Product Development, Cost Seasonality, Region Marginalization, and a More Demanding Consumer

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Abstract

Agricultural production is becoming more like manufacturing in the routinization of processes, the extent to which raw materials are processed, capital intensity, and its emphasis on throughput. Some ascribe the changes to demand-side factors while others look to technological innovations. Emphasizing cost seasonality as a reference indicator for nature's role in agricultural production, this paper develops a simple model that includes both supply and demand sides. We show how cost seasonality can impede product development to meet consumer needs and find that there may be a ceiling level of cost seasonality below which a non-seasonal equilibrium production profile occurs. Price seasonality is decreasing in cost seasonality. An increase in demand for more-processed products induces a shift toward non-seasonal production. Regions with strongly seasonal cost advantages will produce lower-value products while less-seasonal regions will produce higher-value products. If a region with high-cost seasonality has a non-seasonal cost disadvantage, then an increase in demand for processing can reduce the region's competitiveness.

Keywords: industrialization, lifestyle changes, regional production systems, value added.

JEL classification: D2, L2, N5, Q1

PRODUCT DEVELOPMENT, COST SEASONALITY, REGION MARGINALIZATION, AND A MORE DEMANDING CONSUMER

Introduction

Agriculture, and particularly produce from smaller livestock species, has undergone striking changes since 1930 in the higher-income economies. Drabenstott (1994), Boehlje (1996), Blayney (2002), Key and McBride (2003), and others have commented upon many of these changes. Animals are being grown indoors, in a more controlled environment, and with less human intervention. Geographic production shares have changed, scale is larger, throughput is more intense, more attention is being paid to quality, and downstream involvement is more pervasive. The provocative phrases "factory farming" and "industrialized agriculture" have merit as descriptors of the resulting approach to production.

Confinement, genetics, and mechanization are widely regarded as being important in these changes. Less obvious are the drivers of these changes. Some see exogenous events on the demand side as being important for change at the farm (Senauer, Asp, and Kinsey 1991; Barkema 1993) and processing (Connor and Schiek 1997) levels. Official government demographic statistics and other survey statistics suggest that more families in high-income countries are time-stressed and are using higher incomes to purchase convenience, information, and differentiation as well as calories when buying food.

On the other hand, it is difficult to ignore supply-side issues, including innovations in biotechnology that facilitate control, and other technologies that substitute for labor. An important contribution to the literature is by Allen and Lueck (2002), who suggest that traditional, smaller-scale family farms are effective institutions in much of crop agriculture. The reason is that an owner-operator has stronger incentives than do employees to cope with the managerial decisions that arise when nature presents a steady flow of fresh decision contexts. Technologies that promote control and uniformity should reduce the extent of this advantage relative to the benefits of scale economies. Hennessy, Miranowski, and Babcock (2004) suggest that control technologies should also promote product development and accelerate the rate of innovation. Enhancing control often involves reducing the role of nature in production. Erdogdu (2002) and also Roosen, Hennessy, and Hennessy (2004) show that seasonal variability in animal production (particularly hogs and milk) is receding. The latter work suggests that the phenomenon is intimately connected with the incentive to avoid idling capital stock.

Identifying the cause(s) of changes is not necessarily straightforward. For example, more food processing may be occurring because more is known about manipulating food as a result of innovations in genetics and allied technologies. Agriculture receives many of these technologies primarily as benefits from public sector research and from medical sector spillovers. Then the advent of more food processing would be due in part to exogenous factors on the supply side rather than to increased demand for processing. So just observing change is insufficient evidence to ascribe cause. If the argument that exogenous changes on the demand side are driving observed behavior toward the supply end is to merit serious empirical scrutiny, then one must ask what the mechanism might be.

Focusing on the well-established supply-side phenomenon of deseasonalization in production (Tomek and Robinson 2003; Hayenga et al. 1985), this paper studies relationships between consumer preferences, processing activities, and production seasonality. Hennessy and Roosen (2003), and Roosen, Hennessy, and Hennessy (2004) have investigated equilibrium farm-level production seasonality but have not addressed how processing might interact with consumer preferences and equilibrium production seasonality. To the best of our knowledge, no formal economic literature exists on explaining any such relationships.

