PRODUCT AND PROCESS CERTIFICATION IN IMPERFECTLY COMPETITIVE MARKETS

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Consumers, policy makers, and business decision makers are increasingly concerned about food safety and security. In the U.S. meat industry, certification programs could address some of these problems. This study builds a three-sector partial equilibrium model to analyze the distributional effects of implementing a certification program for meat product.

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INTRODUCTION

In this paper, we study the economic impact of a voluntary food product certification-program in the U.S. pork sector. The subject matter is pertinent not only because of increasing total market sales, but also because of rising consumer concerns about food product quality and producer concerns about imperfect competition. U.S. consumers spend approximately ten percent of their disposable income on food products and meat products are the largest category. The market for meat and poultry is in excess of 20 billion dollars and grows by five percent annually (Euro monitor 2004). The market is growing because the disposable income of consumers is increasing and fewer families have an adult member working in the home. It is thus not surprising to learn that the U.S. food firms pursue aggressive product differentiation strategies, by certifying product attribute claims and developing products with convenience attributes in an attempt to capture a rising share of the consumer dollar.

Furthermore, food product certification and food safety is a pertinent issue for the food industry, policy decision-makers, as well as consumers. For example, concerns about obesity and malnutrition, animal welfare, and environmental externalities, have influenced production practices and marketing strategies food products (e.g. see Agency Group 2002, Esfahani 2003, Halkias 2002, Martin 2004, Vansickle 2004). Despite these problems, it is not clear whether according certification standards can enhance consumer's welfare, as it depends on consumer willingness to pay, the product attributes, as well as the degree to which consumers are willing to substitute one version of a differentiated product for another as relative prices change. Furthermore, the impact of certification programs that begin at the farm on the welfare of farmers is ambiguous. The intriguing question is whether the program can enhance economic efficiency in a marketing environment with imperfect competition and imperfect product substitutability. Although these costs and benefits are hypothesized, previous studies do shed light on some of these issues. Golan et al (2001) gives an in-dept overview of current labeling schemes and claim that "labeling may be one of the best tools for increasing the match between preferences and purchases" (2001: p.147). Moreover, they also note that one of the producer benefits of the program is market access for involved

producers (2001: p.162). Marette et al (1999), and Crespi and Marette (2001 and 2002), use the Mussa and Rosen vertical product differentiation model (1978) to analyze a generalized food certification protocol in an imperfectly competitive industry. The model assumes that consumers strictly prefer the certified product, and that only a few firms can produce the certified product. While the policy implications from this model are rather straightforward, the behavioral assumptions built in the model are important drivers of these results. For example, Lutz (1997, 2000) and Nilsson (2002), note that the functional forms of demand, cost of production, but also the type of competitive behavior often drives the results in stylized vertical differentiation models. Antle (1999) argues that consumer preferences are heterogeneous, not all of them will strictly prefer the certified product, and that the cost of certification is often unknown.

In this paper, we develop a conceptual model of a certification scheme in the U.S. pork sector that relaxes the restrictive assumptions discussed above on consumer and producer behavior. The conceptual model allows for imperfect competition in multiple stages of the value chain, as well as imperfect substitutability in demand. The imperfection in product substitutability rests upon the notion that consumers are heterogeneous and demand for the non-certified product may not cease to exist in a post certification era.

The objective of this study is to analyze the economic impacts of implementing a certification protocol in the pork sector. We first build a conceptual model of a certification program in the value chain that encompasses heterogeneity in consumer and producer behavior. Second, we derive and interpret the optimal decision rules and comparative statics analytically for the general model. Third, we parameterize the model in order to quantify the potential economic impact of a certification program in the U.S. pork sector.

Conceptual Model

Figure 1 presents the economic unit of analysis. The upstream suppliers are the live animal farmers, and the downstream suppliers are the packer, the processor, and the retailing firm, which in turn supplies the final product to the consumer. A certification program can control a particular product attribute or the processes by which the product passes through the marketing channel. The program may for example regulate, or prohibit

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the usage of antibiotics, growth-promoting hormones, feed rations, environmental compliance, animal treatment in production, slaughtering practices, as well as the retail-shelf location. The consumer can buy the product Q_v or Q_y, where Q_v is the certified pork product, and Q_y the uncertified or conventional hog product. The certified input quantity is denoted as Q_z, whereas the uncertified or conventional unit is denoted as Q_{xk}. Other than being certified or conventionally produced, the products are homogeneous in characteristics space.

