Strategy and Policy in the Food System: Emerging Issues

EDITED BY
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Proceedings of NE-165 Conference
June 20-21, 1996
Washington, D.C.

PART ONE: Vertical Market Coordination and Power

3. Information Asymmetry as a Reason for Vertical Integration

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Keywords: Vertical integration, information, product quality

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Information Asymmetry as a Reason for Vertical Integration

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The organizational structure of United States agricultural production has changed considerably over the past forty years. Poultry production has become completely industrialized, while vertical integration and production/marketing contracts have become prominent in other agricultural sectors. In 1990, about 22.5 percent of fed cattle were produced under such arrangements, compared with 16.7 percent in 1960 (Barkema et al. 1991). For hogs the change was more dramatic, increasing from 0.8 percent in 1960 to 14.5 percent in 1990. It has been suggested that hog sector industrialization is likely to continue unless counteracting policy actions are taken (Mintert et al. 1995). Further, Drabenstott (1994) reports similar vertical coordination trends over this period for fresh vegetables (from 45 to 65 percent) and processed vegetables (from 75 to 95 percent), and a moderate movement in that direction for feed grains.

There are believed to be two primary reasons for this phenomenon (Barkema 1993). The modern consumer is demanding more processed food because of the increasing percentage of dual-career and time-stressed one-parent families. Thus, there is a demand to move food preparation out of the kitchen and into more centralized locations. Similarly, there are demands for more specialized foods such as low-calorie and ethnic foods (Kinsey 1994, Mercier and Hyberg 1995: 38). At the same time, technology advances have provided the food industry with methods required to deliver highly processed food to the consumer (Barkema et al. 1991). However, the processes often require a qualitatively homogeneous supply of raw materials.

Traditionally, the market-pricing mechanism has been used to procure these materials. Consumers respond quantitatively to supermarket prices, while processors interpret these signals and send modified signals to growers via grades and standards. However, it has been suggested that price signals have become too "fuzzy" to guide the grower, whereas production contracts are "crystal clear" in specifying the genetics, feeding programs, and management programs that will provide the homogeneous product required to "meet the modern consumer's tighter specifications" (Barkema and Cook 1993: 54). Hurt, in his study of hog sector industrialization, also emphasizes the need for product consistency as a primary force behind the changing structure of pork production (Hurt 1994). Cook conjectures that the future may see greatly increased coordination among the producers, genetic suppliers, and processors in the grains and oilseeds industries (Cook 1994).

Others also address the interactions between increasingly fragmented demands and information flows (Streeter et al. 1991). Streeter et al. note that a traditional view of marketing has the retailer expending resources to manipulate consumer tastes and preferences (Packard 1957). They contrast this with a perspective more in line with increasingly information driven modern markets (Rapp and Collins 1990). In this latter paradigm, information structures are used to discover product characteristics and consumer demands, and to render product characteristics more in line with consumer demands. To illustrate the relevance of the more modern paradigm to food marketing, Streeter et al. cite as examples the detailed production specifications that companies such as Pioneer Hybrid and Frito-Lay write into the contractual agreements they require of some of their suppliers. These authors also emphasize the potential for information sharing along the marketing channel.

While the research discussed above has identified the trends and has suggested the causal factors, it has not as clearly identified why the traditional commodity-based approach to supply is not adequate in adapting to accommodate changing consumer and processor demands. Specifically, why are processors not sending adequate signals back to producers by appropriately pricing commodity attributes without becoming involved in the production process through production/marketing contracts or vertical integration? Explaining this coordination failure is the main theme of this paper.

Literature Review

However, before considering this issue, previously established reasons for vertical coordination and integration will be considered. The classic works in this area are the 1937 study by Coase and the more recent investigations of Williamson (1971, 1979, 1986), as discussed in Barkema and Cook (1993). This approach emphasizes transaction costs as principal determinants of the structure of an industry. Barkema and Cook identify two transaction costs that could be reduced or eliminated through integration or the use of contract arrangements—the search cost of procuring a large, steady supply of raw product, and the risk cost of procuring inferior raw product. If these are the root sources of industry reconfiguration, then they merit intense scrutiny because their implications for the family farm and the independence associated with farming may be significant (*Wall Street Journal*).