The issue is important because a frequently mentioned constraint on development in poorer countries is the difficulty in supporting food processing when supply is strongly seasonal (Hicks 2004; Lambert 2001; Dobson 2003). And this constraint is not limited to low-income countries. Under-utilization of milk processing plants because of seasonality is an important problem in Ireland and in New Zealand, as described in a report by Promar International (2003). That report, commissioned by the Irish government, also identifies the dairy industries in Ireland and New Zealand as being less successful than are those in Denmark and the Netherlands in penetrating markets for more extensively processed milk products. Processing was confined largely to lower-margin products that store well, such as butter, skim milk powder, and whole milk powder.

The general issue is also important because governments throughout the world, including at the U.S. state and federal levels, allocate funds to promote food sector value-adding activities. For example, the 2002 U.S. farm bill provided for value-added producer grants. In 2004, $13.2 million was made available in this way. But if the money is to be spent effectively for a particular region, there should be some understanding of roles for regional attributes in incentives to add value. There does not appear to be an economics literature on this theme.

In this paper we connect exogenous changes in consumer preferences to the phenomenon of agricultural industrialization. We do so by developing a model to show that the level of processing should be inversely related to a region's seasonal cost advantages. The reason is that capital is required for processing and some of this capital will remain idle for some of the year whenever throughput is seasonal. For the same reason, growing demand for further processing can induce non-seasonal production even when cost advantages to seasonal production remain. Oddly, we conclude that farmgate price seasonality should decrease with an increase in cost seasonality. The reason has to do with the incentive to process. It is shown that less cost seasonal production regions that are marginally competitive should produce higher-value products. In addition, increased demand for higher-value products should immiserize the more cost seasonal of two production regions because the act of processing dulls comparative advantage.

Model and Supply Side

An industry producing in a two-season year faces seasonal costs at $\bar{c}+\delta$ per unit output of raw materials in season A and $\bar{c}-\delta$ in season B, where $\bar{c}>0$, $\delta\geq 0$, and $\bar{c}>\delta$. Quantity δ is referred to as the cost seasonality parameter. Output share (of total annual output) in high-cost season A is $0.5-z$, with residual $0.5+z$ produced in low-cost season B. Variable z, referred to as the production seasonality variable, is endogenous to the model. The industry also faces farm-level non-seasonal quadratic costs that depend on the share of production in a particular season.

These costs amount to $0.5\gamma(s_i)^2, \gamma > 0, i \in \{A, B\}$, where $s_A = 0.5 - z$ in season A and $s_B = 0.5 + z$ in season B. Our cost specification is scale-neutral in the sense that the per year cost of producing amount Q_1 with share s_A in season A is Q_1 / Q_2 times the cost of producing Q_2 with the same share s_A in season A. The specification is a particular case of that in Hennessy and Roosen (2003), where the effects of policy variables on seasonal prices and production were considered. Share dispersion across seasons increases farm-level costs because the incentive to invest in use-specific skills and resources declines while adjustment costs are incurred when resources are temporarily redeployed.

The raw materials coming from farms can be transformed into processed product and the industry must choose the extent of processing. Produce leaving farms is either perishable or storage over seasons is prohibitively expensive, so that farm production in season $i \in \{A, B\}$ is processed in that season. If processing to level $n > 0$ occurs, then industry revenue amounts to $\alpha_0 n - 0.5\alpha_1 n^2$ per unit output, where $\alpha_0 > 0$ and $\alpha_1 > 0$. A quadratic revenue specification is chosen to preserve a (largely) linear model structure and so provide a simple working model that facilitates insights.

Processing requires capital, and the annual cost of capital for processing to level n is nF per unit of peak-load output, where $F \geq 0$ is the annual cost of capital per unit of processing engaged in. Processed product, as in tinned produce or skim milk powder, is assumed to be readily storable across seasons and we ignore storage costs in processed food markets. Since $\delta \geq 0$, it will readily be shown that peak-load is in season B with production share $0.5 + z$. Thus, annual capital costs are $nF(0.5 + z)$. This peak-load capital cost set-up is consistent with that in Roosen, Hennessy, and Hennessy (2004) except that the cost depends on the level of processing, n, our main variable of interest. Contributions in Tamime and Law 2001 indicate the present extent of mechanization and automation in milk processing and the trend toward more capitalization in processing.