The downstream supplier can use choose between certified and conventional inputs to produce one unit of conventional goods. For notational convenience, the quantity of certified inputs that are allocated into the conventional process is denoted as Q_{zk}. Thus, both Q_{zk} and Q_{xk} are perfect substitutes in producing the conventional consumer good as indicated by the dashed arrow in Figure 1.

On the other hand, if the upstream firm's conventional output, Q_{xk}, were a perfect substitute in the intermediary firm's certified process, the downstream firm's marketing decision would closely resemble that of a Leontief technology, e.g. identical to that of Schroeter and Azzam (1990) and Hyde and Perloff (1998). Schroeter and Azzam (1990) and Hyde and Perloff (1998) derived the optimality conditions for a multi species meat provider to estimate the degree of oligopsony and oligopoly power. These two studies rely on rather strong assumptions about consumer and producer behavior. First, the downstream supplier can perfectly substitute across the products. Second, the marginal cost of processing is constant and independent of the production level of the other species.

Continuing, the consumers are divided into three broadly defined categories. For reasons discussed below, type LOW prefers good D; type HIGH prefers only good C, whereas type IND is indifferent between the two products. The model of demand thus is a mix of a vertical and horizontal differentiation model. Gabszewicz and Thisse define vertical product differentiation as "two variants are vertically differentiated whenever, sold at the same price, all consumers purchase the same variant" (p.283). Conversely, horizontally differentiated products may be preferred by some consumers, but not all. Martin, Petiz and Canoy, and Liu and Serfes (2004) present demand models that encompass the economic space between perfect horizontal and vertical differentiation.

The spirit of this study is to allow for demand that reflects the notion of heterogeneous preferences, and thus it is suitable to use a demand construct that is not a strict vertical or horizontal demand structure.
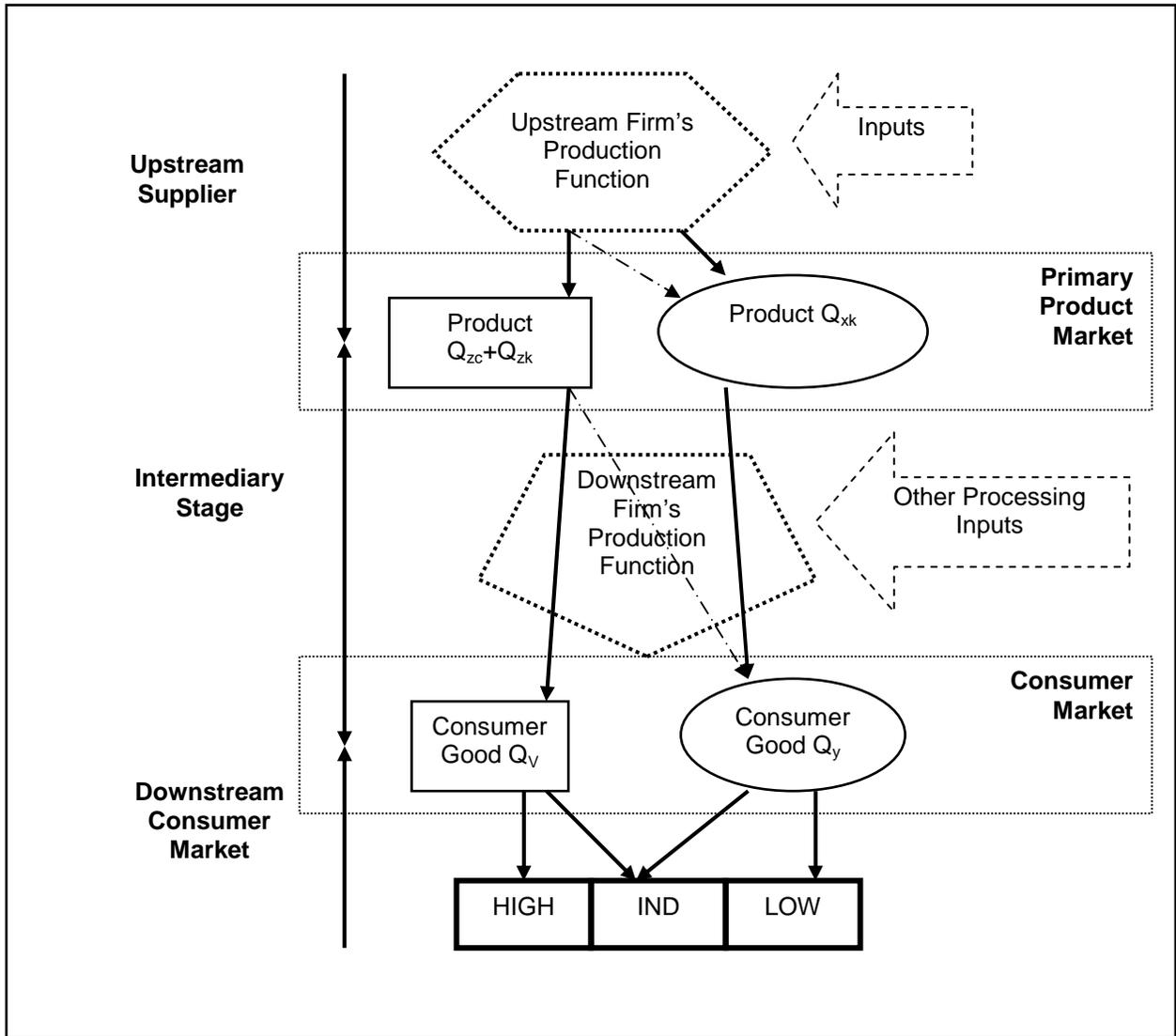