Deterministic transaction costs as discussed by Coase could be a source of the move to increased coordination. While these transaction costs have always existed and may be decreasing due to technology advances, it is possible that more scrutinizing consumers have caused producers and processors to incur more in transaction expenditures.[2] Frank and Henderson (1992) identify transaction costs as a factor in U.S. food industry vertical integration.

There is a long literature on the relationships between vertical coordination and market power. Until about 1980, increased vertical coordination involving a major player in a market was viewed critically for antitrust reasons by U.S. regulators (Rosengren and Meehan 1994). Since then, and with some theoretical and empirical justification, regulators have become more amenable to increased vertical coordination. Except for poultry, minor crops, and crops involving sunk investments and/or dependence on local processors, increased vertical coordination may not impede competition in agriculture.

Arrow identifies product sourcing uncertainty as a motive for vertical integration in the situation where producers know more about the quantity of future product supply than processors but processors could act upon this additional information if they knew it. This context does not seem applicable to agricultural products for two reasons. First, futures markets exist for many agricultural commodities. If producers knew additional information, they could profit from it by using futures contracts, and the futures prices would then aggregate and convey the information to processors. Second, even where futures markets do not exist, U.S. federal and state governments have put in place extensive networks of agricultural information gathering and dissemination in the form of county and Land Grant University extension services. In a related inquiry, Hirshleifer (1989) shows that vertical integration may be viewed as a hedging method when futures markets are not available. Thus, minor crops and regions where basis is variable may be particularly prone to vertical integration. Forward contracts are commonly used for many minor crops, and they provide risk transfer attributes similar to futures contracts.

There are other ways in which production sourcing uncertainty may provide incentive for vertical integration. Using a mail survey to beef packing plant managers by Sersland (1985) and economic engineering data from Duewer and Nelson (1991), Ward (1993) identifies significant increasing returns to size in that industry. Given the variability of weekly supplies that exist in the beef packing industry, the packing company has incentive to extend control over cattle supplies back toward the producer so as to ensure optimal flow through its operation lines (Jensen et al. 1962).

For hogs, Rhodes (1993, 1995) notes that to date industrialization has involved horizontal increases in size driven primarily by economies of size. While processors such as Tyson and Cargill also have very large hog production operations, they purchased their processing operations well after establishing their hog production operations. Rhodes concludes that, while the future may differ substantially from the past, the industrialization of hog production has not yet involved pure vertical integration. However, while formal vertical coordination through integration or producer contracts may not now be the norm in the hog industry, horizontal industrialization has probably facilitated informal coordination. In a University of Missouri survey, Grimes and Rhodes (1994) identified seven producers in the U.S. marketing an average of 0.94 million head in 1993, and fifty other producers marketing an average of 0.11 million head in that year. Together, these fifty-seven producers accounted for thirteen percent of national production. Even if processors are not involved in production, by high volume and statistical record keeping, processors sourcing from these farms will know quite a bit about what they are getting. Thus, one of the benefits of horizontal integration is the reduction in quality related information asymmetries between the producer and the processor.

From the analyses of the authors mentioned in the previous two paragraphs, it is clear that technological change has driven much of the horizontal industrialization phenomenon. For example, in the hog industry it has been estimated (Iowa State University Swine Task Force 1988) that in 1988 the modernized larger producers were producing at unit costs \$3-\$5/hundredweight below unit costs facing the average producer. Not only does new technology appear to be biased toward larger operations, it may be to a large extent embodied in the setting up of completely new "green field" investments. This need for ever-new capital together with ever-increasing returns to size means that those producers who remain in the business will probably require outside capital funding. The suppliers of capital may seek to monitor their investment through vertical integration or otherwise.

