Industry Integration Due to Technological Asymmetry and Market Imperfections: An Alternative Explanation Based on Bargaining Theory

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Abstract

This paper shows that horizontal industry integration can arise from transferable asymmetry in technologies and endowments. Vertical industry integration potential follows from market imperfections and concentration. These conditions fit the broiler industry well and offer an explanation in sharp contrast to the usual explanation based on pooling price risk.

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1. Introduction

This paper examines potential motivations for both horizontal and vertical integration of an industry using bargaining theory. Horizontal integration is shown to be advantageous when agents produce the same product but are characterized by transferable differences in technology and asymmetric endowments. Vertical integration is shown to hold potential when industries are related vertically and competition is less than perfect. In each case, the results are derived by application of the Nash bargaining solution.

A brief review of the broiler industry examines applicability of these characteristics. To date, the main explanation for integration of the broiler industry has been the sharing of input and output price risk (Knoeber and Thurman). The hueristic analysis suggests that the alternative explanation of this paper may be equally applicable. Which explanation better captures observed integration phenomena awaits further empirical analysis. However, given the current trend toward integration of the swine and other industries, entertainment of such alternative explanations is needed as a basis for more robust policy analysis and market structure evaluation.

The paper is organized as follows. In section 2, we study the impact of returns to scale on the potential for cooperation between two agents producing a homogeneous output. Each agent has the same fixed endowment of a productive factor which is used for production. Using the Nash bargaining solution (Nash), we maximize the product of agents' gains over the non-cooperative outcomes to investigate the potential for cooeration. In section 3, we repeat the same exercise for agents with different endowments. In section 4, we extend these models to the case

of many producers and show the potential for horizontal integration based on transferable differences in technology and asymmetric returns to scale. In section 5, we extend the analysis to consider potential for cooperation among vertically related firms in sectors with less than perfect competition. Section 6 argues that the salient features of integration of the broiler industry are consistent with the implications of the bargaining results. Section 7 concludes.

2. Differences in Technologies

Assume that there are two producers, each endowed with an amount L of the productive factor. The productive factor is considered to be essential for the production of output. One producer has technology $f_1(\ )$ and the other producer has technology $f_2(\ )$. We assume that $f_2(\ )$ is superior or identical to $f_1(\ )$ (which requires $f_2'(L) > f_1'(L)$ for all $L > 0$, i.e., the marginal product of the superior technology is greater than the marginal product of the inferior technology at all input levels). We further assume that when both producers cooperate in production they adopt producer 2's technology. Producer 1's share is α and the rest goes to producer 2. The price of output is fixed at unity. The Nash bargaining problem is

$$\max_{\alpha} \ [\alpha f_2(2L) - f_2(L)][(1-\alpha)f_2(2L) - f_1(L)]$$

s.t.

(1) $\quad \alpha f_2(2L) - f_2(L) > 0$

(2) $\quad (1-\alpha)f_2(2L) - f_1(L) > 0.$

These conditions ensure individual rationality, i.e., producers have an incentive to cooperate only if the gain from cooperation exceeds the gain from unilateral production. Constraints (1) and (2) can also be written as:

(1') $\quad \alpha > f_2(L) / f_2(2L)$

(2') $\quad \alpha < [f_2(2L) - f_1(L)] / f_1(2L).$

Combining (1′) and (2′) we get:

$$f_2(2L) - f_1(L) > f_2(L), \text{ or}$$

$$f_2(L) + f_1(L) < f_2(2L).$$

Under increasing returns to scale (IRS),

$$f_2(2L) > 2f_2(L) > f_1(L) + f_2(L).$$

Therefore, we conclude that IRS assures agents gain from cooperation. Gains from cooperation are also possible under decreasing returns to scale (DRS) when technologies are different and the superior technology is adopted. Gains from cooperation are impossible under DRS with identical technologies.

The first order condition (assuming an interior solution) of the Nash bargaining problems is:

(3) $$\{[(1-\alpha)f_2(2L) - f_1(L)] - [\alpha f_2(2L) - f_2(L)]\}f_2(2L) = 0$$

Manipulating (3) we get:

(4) $$\alpha = 1/2 + [f_2(L) - f_1(L)] / 2f_2(2L).$$

Substituting for α into constraints (1) and (2) verifies that both constraints are met under IRS.

Equation (4) suggests two results. First, the share of producer 2, the player with the superior technology, is greater than one half of the total output produced under cooperation. Second, the share of the producer with the superior technology is increasing in the gap between his technology and the other producer's technology and decreasing in the degree of returns to scale.