Figure 1. Conceptual Model of the U.S. Pork Value Chain.

Consumers with a higher willingness to pay (HIGH) may have a higher income, exhibit higher degrees of risk aversion, preferences for product attributes etc., than the IND and LOW segments. Furthermore, consumers with low willingness to pay may not value product attributes at all, but rather choose to purchase the product with the lowest price. The middle segment, however, are both price and product characteristic sensitive.

That is to say, the IND segment would purchase product Q_v if the combination of the number of product characteristics and the price tag would yield a higher level of utility than the Q_y product.

The market in figure 1 can encompass different economic behavior between the agents, such as perfect competition, Cournot or Bertrand, Stackelberg or by overtly colluding in prices, market shares, or quantities. The novelty of this model is that it can describe different types of strategic behavior at several stages of the value added chain. For now, it is assumed that the upstream firms (farms) and the consumers act as price takers, whereas the downstream firm (processor-retailer) has some degree of market power.

Analytical Model

This section presents an analytical model that can encompass imperfect competition, as well as imperfect product substitutability at both the upstream and the consumer end markets. Upstream firms act as price takers and have a linear aggregate inverse supply for conventional and certified products,

$$\begin{aligned} P_X &= a_X + bQ_X + dQ_Z \\ P_Z &= a_Z + bQ_Z + dQ_X \end{aligned}, \text{ where } a_x, a_z, b, d > 0, \text{ and } b^2 > d^2, \qquad (1)$$

where P_x and P_z is the aggregate supply of conventional and certified products, respectively. The parameters a_x and a_z are the supply intercepts, b the own price supply effect, and d the cross price supply effect. The cost of the certification program for the upstream suppliers can potentially be treated as a fixed cost and buried in the intercept a_z so, $a_x \le a_z$. Note that although the quantity coefficients are equal for both products, does not imply that the flexibilities are identical, i.e. the inverse of the price elasticities. recall that the flexibilities depend also on the price quantity ratio for each good.

The two downstream suppliers have market power in both the upstream and the consumer end markets. The firms are symmetric with constant returns to scale technology and so the cost of production is normalized to zero. The cost of certification is also normalized to zero. There are no binding capacity constraints in production, and thus an increase of certified production does not decrease the uncertified production. It is crucial to note that the firms can become potential multiproduct suppliers: this decision is

endogenized, rather than set exogenously as in Marette et al (1999), and Crespi and Marette (2001 and 2002).

Consumers are price-takers and perceive the certified and uncertified products as imperfect substitutes. They have an aggregate symmetric linear inverse demand for the certified and conventional goods,

$$P_V = \alpha_V - \beta Q_V - \gamma Q_Y$$
$$P_Y = \alpha_Y - \beta Q_Y - \gamma Q_Y$$
, where $\alpha, \beta > 0$, and $\beta^2 > \gamma^2$. $\qquad$ (2)

where P_v is the price for the certified good, P_y the price for the conventional good, α_v and α_y the overall willingness to pay for the certified and conventional product respectively. The marginal effects on quantities β and γ are assumed to be equal for both inverse demands, where β is the own price effect, and γ the cross-price effect. As with the aggregate supply relationship, the own price effect has to dominate the cross-price effect. The linear form of demand can be seen as a first order approximation to any true underlying aggregate long run demand function. Because the focus of this paper is to study the ex-ante and the ex-post long run equilibrium situation, this assumption comes at a relatively low cost.