Carlton (1979) identified the failure of markets to clear as a motive for vertical coordination. A point to be made in favor of this possible reason is that the failure of a market to clear could give rise to stale product, and consumers may now be less tolerant of dated product than in the past. However, on the whole, this does not appear to be a satisfactory motive because, unlike many industrial markets, agricultural markets tend to be widely and promptly reported on. Further, improvements in transportation, storage, and information technology should have diminished any market-clearing problems.

Another possible motivation for vertical integration and/or production contracts involves the exclusive dealing attribute of these arrangements. If a producer is contractually bound to deal exclusively with a processor, then the costs of marketing can be avoided. The contract often entitles the processor to reject low quality product. Because grading can be arbitrary, and because it is often conducted by the processor, the producer is vulnerable to manipulation. Vertical integration solves this problem. This issue has been considered in detail by Gallick (1984). A related problem is that of asset specificity (Chisholm 1993, DeCanio and Frech 1993, Joskow 1985, 1987). It is often the case that a producer must deal with a particular processor because of location, the structure of the market, or human capital investments. This presents the processor with the opportunity to extract economic rent from producers by exercising market power. To be assured that this does not happen, vertical integration may occur or the producer may demand a long-term price-fixing contract prior to becoming involved in the industry. Asset specificity may be a concern for hog and poultry producers, and perhaps for sugarbeet producers contemplating the purchase of enterprise specific machinery.

In summary, many reasons have been identified for vertical coordination and some of them appear to be relevant to agriculture. These have mainly involved the circumvention of transaction costs, though some have emphasized the acquisition of firm-level information by processors. This paper will consider a market failure in conveying information about quality as a motive for increased vertical coordination. As such, it elaborates on the fuzzy information problem mentioned by Barkema and Cook, by Hurt, and by Streeter et al. among others. This market failure is identified as a possible reason for the inability of the market-pricing system to accommodate the consumer-driven demands for more detailed and homogeneous product specifications. The problem is akin to those discussed by Williamson (1971), who presents a general discourse on the effects of market failures on the structure of production; Rotemberg (1991), who shows that quality variability can make it more profitable, yet socially inefficient, to internally supply an input than to source the input from outside; and McGuire and Ruhm (1993), who demonstrate that a rational information-based wage schedule does not fully shift the productivity effects of drug use onto the remunerations of drug-using workers.

Information Market Failure

Processing firms that procure raw materials on the open market inspect the material and generally pay according to a predetermined price-quality schedule. Because testing is costly, tested material is often rendered inedible, and the biological determinants of the quality of the retail product are often incompletely understood, the quality tests provide only an indication of the suitability of raw material for the intended purpose. Mercier and Hyberg (1995: 37) make this point in the context of wheat quality, and state: "The lack of technology to easily and accurately predict end-use grain quality characteristics makes domestic millers and other end-users reluctant to pay quality premia for grain." Some of the rejected raw material may be suitable (statistical type I error), while some of the accepted material may be unsuitable (statistical type II error).

As the amount of value-added occurring in food processing increases and as the required specifications for the raw material become more stringent, material inspection must become more rigorous to keep pace. For example, U.S. Department of Agriculture (USDA) grades have long ceased to be adequate quality measures to meet the needs of food processors (Mercier and Hyberg 1995: 37). In March 1992, an executive from a major flour milling company identified and compared four criteria for measuring wheat quality (*Milling and Baking News* 1992). These four criteria were: (a) USDA grade standards, (b) a wheat millability quality index, (c) a measure of how the wheat's flour would meet end-user needs, and (d) Food and Drug Administration (FDA) food safety and nutrition standards. Ranking the criteria in order of importance for the milling industry, he placed them in reverse order—with FDA standards being most important and USDA grades being least important. This suggests that the processing industry takes food safety very seriously.

Their concerns are well founded. Quite apart from the human suffering, it has been estimated that the annual economic cost of contaminated food is between $4.5 and $12.4 billion (Roberts 1992). Caswell et al. (1994: 236) argue that an integrated food-quality control program is necessary to ensure food safety. They maintain that, "Farmers need more assurance than a spot market can offer that their efforts to produce products with improved safety will be compensated. Similarly, spot markets are also unlikely to provide adequate coordination to meet processor needs."