The industry is perfectly competitive, so that industry choices of n and z are consistent with the maximization problem

$$\begin{aligned} \max_{n,z} \quad V(n,z) = \max_{n,z} \quad & \alpha_0 n - 0.5\alpha_1 n^2 - (\bar{c} + \delta)(0.5 - z) - (\bar{c} - \delta)(0.5 + z) \\ & - 0.5\gamma(0.5 - z)^2 - 0.5\gamma(0.5 + z)^2 - nF(0.5 + z). \end{aligned} \tag{1}$$

The objective function is clearly concave in n and z whenever $\Delta \equiv 2\gamma\alpha_1 - F^2 > 0$. Concavity is violated for F that is sufficiently large, but $V(n,z)$ is never convex in its arguments. We assume throughout that $\Delta > 0$. The first-order conditions for interior solutions establish

$$z^* = \frac{2\delta\alpha_1 - \alpha_0 F + 0.5F^2}{\Delta}; \qquad n^* = \frac{2\gamma\alpha_0 - \gamma F - 2\delta F}{\Delta}. \tag{2}$$

Both argument values are strictly positive (i.e., interior) when the value of $F \geq 0$ is sufficiently small. Observe that z^* and n^* are not linear in the value of F. This non-linearity arises from the fact that capital must meet peak-load needs, as reflected in the capital cost $nF(0.5+z)$.

It must be that $n^* > 0$ because otherwise non-positive revenue would attend positive costs. Therefore, $F < 2\gamma\alpha_0/(\gamma+2\delta)$. Notice also that z^* is bounded from below by 0 because $z^* < 0$ would imply high production in the higher-cost season and there are no countervailing motives in the model. Setting its value at the lower bound, $z^* = 0$, we have $\delta = (\alpha_0 - 0.5F)F/(2\alpha_1)$ as the set of parameters in (F,δ) space such that $z^*(F,\delta) = 0$. In addition, $\delta = (\gamma\alpha_1 + \alpha_0 F - F^2)/(2\alpha_1)$ is the parameter indifference curve along which $z^* = 0.5$.

RESULT 1. Let $\min\left[2\gamma\alpha_0/(\gamma+2\delta), \sqrt{2\gamma\alpha_1}\right] > F$. Then competitive equilibrium seasonality in the production of raw materials is

(a) null (i.e., $z^* = 0$) if $\delta \leq (\alpha_0 - 0.5F)F/(2\alpha_1)$. In that case, $n^* = (\alpha_0 - 0.5F)/\alpha_1$.

(b) completely seasonal ($z^* = 0.5$) if $\delta \geq (\gamma\alpha_1 + \alpha_0 F - F^2)/(2\alpha_1)$. In that case, $n^* = (\alpha_0 - F)/\alpha_1$.

Notice that $\gamma\alpha_1 + \alpha_0 F - F^2 > \alpha_0 F - 0.5F^2$ whenever $\Delta > 0$, which is assumed in Result 1. So the intervals defined in parts (a) and (b) of Result 1 do not overlap. For the second statement in each of parts (a) and (b), optimize equation (1) conditional first on

$z = 0$ and then on $z = 0.5$. To confirm the role of capital used in processing for equilibrium, set $F = 0$.

COROLLARY 1. Production seasonality is never null ($z^* > 0$) when $F = 0$ and $\delta > 0$. Production is completely seasonal when $F = 0$ and $\delta \geq 0.5\gamma$.

EXAMPLE 1. If $\alpha_0 = 10$, $\alpha_1 = 1$, and $\gamma = 1$, then $\min\left[2\gamma\alpha_0/(\gamma + 2\delta), \sqrt{2\gamma\alpha_1}\right] =$ $\min\left[20/(1+2\delta), \sqrt{2}\right]$. The result's part (a) requires that $2\delta \leq (10 - 0.5F)F$. If $F = 1$, then $\min\left[2\gamma\alpha_0/(\gamma + 2\delta), \sqrt{2\gamma\alpha_1}\right] > F$ and $2\delta \leq (10 - 0.5F)F$ whenever $\delta \leq 4.75$. Then there is null seasonality. On the other hand, $(\gamma\alpha_1 + \alpha_0 F - F^2)/(2\alpha_1) = 5$ while $\min\left[20/(1+2\delta), \sqrt{2}\right] > 1$ whenever $9.5 > \delta$. So $\delta \in [5, 9.5)$ ensures complete seasonality.

Suppose that $\alpha_0 = 10$, $\alpha_1 = 1$, and $F = 1$, as before, but $\gamma = 5$ instead. Then $\min\left[2\gamma\alpha_0/(\gamma + 2\delta), \sqrt{2\gamma\alpha_1}\right] > F$ if $47.5 > \delta$, while $\delta \leq (\alpha_0 - 0.5F)F/(2\alpha_1)$ if $\delta \leq 4.75$ so that null seasonality applies whenever $\delta \leq 4.75$. On the other hand, $(\gamma\alpha_1 + \alpha_0 F - F^2)/(2\alpha_1) = 7$ so that partial seasonality occurs whenever $\delta \in (4.75, 7)$ and complete seasonality occurs whenever $\delta \in [7, 47.5)$. As Corollary 1 suggests, a larger value for convexity parameter γ ensures a wider range of circumstances under which partial seasonality can occur.

