 100% of bargaining power and the grower has no outside option, neither situation yields a distinct advantage.

Thus, if the intermediary can extract all the surplus from a relationship, contracting weakly dominates. Under contracting, the grower is willing to invest something because there is always the possibility that the relationship will dissolve. When the intermediary owns the production assets and expropriates all gains from trade, however, the grower's incentive to make relationship-specific investments completely subsides. This is important enough that the intermediary is best off contracting with an independently owned and operated grower.

Summary and Conclusions

Most large pork producers contract out production of their hogs as well as carry out production in-house. Recently the share of U.S. hogs produced in-house has been rising and it seems possible that independently owned-and-operated pork producers with production contracts could eventually be superseded by a small number of fully integrated firms. This article examines the tendency of a very large pork producer to contract out production of its hogs to independent growers with their own facilities (contracting), versus use hired management and raise its hogs on company-owned farms (integration).

A key factor underlying the tendency to integrate versus contract is incompleteness in the production contract. In a rapidly evolving industry, the party who owns the production facilities controls their use regarding those aspects not adequately covered by the contract. Thus, contracting may at times restrict an intermediary from exercising control over certain tasks that might otherwise be done more seamlessly and efficiently. Yet integration takes away certain incentives from the grower, who in this case is a hired manager instead of an independent owner-operator under contract. Which of these two opposing forces dominates is examined within five cases designed to reflect recent events in the industry.

One finding is that integration is optimal when there are increasing burdens on the intermediary, owing to forces such as development of value-added and branded products, increasing liability for environmental outcomes, and the need for traceability in the food system. These create asymmetries in intermediary versus grower investment importance, and so integration helps align upstream and downstream investment incentives to maximize value in the supply chain. In a practical sense, integration may reduce the delay in implementing new genetic traits, for example, and eliminate the need to write complicated production contracts that attempt to handle the set of tasks associated with animal waste management.

A distinct source of integration is horizontal consolidation among intermediaries, or simply any situation in which the number of outside options for an grower is small or nonexistent. In these cases, the productivity of specific investments fall to zero should a relationship break down. As a result, a contract grower invests in effort and human capital no more than they would under integration. Since the latter gives the intermediary full residual rights of control without a drawback elsewhere, integration becomes optimal.

The other three cases reveal that full-scale integration “from squeal to meal” is by no means inevitable. The industry is going through a major transformation, and it is quite possible that the advantages of contracting will prevail once the industry becomes more stable and mature. Even when there is contractual incompleteness and a need for growers and intermediaries to coordinate their relationship-specific investments, contracting is

optimal as long as investment importance is similar. Unlike an independent grower, a hired manager of an intermediary's production division does not have residual rights of control over production assets. This lowers the incentive to make investments in effort, human capital, and forward-thinking managerial decisions, and makes production relatively costly under integration. Furthermore, as the bargaining power of intermediaries grows, integration is less likely, all else the same. In this case integration harms the incentives of growers. Contracting, on the other hand, preserves the grower's possibility of pursuing outside options should the relationship with a given intermediary fall through.¹²

¹² In the extreme case, when the intermediary has 100% of bargaining power and the grower has no outside option, neither situation yields a distinct advantage (see Case 5).

Table 1. Relative Investment Importance and Optimal Industry Structure

	Case 1	Case 2	Case 3	Case 4
Productivity of grower (G) and intermediary (I) investment				
G_T Trade	4	6	6	6
G_{NT}^{CON} No trade and contracting	4	2	2	0
I_T Trade	4	6	10	6
I_{NT}^{INT} No trade and integration	4	4	4	4
I_{NT}^{CON} No trade and contracting	4	2	2	2
Optimal grower investment				
Contracting $i_G^{CON} = [(1-\theta)G_T + \theta G_{NT}^{CON}]^2$	16	16	16	9
Integration $i_G^{INT} = [(1-\theta)G_T]^2$	4	9	9	9
First Best $i_G^{FB} = (G_T)^2$	16	36	36	36
Optimal intermediary investment				
Contracting $i_I^{CON} = [\theta I_T + (1-\theta)I_{NT}^{CON}]^2$	16	16	36	16
Integration $i_I^{INT} = [\theta I_T + (1-\theta)I_{NT}^{INT}]^2$	16	25	49	25
First Best $i_I^{FB} = (I_T)^2$	16	36	100	36
$S^{CON} - S^{INT} = (1-\theta)^2[(2I_T - I_{NT}^{CON})I_{NT}^{CON} - (2I_T - I_{NT}^{INT})I_{NT}^{INT}] + \theta^2(2G_T - G_{NT}^{CON})G_{NT}^{CON}$				
Relative surplus under contracting	+ 4	+ 2	- 2	- 3
Optimal structure	Contracting	Contracting	Integration	Integration

Notes: Numerical illustrations are a supplement to comparative statics with equation (14) for conveying the results. Although not considered in this paper the model can also predict both contracting and integration at the same time in the sense that neither arrangement dominates the other. Surplus from trade is divided as in the Nash bargaining solution ($\theta = 1/2$).

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