These conjectures will be addressed in this paper. Food quality problems occur in part because substandard food leaves the farm and is not primary-source identified thereafter. It will be demonstrated that a price-grade type incentive structure will cause a systematic underinvestment in farm-level food quality control when there is uncertainty in the grading and testing mechanisms. That such uncertainty exists is definite because of the usual sampling and measurement errors, because many of the tests identify proxies or indicators of the attribute that is truely of interest, and because if testing were completely accurate, then farm-level hygiene breakdowns would never be the source of foodborne diseases. This information failure gives rise to a processor incentive to circumvent test costs by vertically integrating or sourcing via production contracts.

The problem may be particularly relevant for products where quality is hard to identify in raw product, or is at a premium. Examples might be produce for niche or export markets, produce for processors who need consistent inputs, and produce prone to food safety problems. Caswell et al. (1994: 229) state:

> "Delivering food products with improved safety characteristics requires coordination among producers, first handlers, processors, and retailers. Vertical quality control systems can assure that such coordination can take place and is effective. Examples include specifying farm-level pesticide applications, setting acceptable animal drug residues, and enforcing sanitation standards."

Pesticide residues provide a good illustration of vertical coordination problems. It is well-known that pesticide residues are altered as produce moves toward the point of consumption (Eilrich 1991). The United States Office of Technology Assessment has also expressed concerns about the methodologies used to detect residues (Moye 1991). A National Research Council special committee (1993: 224) suggested that pesticide residue measurement errors may be of the order of 200 percent or more. This is in addition to the fact that sample residues may not be representative of average levels. Thus, a company seeking to safeguard its reputation or the reputation of a market it has a significant interest in may want to closely monitor pesticide management practices at the farm level.

The Model

Let there be two types of farms, identical in all aspects including volume of output except that one type has invested in quality-related capital and the other type has not. Such capital could be comprised of genetic stock, technical education, harvesting or storage equipment, or a new way of using inputs. Though many examples can be cited, for the purpose of exposition the reader might consider a dairy farmer who is contemplating investing in a new bulk refrigerated storage tank to reduce milk bacterial cell counts. This will increase the frequency of receiving the top grade price if price premia are paid for milk with low bacterial test counts.

Categorize product into two types: g for high-grade and b for low-grade.[3] While the firm that invests in capital may produce some low-grade products, the share of low-grade output in total output for the invested firm, denoted by $t_{b|i}$, is less than $t_{b|ni}$, which is the share of low-grade output in total output for the noninvesting firm. Let there initially be a strictly positive fraction, r_{ni}^{0}, of total producers that have not invested in the quality-improving technology. Equivalently, because all firms are identical in volume of production, r_{ni}^{0} can be interpreted as the fraction of total product coming from noninvested firms. The superscript 0 stands for the initial time point. Consider a later time point, denoted by the superscript 1, when the noninvestors have had time to reconsider their investment decision. Let the fraction of noninvestors who have decided to invest over this time period be $s_{i|ni}$, so that the time 1 share of total producers that have not invested is:

$$(1) \qquad r_{ni}^{1} = r_{ni}^{0}\left(1 - s_{i|ni}\right).$$

To rule out the trivial case where the incentive to invest is so strong that all have invested by time 1, let $r_{ni}^{1} < 1$ hold. If one allows for asset obsolescence, then $s_{i|ni}$ could be negative. This initial model specification is in the manner of McGuire and Ruhm (1993).

Now consider a food processor that does not observe farm-level decisions, but only the product at the factory intake point. The processing industry is perfectly competitive. The processor sample tests all product at the intake point but, because of sampling, the limitations of nondestructive testing, and cost considerations, the tests are not completely accurate. The testing procedure is common to all competing processors. Because of sampling, some lots of the product may not even be tested. A share $u_{-|g}$ of high-grade products is identified as low-grade by a minus on the test, and a share $1 - u_{-|b}$ (i.e., $u_{+|b}$) of low-grade products is identified as high-grade by a plus score on the test. Both $u_{-|g}$ and $u_{-|b}$ are assumed to be contained in the interior of $[0,\ 1]$. The processor recognizes the failings of its quality testing mechanisms, and is forced by competition from other processors to incorporate these failings into its quality pricing schedule.