Part (a) in Result 1 indicates how peak-load fixed costs can require complete suppression of production seasonality in order to make best use of processing capital. When the value of F is sufficiently low relative to the cost seasonality parameter, then it will always be optimal not to take advantage of cost seasonality. This might be the case in modern, large-scale hog production and dairying. In contrast, when the value of the cost seasonality parameter breaches a larger threshold then it is best to concentrate production in one season. This scenario is more relevant for crop production. We turn now to the case where $\gamma\alpha_1 > 2\alpha_1\delta + F^2 - \alpha_0 F > 0.5F^2$, i.e., interior solutions. From equation (2), we have the following.

RESULT 2. Let $\min\left[2\gamma\alpha_0/(\gamma+2\delta), \sqrt{2\gamma\alpha_1}\right] > F$. For interior competitive equilibrium seasonality in the production of raw materials, production seasonality increases with cost seasonality ($dz^*/d\delta \geq 0$) and the extent of processing decreases with cost seasonality ($dn^*/d\delta \leq 0$).

While neither of these comparative statics should be at all surprising, they do provide a clear microeconomic justification for concerns among agribusiness analysts that high farm-level cost seasonality impedes processing. We turn now toward developing an understanding of the roles of capital and product development in determining the pricing of raw materials. The industry is competitive, so prices for raw materials at the farmgate will be set at marginal costs. Write p_A and p_B as the respective season A and season B farmgate prices that support these output shares. Now for an interior solution, season A cost is $(\bar{c}+\delta)s_A + 0.5\gamma(s_A)^2$ so that season A marginal cost per unit of annual output is $\bar{c}+\delta+\gamma s_A = \bar{c}+\delta+0.5\gamma-\gamma z$.[1] Likewise, season B marginal cost is $\bar{c}-\delta+0.5\gamma+\gamma z$.

Substitute in from equation (2) at the optimum to obtain the equilibrium inter-season price spread as

$$p_A - p_B = \frac{2\gamma\alpha_0 F - \gamma F^2 - 2\delta F^2}{\Delta} = n^* F. \tag{3}$$

But Result 2 assures that $dn^*/d\delta \leq 0$.

RESULT 3. Let competitive equilibrium seasonality in the production of raw materials be interior. The inter-season price spread is decreasing in the extent of cost seasonality.

Price dispersion diminishes with an increase in δ because larger cost seasonality encourages more production seasonality. This is not helpful in facilitating throughput and capital use efficiency for any processor. In response, processors will reduce the extent of processing. This allows for a narrowing of the inter-season price spread because there is less exposure to the inefficient utilization problem.

Demand Side

With industry revenue as $\alpha_0 n - 0.5\alpha_1 n^2$, the marginal value of an increase in the extent of product development is $\alpha_0 - \alpha_1 n$. An increase in that marginal value may be represented by an increase in the value of α_0. Consumers seeking more processed foods may be viewed as having a larger value of α_0. Now considering interior solutions, we have from equation (2), $dn^* / d\alpha_0 = 2\gamma / \Delta > 0$ and $dz^* / d\alpha_0 = -F / \Delta < 0$. In addition, equation (3) conveys that $d(p_A - p_B) / d\alpha_0 = 2\gamma F / \Delta > 0$. Notice too from equation (2) that z^* has value 0 whenever $\alpha_0 \geq (2\delta\alpha_1 + 0.5F^2)/F$ and value 0.5 whenever $\alpha_0 \leq [(2\delta - \gamma)\alpha_1 + F^2]/F$.

RESULT 4. Let $\min\left[2\gamma\alpha_0/(\gamma + 2\delta), \sqrt{2\gamma\alpha_1}\right] > F$. Then

(a) production seasonality is null if $\alpha_0 \geq (2\delta\alpha_1 + 0.5F^2)/F$, and complete if $\alpha_0 \leq [(2\delta - \gamma)\alpha_1 - F^2]/F$.

For $z^* \in (0, 0.5)$,

(b) the inter-season price spread is increasing in the demand for product development; and

(c) production seasonality is decreasing in the demand for product development.