3. Different Endowments

Consider the case where the two producers have different endowments, i.e., producer 1 has an amount βL of the productive factor, where β is a positive scalar, and producer 2 has an amount L. We maintain our assumption that $f_2(\,)$ is superior or identical to $f_1(\,)$. The Nash bargaining problem is as follows:

$$\max_{\alpha} [\alpha f_2((1+\beta)L) - f_2(L)][(1-\alpha)f_2((1+\beta)L) - f_1(\beta L)]$$

s.t.

(5) $\alpha f_2((1+\beta)L) - f_2(L) > 0$

(6) $(1-\alpha)f_2((1+\beta)L) - f_1(\beta L) > 0$.

As before, conditions (5) and (6) ensure individual rationality.

The solution to the Nash bargaining problem is:

(7) $\alpha = 1/2 + [f_2(L) - f_1(\beta L)] / 2f_2((1+\beta)L)$

Substituting (7) into constraints (5) and (6) yields the feasibility condition:

$$f_2(L) + f_1(\beta L) < f_2((1+\beta)L).$$

Clearly, when identical technologies and DRS are present simultaneously, this inequality will not hold. However, gains from cooperation exist under DRS and different technologies given that the second technology is sufficiently superior to the first technology. Under IRS, potential gains from cooperation are certain because

$$f_2(L) + f_1(\beta L) \leq f_2(L) + f_2(\beta L) < f_2((1+\beta)L).$$

Two conclusions follow. First, $\beta < 1$ is a sufficient condition for the producer with the superior technology to get a share of the produce which is greater than or equal to 1/2. Otherwise, results are not conclusive regarding the share of the producer with the superior technology. Second, the share of the producer with the superior technology, producer 2, is decreasing in β for two reasons: (i) the higher the value of β, the higher is the share of producer 1 in the total amount of the pooled factor, and (ii) with a higher β the increase in production that results from cooperation arises more because of IRS than technology differences.

4. A Bargaining Explanation for Horizontal Integration

Now consider extension of the results of sections 2 and 3 to the case with many producers. This can be done allowing differences among producers either according to technology or

endowments. Clearly, the results of sections 2 and 3 demonstrate that producers can benefit from horizontal cooperation if either producers differ in technological superiority or in endowments of productive factors. For illustrative purposes, suppose n firms have different technologies and are ordered so that producer 1 has a technology superior to producer 2, producer 2 has a technology superior to producer 3, and so on. The following result demonstrates where the strongest attractions for horizontal integration are likely to be found.

Proposition 1: *If there are n producers indexed by numbers 1 to n such that the technology of producer i is superior to producer j for $i > j$, then (i) producer i will always prefer a coalition with producer j-k rather than producer j when $0 < k < j$, and (ii) producer j will always prefer to form a coalition with producer i+k rather than producer i where $0 < k < n-i$.*

Proof: (i) If producer i forms a coalition with producer j-k, then share that goes to producer i is

$$1/2 + (f_i(L) - f_{j-k}(L))/2f_i(2L), \quad k \geq 0,$$

and the amount producer i receives is

$$\{f_i(2L) + (f_i(L) - f_{j-k}(L))\}/2, \quad k \geq 0.$$

Since, by assumption $f_j(L) > f_{j-k}(L)$, producer i will prefer to form a coalition with producer j-k rather than producer j. (ii) If producer j forms a coalition with producer i+k, then the output that producer j gets is

$$\{f_{i+k}(2L) + (f_j(L) - f_{i+k}(L))\}/2, \quad k \geq 0.$$

Clearly, producer j will prefer to form a coalition with producer i+k rather than with producer i if

$$(8) \qquad \{f_i(2L) - f_i(L)\} < \{f_{i+k}(2L) - f_{i+k}(L)\}.$$

By the assumptions of technological superiority, condition (8) always holds. (QED)

Proposition 1 shows that horizontal integration will form first between the firm with the most superior technology and the firm with the most inferior technology because each has more

to gain by that cooperation. By repeated application of this result, one can show that producers with the most inferior technology will be successively recruited for further cooperation until other considerations come into play. That is, initial application of Proposition 1 implies that producer 1 will prefer a coalition with producer n and producer n will prefer a coalition with producer 1. Once this coalition has formed, regard the new coalition as producer 1 and reduce the number of producers by 1. Then a coalition will form between producer 1 and producer n-1, and so on. This growth in horizontal integration will occur in this fashion because of the transferability of technology. While not discussed explicitly here, a similar result based on differences in endowments can also be developed based on the results of section 3.

5. A Bargaining Explanation for Vertical Integration

This section turns to similar considerations among vertically related firms or industries (called producers). Consider n producers vertically linked such that the output of producer 1 is used as an input by producer 2, the output of producer 2 is used as an input by producer 3, and so on. Suppose producer k produces output Q using factors K and L where K is the output produced by industry k-1. Consider a case with less-than-perfect competition where producer k faces a downward sloping demand curve for its product (consider the vertical industry structure used by Just, Hueth, and Schmitz). For simplicity of illustration, suppose the price of K is fixed at some level p above its marginal cost and let its marginal cost be given by unity (see figure 1). This distortion in the input market may be due to a government regulation or other less-than-perfect competition associated, for example, with monopoly or oligopoly (or monopsony or oligopsony).