At time point 1, the share of total product that is of good quality is:

$$m_g = \left(1 - t_{b|ni}\right) r_{ni}^1 + \left(1 - t_{b|i}\right)\left(1 - r_{ni}^1\right). \tag{2}$$

The first product term on the right-hand side is the share of good quality product coming from noninvested firms, while the other term is the share of good quality product coming from invested firms. The probability of a product being of high grade given a quality test failure can be calculated as:

$$\pi_{g|-} = \frac{u_{-|g}\, m_g}{u_{-|g}\, m_g + u_{-|b}\left(1 - m_g\right)} \tag{3}$$

from Bayes' theorem (Larson 1974). This equation can be motivated by a pooling argument. The numerator, $u_{-|g} m_g$, is the fraction of good quality product that fails the test. The denominator is the sum of the fraction of good quality product that fails the test and the bad quality product that fails it. Thus, the denominator is the fraction of total product that fails, and the ratio gives the fraction of test failures that are of good quality. Similarly, Bayes' theorem gives the probability of a product being of high grade given a quality test pass as:

$$\pi_{g|+} = \frac{\left(1 - u_{-|g}\right) m_g}{\left(1 - u_{-|g}\right) m_g + \left(1 - u_{-|b}\right)\left(1 - m_g\right)}. \tag{4}$$

Let P be the value of high-quality product to the processor, while $P - \delta$ is the value of low-quality product. Both high and low quality product are applied to the same use, so the purpose of testing is not to sort, but rather to control quality and protect the processor's reputation in the consumer marketplace. When quality is not certain, then the price paid is considered to be a probability weighted interpolation between P and $P - \delta$.[4] Thus, the price for product passing the test is:

$$P_+ = P\pi_{g|+} + \left(P - \delta\right)\left(1 - \pi_{g|+}\right) = P - \left(1 - \pi_{g|+}\right)\delta, \tag{5}$$

and the price for product not passing the test is:

$$P_- = P\pi_{g|-} + \left(P - \delta\right)\left(1 - \pi_{g|-}\right) = P - \left(1 - \pi_{g|-}\right)\delta. \tag{6}$$

Given the same processing technologies, if one processor does not pay these prices, then competition ensures that another will.

The farm which has invested in quality improvement receives P_+ on the share:

$$\mathcal{L}_{+|i} = \left(1 - t_{b|i}\right)\left(1 - u_{-|g}\right) + t_{b|i}\left(1 - u_{-|b}\right)$$

of output, and P_- on the share $1 - \mathcal{L}_{+|i}$ of output. Thus, the average price received by the investing firm is:

$$\bar{P}_i = P_+\mathcal{L}_{+|i} + P_-\left(1 - \mathcal{L}_{+|i}\right) = P - \left[\mathcal{L}_{+|i}\left(1 - \pi_{g|+}\right) + \left(1 - \mathcal{L}_{+|i}\right)\left(1 - \pi_{g|-}\right)\right]\delta, \tag{7}$$

from equations (5) and (6). From (2), (3), (4), and (7), it can be seen that the average price received by the invested producer is a nonlinear function of the parameters $\left\{t_{b|i},\ t_{b|ni},\ u_{-|g},\ u_{-|b}\right\}$. This demonstrates the nontrivial impact that detection failures and uncertainties about the nature of quality can have on production incentives.

Under substitutions similar to those giving rise to equation (7), it is found that the noninvested producer receives an average price:

$$\bar{P}_{ni} = P - \left[\mathcal{L}_{+|ni}\left(1 - \pi_{g|+}\right) + \left(1 - \mathcal{L}_{+|ni}\right)\left(1 - \pi_{g|-}\right)\right]\delta, \tag{8}$$

where $\mathcal{L}_{+|ni} = \left(1 - t_{b|ni}\right)\left(1 - u_{-|g}\right) + t_{b|ni}\left(1 - u_{-|b}\right)$.