Part (c) conveys the idea that processors need to dampen production seasonality when growing demand for product development involves larger capital outlays on the part of processors. Eventually higher demand for product development will require a non-seasonal supply base; see part (a). Procuring a less-seasonal supply base will involve widening the inter-season price spread, the content of part (b). Part (b) bears consideration with Result 3. Suppose, as may well be the case, that technological innovations are biased over time toward cost deseasonalization and also that growing income has increased demand for product development. Then the net effect on the temporal trend in the inter-season price spread is to widen it. However, when production is under a contract with specified delivery schedules then inter-season price spreads should not have incentive effects.

Regional Systems and Changing Demand

To be clearer about the role that a change in demand could have on the organization of production, in this section we will modify the demand structure to be more flexible. Let there be two levels of product development, $n = 1$ and $n = 2$. Households are willing to pay T_1 for the less-developed product and $T_2 = T_1 + \mu$, $\mu > 0$, for the more-developed product. The number of households is fixed at $\bar{Q}$. Each household demands one unit of the good in total because the good is a necessity. There are also two production regions. Region N has cost seasonality δ_N while region S has cost seasonality $\delta_S < \delta_N$. Region N (S) has the capacity to produce Q_N (Q_S).

Region *N*

If the region chooses $n \in \{1,2\}$, then the cost per unit of annual output is given by the solution to

$$\begin{aligned}&\min_z \quad (\bar{c} + \delta_N)(0.5 - z) \\ &+(\bar{c} - \delta_N)(0.5 + z) + 0.5\gamma(0.5 - z)^2 + 0.5\gamma(0.5 + z)^2 + nF(0.5 + z).\end{aligned} \tag{4}$$

The first-order condition is

$$z_N^{*,n} = \frac{2\delta_N - nF}{2\gamma}, \tag{5}$$

so that cost for an interior solution is

$$C_N^n = \bar{c} + \frac{0.25\gamma^2 - \delta_N^2 - 0.25n^2F^2 + 0.5nF\gamma + nF\delta_N}{\gamma}, \tag{6}$$

with $dC_N^n / dn = 0.5F + z_N^{*,n} F \geq 0$ by equation (5). If prices for products n, P_n, satisfy

$$P_2 - P_1 > \frac{(0.5\gamma + \delta_N - 0.75F)F}{\gamma}, \tag{7}$$

then region N will produce the $n = 2$ good.

Region *S*

From equations (6) and (7), if $P_2 - P_1 > (0.5\gamma + \delta_S - 0.75F)F/\gamma$, then region S will produce the $n = 2$ product. Clearly, $\delta_S < \delta_N$ ensures that region S is the more likely to produce the $n = 2$ product. Using equation (5), the difference between region costs is

$$C_N^n - C_S^n = (\delta_N - \delta_S)\frac{(nF - \delta_N - \delta_S)}{\gamma} = (\delta_S - \delta_N)(z_N^{*,n} + z_S^{*,n}) \leq 0. \tag{8}$$

Thus, at either n value, region N is the more competitive. This is because the only cost difference between regions is given by parameter comparison $\delta_S < \delta_N$, and N can better tailor production to avail of the costs in its low-cost season. But $d[C_N^n - C_S^n]/dn =$ $(\delta_N - \delta_S)F/\gamma \geq 0$, so that the region's comparative advantage decreases at higher levels of product development. Its comparative advantage disappears entirely whenever both regions find non-seasonal production to be efficient.

Supply Meets Demand

We require that $Q_N + Q_S > \bar{Q} > \max[Q_N, Q_S]$, so that capacity will be slack in one or the other region. Since the good is a necessity, $T_1 > \max\left[C_N^1, C_S^1\right]$. There are three possible situations,

(1) $\mu \geq C_N^2 - C_N^1$: In this case, $\mu > C_S^2 - C_S^1$ and both regions produce the $n = 2$ product. Since S must be the marginal producer, $P_2 = C_S^2 > C_N^2$. Surplus of N is $(C_S^2 - C_N^2)Q_N > 0$, while that of S is 0.