Assume initially that producers k and k-1 do not cooperate (are not integrated). The amount of K that producer k employs is given by the level at which marginal revenue product of

the producer is equal to p. Profit to producer k is given by the area labeled A in figure 1 whereas the profit for producer k-1 is given by the area labeled B. The combined profit is given by A + B. If the two producers integrate, it can be shown that the Nash bargaining solution will maximize the sum of profit to the two producers. For the integrated producer, K is available at its marginal cost. Thus, the amount of K employed by the integrated producer is given by $K^* > \hat{K}$. The profit of the integrated producer is given by the area labeled A + B + C which exceeds the combined profit of the non-integrated producers. Gains from integration equal to the area labeled C are available to split among the two parties in proportion to initial profits following the Nash bargaining solution.

A similar result can also be developed for a producer k facing an upward sloping input supply from producer k-1 and a fixed output price below the marginal value of use by producer k+1. (Furthermore, with more space, these results can be generalized to cases where the fixed price assumptions are relaxed.) These results demonstrate the following proposition.

Proposition 2: *In vertically related industries with less-than-perfect competition, the incentive for vertical integration between two related firms is given by the deadweight loss associated with market distortions internalized by the integration.*

This result suggests that gains from integration are larger and integration more likely where market distortions in absence of integration are larger and where elasticities of demand or supply are larger for given price distortions.

A by-product of this result is that this type of integration only makes sense when producers are directly related in the marketing chain. If they are not, then distortions are not internalized. This result also suggests that industry integration may eliminate much of the deadweight loss of less-than-perfect competition.

6. Application to Integration of the Broiler Industry

The integration of the broiler industry took place in the 1960's. Prior to the 1960's, the broiler industry was dominated by independent units of production including hatcheries, feed companies, farms, and processing plants. Perhaps the most successful integrator in the Delmarva Poultry Industry (which includes Delaware, Maryland and Virginia) was Frank Perdue. His success story began as a grower who developed a superior technology. Interestingly, the early stages of integration began by developing contracts with existing growers who possessed inferior technology or growers who were just getting into the business and had limited resources (labor, housing, energy, and water). Large growers who possessed adequate technology and substantial resources of their own were the last to integrate. As this integration took place, growers adopted housing specifications, farming instructions, and other inputs provided by the integrator. Thus, the technology of the superior producer was effectively imported to all integrated producers as producers cooperated in pooling resources. These observations parallel closely the implications of the horizontal integration results of Proposition 1 based on bargaining theory. Integration was motivated first by the largest technology gaps. Then the degree of integration increased to include firms with smaller technology gaps apparently as the capacity of marketing channels could be developed by the integrator.

Next consider observed vertical integration. The owners of processing plants and feed companies initiated the process of integration in the Delmarva Poultry Industry. Some (large) firms from each of these industries entered into contracts with growers by which growers and integrators became partners in raising and producing broilers. Subsequently, the broiler industry has continued to integrate to include not only processors, growers, and feed companies but successively also hatcheries, financial credit, veterinarian services, and research facilities in the

same integrated organization. Consistent with the implications of the vertical integration theory of section 5, in each case, integration took place by the coordination of successive stages of production directly linked in the marketing chain (USDA; Chavas and Johnson). Another factor worth noting is that the scale of firms involved in processing and feed milling were typically quite large so that perfect competition hardly seems to be an applicable model. For example, Perdue has an extensive radio and television advertising effort and commands considerable product recognition much as Tyson's does from the Arkansas production area. Thus, the market structure assumptions of Proposition 2 appear applicable.

7. Conclusions

The results of this paper demonstrate a substantial basis for observed horizontal and vertical integration of the broiler industry based on bargaining opportunities. Horizontal bargaining potential arises because of differences in technologies and asymmetric endowments of resources among producers. Vertical bargaining potential arises because of market distortions and imperfections, for example, when some stages of the marketing chain are concentrated. These explanations for integration stand in sharp contrast to explanations based on pooling input and output price risk advanced thus far in the literature.

A comprehensive or empirical test of the hypotheses of this paper against those advanced in the literature thus far is beyond the scope of this paper. However, a cursory heuristic analysis of the broiler industry illustrates that several critical characteristics of the framework advanced here were and are present in the Delmarva Poultry Industry supporting both horizontal and vertical integration. Obviously, more rigorous and comprehensive empirical testing is needed.

However, at this point, a bargaining explanation quite independent of price risk pooling appears to hold promise as a competing explanation for integration.

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Figure 1 : The need for integration