Let the cost of investment per unit output be I. This investment decreases the percentage of low-quality output in total output from $t_{b|ni}$ to $t_{b|i}$. The farm will invest if the investment increases profit, i.e., if:

$$\bar{P}_i - \bar{P}_{ni} > I. \tag{9}$$

If the reverse inequality holds, then the farm will refrain from investing. Substituting (7), (8), $\mathcal{L}_{+|i}$, and $\mathcal{L}_{+|ni}$ into (9) gives the condition for investing as:

$$\left(t_{b|ni} - t_{b|i}\right)\left(u_{-|b} - u_{-|g}\right)\left(\pi_{g|+} - \pi_{g|-}\right)\delta > I. \tag{10}$$

Referring back to equation (1), the equilibrating variable is $s_{i|ni}$, the share of noninvesting farms that decide to invest over the time interval $[0,\ 1]$. Noninvestors will invest until either all have invested or inequality (10) holds with equality. Here the increase in the probability of high quality, $t_{b|ni} - t_{b|i}$, can be considered as the marginal product of investment, and $\left(t_{b|ni} - t_{b|i}\right)\delta$ as the value of marginal product. The expression $\left(\pi_{g|+} - \pi_{g|-}\right)\ \left(u_{-|b} - u_{-|g}\right)$ can be viewed as an index of the accuracy of testing because it would equal one if testing provided perfect information, and would equal zero if test results were uncorrelated with quality.

Will market forces induce a maximization of economic surplus to the industry? The investment increases the fraction of an initially noninvesting firm's product that is of good quality from $1 - t_{b|ni}$ to $1 - t_{b|i}$. From the discussion above, the investment increases industry revenue by $\left(t_{b|ni} - t_{b|i}\right)\delta$ per unit, so that the investment increases (decreases) industry surplus if:

$$\left(t_{b|ni} - t_{b|i}\right)\delta >(<) I. \tag{11}$$

For a Pareto optimal solution, a firm should invest if $\left(t_{b|ni} - t_{b|i}\right)\delta > I$, and this is the rule for investment when the processor and producer are integrated. Marketplace incentives ensure that initially noninvested firms invest until equation (10) holds with equality or all have invested. Therefore insufficient investment occurs when:

$$\left(t_{b|ni} - t_{b|i}\right)\left(u_{-|b} - u_{-|g}\right)\left(\pi_{g|+} - \pi_{g|-}\right)\delta < \left(t_{b|ni} - t_{b|i}\right)\delta, \text{ or}$$

(12)
$$\left(u_{-|b} - u_{-|g}\right)\left(\pi_{g|+} - \pi_{g|-}\right) < 1.$$

Because $u_{-|b}$, $u_{-|g}$, $\pi_{g|+}$, and $\pi_{g|-}$ are all in the interval [0, 1], with $u_{-|b}$ and $u_{-|g}$ being in the interior, this inequality always holds. Thus, underinvestment will occur whenever $r^1_{ni} < 1$ holds. For optimal investment to occur, I must not exceed the left-hand side of (10), a more stringent condition than being less than $\left(t_{b|ni} - t_{b|i}\right)\delta$. Subtracting the left-hand side of equation (10) from the left-hand side of (11) gives:

$$\left(t_{b|ni} - t_{b|i}\right)\left[1 - \left(u_{-|b} - u_{-|g}\right)\left(\pi_{g|+} - \pi_{g|-}\right)\right]\delta,$$

a positive number. This is the increase in surplus that would occur upon moving from a nonintegrated industry to a vertically integrated industry.

So why is surplus not maximized under the nonintegrated scenario? When establishing $\bar{P}_i$ and $\bar{P}_{ni}$ in equations (7) and (8), respectively, the producer is always paid the expected value of product given the test signal the processor receives. Thus, any distortions that arise are not due to biases in perceived values. Product that is graded as good receives a fair price, i.e., expected value, as does product that is graded as bad. The problem arises because, as reflected in equations (9), (10), and (11), the effect of inaccurate testing is to make average revenue for an invested firm and average revenue for a noninvested firm converge. At the limit, if the test provides no information, then $\bar{P}_i = \bar{P}_{ni}$ would result, and there would be no incentive to invest because there would be no pecuniary return on the investment.