(2) $C_N^2 - C_N^1 > \mu \geq C_S^2 - C_S^1$: In this case, S produces the $n = 2$ product but N produces the $n = 1$ product. Competition ensures that $P_1 - C_N^1 \geq P_2 - C_N^2$ and $P_2 - C_S^2 \geq P_1 - C_S^1$, that is, $C_N^2 - C_N^1 \geq$ $P_2 - P_1 \geq C_S^2 - C_S^1$. But $Q_N + Q_S > \bar{Q} > \max[Q_N, Q_S]$ means there

is surplus supply and it must come from S because that region has a higher cost for either product. And so $P_2 = C_S^2$, meaning that $P_1 - C_N^1 \geq C_S^2 - C_N^2$ so that surplus of N is $(P_1 - C_N^1)Q_N \geq (C_S^2 - C_N^2)Q_N > 0$, while that of S is 0. Relative to case (1), surplus of N is larger while that of S is the same.

(3) $C_S^2 - C_S^1 > \mu$: In this case, both regions produce the $n = 1$ product. Price is $P_1 = C_S^1$, so that surplus of N is $(C_S^1 - C_N^1)Q_N$. To compare with case (2), there $P_2 - P_1 \geq C_S^2 - C_S^1$ while $P_2 = C_S^2$ so that $C_S^1 \geq P_1$ and $(C_S^1 - C_N^1)Q_N$ is an upper bound on surplus of N in case (2).

Summarizing, we have the following.

RESULT 5. Under the specified conditions, region S produces the higher-value product in cases (1) and (2), while N produces that product in case (1) only. Surplus of region N is strictly positive. It decreases as preferences for the higher-value version of the necessity increases from $C_S^2 - C_S^1 > \mu$ through $C_N^2 - C_N^1 > \mu \geq C_S^2 - C_S^1$ to $\mu \geq C_N^2 - C_N^1$. In all cases, region S has zero surplus.

Non-seasonal Cost Advantage to Region *S*

To conclude we will model a slightly different scenario. Region N continues to have a seasonal cost advantage due to $\delta_S < \delta_N$ and (8). But region S has a non-seasonal cost advantage in the sense that cost per unit over the year is $\hat{C}_S^1 = C_S^1 - \rho$ for $n = 1$ and $\hat{C}_S^2 = C_S^2 - \rho$ for $n = 2$ where $\rho > 0$. This unit cost advantage may be due to lower energy, labor, land, or environmental compliance costs. The three cases are now as follows.

(1) $\mu \geq C_N^2 - C_N^1$: As before, $\mu > C_S^2 - C_S^1 = \hat{C}_S^2 - \hat{C}_S^1$ and both regions produce the $n = 2$ product.

The case has two possible situations,

(*i*) $C_S^2 - C_N^2 \leq \rho$: Then N is the marginal producer and $P_2 = C_N^2 \geq C_S^2 - \rho$. Surplus to S is $(C_N^2 - C_S^2 + \rho)Q_S \geq 0$, while that to N is 0.

(*ii*) $C_S^2 - C_N^2 > \rho$: Then S is the marginal producer and $P_2 = C_S^2 - \rho > C_N^2$. Surplus to N is $(C_S^2 - \rho - C_N^2)Q_N > 0$, while that to S is 0.

(2) $C_N^2 - C_N^1 > \mu \geq \hat{C}_S^2 - \hat{C}_S^1$: In this case, S produces the $n = 2$ product but N produces the $n = 1$ product. Again, there are two possible situations:

(i) $C_S^2 - C_N^1 \leq \mu + \rho$: Then N is the marginal producer and $P_1 = C_N^1$. Surplus to S is $(C_N^1 - C_S^2 + \mu + \rho)Q_S \geq 0$, while that to N is 0.

(ii) $C_S^2 - C_N^1 > \mu + \rho$: Then S is the marginal producer and $P_2 = C_S^2 - \rho$. Surplus to N is $(C_S^2 - C_N^1 - \mu - \rho)Q_N > 0$.

(3) $\hat{C}_S^2 - \hat{C}_S^1 > \mu$: In this case, both regions produce the $n = 1$ product. The two possibilities:

(*i*) $C_S^1 - C_N^1 \leq \rho$: Then N is the marginal producer and $P_1 = C_N^1 \geq C_S^1 - \rho$. Surplus to S is $(C_N^1 - C_S^1 + \rho)Q_S \geq 0$, while that to N is 0.

(*ii*) $C_S^1 - C_N^1 > \rho$: Then S is the marginal producer and $P_1 = C_S^1 - \rho > C_N^1$. Surplus to N is $(C_S^1 - \rho - C_N^1)Q_N > 0$, while that to S is 0.

This case-by-case information supports the following.

RESULT 6. An increase in the value of μ always reduces surplus to region N and may leave that region as the marginal producer with zero economic surplus.