The duopolistic firms have market power in both the input as well as the output markets, here referred to as bi-lateral market power. The firms play a myopic static Nash-Cournot game by maximizing profits with respect to the two strategic variables conventional and certified quantities (the technology in this study is not specified to allow a substitution of the certified good with conventional, however, preliminary findings indicate that this omission is not very costly).

The Nash assumption implies that the firm has no incentive to deviate from their strategy, and thus has zero conjectures with respect to the other firm's output choice. Furthermore, it is also assumed that the cross-good conjectures are zero, i.e. changes in output levels in other markets do not have an impact on the current output level.

For notational convenience, the (first) firm's quantities are $q_{z,1}$, which is the certified input marketed in the certified market, and $q_{x,1}$, the conventional good. Because there are two symmetric firms in the market, it suffices to characterize the first firm's optimization problem.

The firm's maximization problem is,

$$Max \ \pi = P_V q_{z,1} + P_Y q_{x,1} - P_X q_{x,1} - P_Z q_{z,1} \quad w.r.t. \ q_{x,1} \ , \ q_{z,1} \tag{3}$$

The (first) firm's first order conditions are

$$\partial\pi_1/\partial q_{x,1} = -\gamma q_{z,1} - \beta q_{x,1} + \alpha_y - \beta \ (q_{x,1}+q_{x,2}) - \gamma(q_{z,1}+q_{z,2}) + dq_{z,1} - bq_{x,1} - a_x - b \ (q_{x,1}+q_{x,2})$$
$$- d \ (q_{z,1}+q_{z,2})=0, \tag{4}$$

and

$$\partial\pi_1/\partial q_{z,1} = -\beta q_{z,1} + \alpha_v - \beta(q_{z,1}+q_{z,2}) - \gamma(q_{x,1}+q_{x,2}) - \gamma \ q_{x,1} - b \ q_{z,1} - a_z - b(q_{z,1}+q_{z,2}) +$$
$$d(q_{x,1}+q_{x,2}) - d \ q_{x,1} = 0. \tag{5}$$

It is assumed that the optimal solution is in the interior part of $R^{++}2$. Consequently, the duopolies buy $Q_X^* = n \cdot q_X^* = 2 \cdot q_X^*$ units of the conventional products, and $Q_Z^* = n \cdot q_Z^* = 2 \cdot q_Z^*$ units of the certified products. The duopolies provides $Q_V^* = n \cdot q_V^* = 2 \cdot q_V^*$ and $Q_Y^* = n \cdot q_Y^* = 2 \cdot q_Y^*$ units of the certified and uncertified good, respectively. Furthermore, we note that the optimal output levels can be solved in terms of the demand and supply parameters, and it is possible to calculate equilibrium prices and outputs, with and without certification. Thus, the equilibrium firm-level quantities are,

$$q_{x,1} = \frac{(\gamma+d)(\alpha_y - a_x) - (\beta+b)(\alpha_v - a_z)}{3D}, \tag{6}$$

and

$$q_{z,1} = \frac{(\gamma+d)(\alpha_v - a_z) - (b+\beta)(\alpha_y - a_x)}{3D}. \tag{7}$$

The total output is

$$Q_x = \frac{2(\gamma+d)(\alpha_y - a_x) - (\beta+b)(\alpha_v - a_z)}{3D}, \tag{8}$$

and

$$Q_z = \frac{2(\gamma+d)(\alpha_v - a_z) - (b+\beta)(\alpha_y - a_x)}{3D}. \tag{9}$$

where the denominator is $D \equiv (\beta+b)^2 - (\gamma+d)^2$ and it is always positive since $\beta > \gamma$ and $b > d$.

The firm's second order conditions are

$$H = \begin{bmatrix} -2(\beta+b) & -2(\gamma+d) \\ -2(\gamma+d) & -2(\beta+b) \end{bmatrix},$$ (10)

and for profit maximization, the Hessian must be negative definite, which implies that $|H_1| < 0$ and $|H_2| > 0$ (Novshek, 1993). The first minor, H_1, is negative because β and b are always positive. The second minor, H_2, is always positive because $b\beta > \gamma d$. Consequently, the negative definiteness of the matrix implies that the profit function is strictly concave and there is a unique global maximum for this problem.