The limiting case, where the test provides no information, is of some interest because in this case the externality involved is clear. The investing firm receives no reward for its outlay, but the expected value of total output increases. When the test is somewhat informative, then the firm receives some compensation for the outlay through an increase in average price received. However, the gap between invested firm and noninvested firm average revenues does not increase sufficiently to ensure a Pareto efficient outcome. Because imperfect information causes the market to insufficiently compensate the investing firm relative to the noninvesting firm, overinvestment will never occur. If I is sufficiently high that some but not all firms invest, then underinvestment will occur because there is an incentive for some firms to free-ride on the assumptions about quality that have been created by the investing firms.

When Testing is Costly

Now consider the case where testing is costly, at F per unit tested, and this cost is incident upon the producer. Let there be two types of product purchasing companies; those that test incoming product, and those that do not. There are now two decisions to be modeled; the investment decision, and which company to sell to. Because no premium is to be gained, product submitted to nontesting purchasing companies will come entirely from noninvested firms. Therefore, nontesting companies know that the unit value of incoming product is $P - \delta\, t_{b|ni}$, and pay accordingly. Thus, noninvesting firms will submit to nontesting companies if and only if $\bar{P}_{ni} - F < P - \delta\, t_{b|ni}$.

Because of the introduction of the market for untested product, it is necessary to redefine r^1_{ni}. In the new market situation, r^1_{ni} is the share of total tested product that comes from noninvested firms. Alternatively, r^1_{ni} can be interpreted as the share of noninvested firms who submit their product to testing companies in all firms who submit their product to testing companies. Expression m_g then becomes the share of total product submitted to testing companies that is of good quality. All other symbols retain their original meaning.

Now note that $\bar{P}_{ni}$ is decreasing in r_{ni}^1. This can be seen from noting that $\partial m_g / \partial r_{ni}^1 = t_{b|i} - t_{b|ni} < 0$ from equation (2), that $\partial \pi_{g|-} / \partial m_g > 0$ and $\partial \pi_{g|+} / \partial m_g > 0$ from equations (3) and (4), and that $\partial \bar{P}_{ni} / \partial \pi_{g|-} = (1 - \mathfrak{L}_{+|ni})\,\delta > 0$ and $\partial \bar{P}_{ni} / \partial \pi_{g|+} = \mathfrak{L}_{+|ni}\,\delta > 0$ from equation (8), and then using the chain rule to differentiate $\bar{P}_{ni}$ in equation (8) completely with respect to r_{ni}^1. When a noninvesting firm redirects its product from a testing company to a nontesting company, the share of total tested product that is from noninvesting firms decreases, i.e., r_{ni}^1 decreases. Therefore, when $\bar{P}_{ni} - F < P - \delta t_{b|ni}$ the markets are in disequilibrium and equilibrium is reestablished by noninvesting firms redirecting supply from testing companies to nontesting companies until $\bar{P}_{ni}$ increases to satisfy $\bar{P}_{ni} - F = P - \delta t_{b|ni}$.

The disequilibrium may be caused initially in many ways, but for the purpose of this section it will be assumed that an increase in F, possibly from zero, is the cause. However, note that when noninvesting firms redirect supply in this manner, $\bar{P}_i$ is affected also (it increases also). Through expression (9), this affects the incentive to invest. From expressions (9) and (10) and the fact that $(t_{b|ni} - t_{b|i})(u_{-|b} - u_{-|g})$ is independent of m_g, the effect of m_g on $\bar{P}_i - \bar{P}_{ni}$ has the same sign as the effect of m_g on $\pi_{g|+} - \pi_{g|-}$. Subtract (3) from (4) to obtain:

$$\text{(13)} \qquad \pi_{g|+} - \pi_{g|-} = \frac{m_g (1 - m_g)\,(u_{-|b} - u_{-|g})}{\left[(1 - u_{-|g}) m_g + (1 - u_{-|b})\,(1 - m_g)\right]\left[u_{-|g} m_g + u_{-|b}\,(1 - m_g)\right]},$$