A proof is provided in the Appendix. Region *S*, on the other hand, can only gain from strengthened demand for the more processed good. Notice that the region *N* production share decreases with μ. Blayney (2002) reports a decline in the traditional dairy region shares of U.S. milk production over 1975-2000.[2] The result is interesting because it identifies a context in which a region that has traditionally been very competitive as a production center becomes marginalized only because of how events on the demand side interact with the processing technology. Gains from taking advantage of seasonal cost efficiencies decline as demand for processing increases and other cost issues become more critical.

Conclusion

The intent of this paper has been to understand better how agricultural production systems interact with changing consumer demands. We chose one feature of the grower's decision environment that differentiates production systems: seasonality in cost. We showed that capital fixities in processing can make it efficient for a cost-seasonal production region to produce non-seasonally. Our model provides support for the opinions of many commentators that cost seasonality can impede the production of higher-value products. The inter-season price spread should decrease with the extent of cost seasonality but should increase with demand for product development. We also describe a scenario in which a traditionally profitable production region becomes marginal when demand for a more processed version of the commodity grows. This is because processing inadvertently erodes the traditional region's competitive advantage. We believe that these findings should be testable as hypotheses regarding the evolution of livestock markets.

Our model has not considered how demand-side seasonality could affect incentives to process. Demand-side seasonality is important for festive and religious food markets (e.g., Easter lamb). Over the past thirty years, production seasonality in the U.S. turkey sector has declined markedly, in large part because of industry efforts (Strausberg 1995). The National Turkey Federation represents growers and processors. It and its state-level affiliates have used state fairs, school visits, free recipe pamphlets, and the Internet to promote turkey TV dinners, summer turkey grilling, and winter soup recipes. In February 2003, the Federation awarded the Subway franchise restaurant chain as the first recipient of its annual Turkey on the Menu (T.O.M.) award (*Turkey Talk* 2003). The award citation reads, "Throughout its history, Subway has leveraged the broad appeal of turkey, which has become a popular item year-round and is closely associated with the great taste of Subway sandwiches." Clearly, the Federation believes that demand seasonality can be altered with effort. Whether animal production sectors over the years have made significant, deliberate, and costly efforts to deseasonalize cost structures is not presently apparent. But the nature of economic incentives to improve sector performance by attempting to reduce cost and or preference seasonality should be of interest to those concerned with food product development.

Endnotes

1. Remember, the model assumes that all fixed capital used is used in processing.

2. One should not confuse “region” with “regional system.” It may even become profitable for a farm in a traditional production region to use a system developed in another region. This will be more likely to occur when a system does not rely heavily on regional endowments.

Appendix

Proof of Result 6

Consider case (3*ii*). An increase in the value of μ from μ^0 to $\mu^0+\varepsilon$, $\varepsilon>0$, generates no change in surplus to N if the case does not change from (3). Leaving a change to case (1) for later, consider a change so that case (2) occurs. If the case becomes (2*i*), then surplus to N certainly falls. If the case becomes (2*ii*), then the change in surplus to N is $(C_S^2-C_N^1-\mu^0-\varepsilon-\rho)Q_N-(C_S^1-\rho-C_N^1)Q_N=(C_S^2-C_S^1-\mu^0-\varepsilon)Q_N<0$, where case (2) conditions are used.

Consider (3*i*). If the case becomes (2*i*) after an increase in the value of μ, then surplus to N does not change. Were the case to become (2*ii*), then surplus to N would increase. Can the case become (2*ii*)? That is, can $C_S^1-C_N^1\le\rho$ and $C_S^2-C_N^1>\mu^0+\varepsilon+\rho$? Namely, can $C_S^1-C_N^1\le\ \rho<C_S^2-C_N^1-\mu^0-\varepsilon$? No, because $C_S^1<C_S^2-\mu^0-\varepsilon$ violates the conditions of case (2). Therefore, the increase in the value of μ involves transition to case (2*i*) (or case (1), to be dealt with next).

Consider case (2*ii*). Surplus to N does not change whenever the case remains (2). If the case becomes (1*i*), then surplus to N falls. If the case becomes (1*ii*), then the change in surplus to N is $(C_S^2-\rho-C_N^2)Q_N-(C_S^2-C_N^1-\mu^0-\rho)Q_N=(C_N^1-C_N^2+\mu^0)Q_N<0$, where case (2) conditions are used.

Consider case (2*i*). If the case becomes (1*i*) after an increase in the value of μ, then surplus to N is unaffected. Can the case become (1*ii*), so that surplus to N would increase? This requires $C_S^2-C_N^2>\rho$ and $C_S^2-C_N^1\le\mu^0+\rho$, that is, $C_S^2-C_N^1-\mu^0\le\rho<C_S^2-C_N^2$. This is not possible because $C_N^2-C_N^1<\mu^0$ violates case (2) assumptions. Finally, when equilibrium is initially in either of cases (1*i*) or (1*ii*), then an increase in the value of μ has no effect. ■

References

Allen, D.W., and D. Lueck. 2002. The Nature of the Farm: Contracts, Risk, and Organization in Agriculture. Cambridge, MA: MIT Press.

Barkema, A. 1993. "Reaching Consumers in the Twenty-first Century: The Short Way Around the Barn." American Journal of Agricultural Economics 75(December): 1126–31.

Blayney, D.P. 2002. "The Changing Landscape of U.S. Milk Production." Statistical Bulletin No. 978, U.S. Department of Agriculture, Economic Research Service. Washington, DC.

Boehlje, M. 1996. "Industrialization of Agriculture: What Are the Implications?" Choices, vol. 11, First Quarter, pp. 30–34.

Connor, J.M., and W.A. Schiek. 1997. Food Processing: An Industrial Powerhouse in Transition, 2nd ed. New York: John Wiley and Sons.

Dobson, W.D. 2003. "Strategies for Developing Domestic and International Markets for Nicaragua's Dairy Products." Discussion Paper No. 2003-1. Babcock Institute, University of Wisconsin, Madison.

Drabenstott, M. 1994. "Industrialization: Steady Current or Tidal Wave?" Choices, vol. 9, Fourth Quarter, pp. 4–8.

Erdogdu, O.S. 2002. "Industrialization of Animal Agriculture: Seasonality in the Pork, Beef, and Milk Markets." MS thesis, Department of Economics, Iowa State University.

Hayenga, M., V.J. Rhodes, J.A. Brandt, and R.E. Deiter. 1985. The U.S. Pork Sector: Changing Structure and Organization. Ames, IA: Iowa State University Press.

Hennessy, D.A., Miranowski, J.A., and B.A. Babcock. 2004. "Genetic Information in Agricultural Productivity and Product Development." *American Journal of Agricultural Economics* 86(February): 73–87.

Hennessy, D.A., and J. Roosen. 2003. "A Cost-Based Model of Seasonal Production with Application to Milk Policy.*" Journal of Agricultural Economics* 54(July): 285–312.

Hicks, A., ed. 2004. Rural Based Food Processing Industry. Report of the APO Multi-Country Study Mission on Rural-Based Food Processing Industry (SME-OS1-00). Tokyo: Asian Productivity Organization.

Key, N., and W. McBride. 2003. "Production Contracts and Productivity in the U.S. Hog Sector." *American Journal of Agricultural Economics* 85(February): 121–33.

Lambert, I. 2001. "Problems and Constraints to the Development of the Agro-Processing Sector." Paper presented at the Dominica Country Conference, Cave Hill Campus, University of the West Indies, Barbados, January.

Promar International. 2003. Strategic Development Plan for the Irish Dairy Processing Sector. Report written on behalf of the Department of Agriculture and Food Enterprise Ireland, the Irish Co-operative Organisation Society, and the Irish Dairy Industries Association. March. http://www.agriculture.gov.ie/publicat/irish_dairy/contents.pdf. (accessed November 12, 2004).

Roosen, J., D.A. Hennessy, and T.C. Hennessy. 2004. "Seasonality, Capital Inflexibility, and the Industrialization of Animal Production." CARD Working Paper 04-WP 351, Center for Agricultural and Rural Development, Iowa State University.

Senauer, B., E. Asp, and J. Kinsey. 1991. Food Trends and the Changing Consumer. St. Paul, MN: Eagan Press.

Strausberg, S.F. 1995. From Hills and Hollers: Rise of the Poultry Industry in Arkansas. Arkansas Agricultural Experiment Station Special Report 170. University of Arkansas, Fayetteville.

Tamime, A.Y., and B.A. Law, eds. 2001. Mechanisation and Automation in Dairy Technology. Sheffield, UK: Sheffield Academic Press.

Tomek, W.G., and K.L. Robinson. 2003. Agricultural Product Prices, 4th ed. Ithaca, NY: Cornell University Press.

Turkey Talk. 2003. "Subway7 Takes Home National Turkey Federation's 1st Annual T.O.M. Award." Iowa Turkey Federation, Ames, IA. Spring, p. 14.