which has an ambiguous comparative static with respect to m_g. Therefore, an increase in F can either increase or decrease $\bar{P}_i - \bar{P}_{ni}$ through its effect on the share of noninvested product being tested. If it happens that $\bar{P}_i - \bar{P}_{ni}$ increases, then some noninvesting firms that continue to supply to testing companies will invest. If it happens that $\bar{P}_i - \bar{P}_{ni}$ decreases, then the incentive to invest decreases and investment will eventually decline through obsolescence.

The case where $\bar{P}_{ni} - F \geq P - \delta t_{b|ni}$ can be similarly analyzed. In either case, because the effect of r_{ni}^1 (through m_g) on $\bar{P}_i - \bar{P}_{ni}$ is indeterminate, the possibility of multiple equilibria cannot be ruled out. The following is clear, however. Eventually, as F increases, it will become prohibitive so that all firms will submit to nontesting companies and no firm will invest. In this way it can be seen that the existence of testing costs can deter investment, and will eventually do so if testing costs are too high. This motivates vertical integration because a firm that both produces and processes does not need to test to learn about average quality. This testing cost motive for vertical coordination exists whether or not the test is accurate. Testing equilibria, with or without costly tests, cannot increase industry surplus relative to the integrated solution because the integrated solution completely solves the information asymmetry problem, while the testing solutions give rise to equilibria where the level of investment may be insufficient and may incur extra costs.

Discussion and Conclusions

The possible reasons for vertical integration are many and varied. Those that may be of importance to agricultural production include the Coase firm structure approach suggested by Rhodes (1995), Gallick (1984), and Joskow (1985, 1987), and the desire to control the variability of supply as suggested by Jensen et al. (1962), and by Ward (1993). To these reasons we add another; one which can to some extent be placed in the context of the Coase theory of firm structure. One of the "costs" involved in marketing intermediate goods is the cost of identifying quality. Even if it is costless to test for quality, the test will not be completely accurate. This imperfect accuracy is shown to decrease the market revenue of invested firms relative to noninvested firms. The incentive to invest in ensuring quality is reduced relative to the perfect information scenario because the difference in market revenues is lower than that which would maximize social surplus. As a result, underinvestment in the provision of quality occurs, and this underinvestment may occur particularly for crops where it is difficult and/or costly to detect quality differences. The reason is that imperfect information constitutes an externality. By increasing the average quality of product, investing firms provide benefits that the market does not fully reward. Vertical integration and, to a lesser extent, production contracts solve this problem because they remove the need to test for quality. This is the Coase (1960) solution to an externality, i.e., internalize it.

Other approaches to the problem exist. The Pigouvian subsidy approach has some merit. One could subsidize the cost of investment until optimum investment occurs. However, this requires detailed knowledge of the technology. Such knowledge is unlikely, even if data were readily available upon which to make engineering or econometric estimates. Also, in this scenario testing still occurs and if testing is costly then vertical integration still dominates the Pigouvian approach. Another second best approach would be to subsidize testing costs or research into testing for quality, but again avoidable costs are incurred. Further, investment would continue to be insufficiently rewarded because it cannot be fully verified.

Notes

[1]David A. Hennessy is Assistant Professor, Department of Economics, Iowa State University. He would like to thank the Department of Agricultural Economics at Washington State University for funding this research. He also appreciates the comments of Lee Blakeslee and two anonymous reviewers. Copyright 1996 by the American Agricultural Economics Association. Reprinted with permission from the *American Journal of Agricultural Economics* 78(1996):1034-1043.

[2]In the mid-1930s, Coase had been thinking about nondeterministic transaction costs. Though never published, his notes entitled "A Theory of Contract" are preserved at the University of Chicago's Regenstein Library.

[3]A continuous quality variable could be modeled for, but this would render the analysis less clear without affecting the nature of the results.

[4]For ease of exposition, linear interpolation is employed; however, nonlinear interpolations give qualitatively identical results.

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