However, although the Hessian matrix is negative definite, the optimal solution may not lie in the economic relevant region, i.e. the optimum might lie in the negative real domain. For an interior solution with strictly positive output the gradient vectors of the profit function must be positive around the borders, the first order conditions are evaluated at their optimal level, and an interior real positive solution implies that $\nabla F|_{x \neq 0, z=0} > 0, \nabla F|_{x=0, z_k=0, z \neq 0} > 0$. If the gradients are negative at their border, it implies that profit decreases if the firm increases production. Thus, the firm maximizes its profit by choosing not to produce that output and a non-interior solution is optimal. For the first gradient, we have,

$$\nabla F|_{\substack{x \neq 0 \\ z=0}} \begin{bmatrix} -\beta q_{x,1} + \alpha_y - \beta(q_{x,1} + q_{x,2}) - \gamma q_{z,2} - b q_{x,1} - a_x - b(q_{x,1} + q_{x,2}) - d q_{z,2} \\ \alpha_v - \beta q_{z,2} - \gamma(q_{x,1} + q_{x,2}) - \gamma q_{x,1} - a_z - b q_{z,2} - d(q_{x,1} + q_{x,2}) - d q_{x,1} \end{bmatrix} (11)$$

for the second gradient,

$$\nabla F|_{\substack{x=0 \\ z \neq 0}} \begin{bmatrix} -\gamma q_{z,1} + \alpha_y - \beta q_{x,2} - \gamma(q_{z,1} + q_{z,2}) + d q_{z,1} - a_x - b q_{x,2} - d(q_{z,1} + q_{z,2}) \\ -\beta q_{z,1} + \alpha_v - \beta(q_{z,1} + q_{z,2}) - \gamma q_{x,2} - b q_{z,1} - a_z - b(q_{z,1} + q_{z,2}) - d q_{x,2} \end{bmatrix} (12)$$

Hence, the sign of the gradients depend on the endogenous output levels. Although the profit function has a mathematically correct unique global maximum, the economic optimum may be a non-interior solution.

The economic insight offered by these systems of equations may have strong economic implications, both at a managerial firm level perspective, as well as from a policy perspective. In particular, situations can arise in which a single product firm does not wish to become multiproduct provider, despite the fact that it has market power. Thus, the firm's decision to become a multiproduct provider depends on equilibrium output, prices, and demand and supply characteristics. Previous literature might have

missed this point when studying the behavior of multiproduct oligopolies that have market power only in one market (input or output), whereas this study assumes market power in potentially both. Shaked and Sutton (1982) were amongst the first to note this particular peculiarity in imperfectly competitive industries, when they studied strategic interactions between an incumbent firm and an entrant. Marette et al (1999), however, does not consider endogenizing the firm's decision to become a certified provider.

Thus, from a policy standpoint, it is warranted to consider how firms react to changes in demand and/or supply due to the implementation of a certification scheme. If the firms have market power, an implementation of a certification scheme or introduction of a new product line, may actually crowd out the old products. On the other hand, there may also be a situation in which a public initiative to implement a voluntary certification system is not adopted by the industry stakeholders: it may not be in the best interests of the industry stakeholders to implement a certified product line, if the firms maintain higher profit by not producing the certified product. Alternatively, substitution or complementary relationships in demand may provide opportunities to further exploit market power in one or both markets.

Comparative Statics

If an economically interesting interior solution to the problem exists, it is possible to analyze how a change in the demand and supply parameters affects the equilibrium output levels. The comparative static exercise in this problem is slightly complex due to the imperfect competition and imperfect substitutability assumptions.

The welfare impact of the differentiation program in an imperfectly versus perfectly competitive market can be potentially vastly different. Bulow et al (1985), Quirmbach (1988), and Caputo (1996 and 1998) provide insight on these complexities. Bulow et al study how the competitive behavior between suppliers changes when the option arises to serve two independent markets. They coin the terms strategic substitutes and strategic complements, and show that depending on how the firm's perception of competition determines the equilibrium when accessing a new market. They show that the producer's profit, as well as consumers' surplus may decrease when firms are segmenting the markets. Quirmbach (1988) analyzes an oligopolistic market and shows that when there is a positive demand shift, the effects on prices and quantities are

ambiguous. Essentially, the effect on production level and prices of a positive demand shift depends on the demand and supply elasticities, firm conjectures, and the comparative advantage compared to international markets. Caputo's framework, furthermore, has the potential to address both Bulow et al and Quirmbach problem. By approaching the optimality conditions of an imperfectly competitive industry via the Primal-Dual approach (Silberberg 1974), Caputo derives the optimal response by each firm. In our model, however, we extend this perspective further by allowing for imperfect substitutability as well as market power at multiple stages.

With a little abuse of notation, the following condition must hold at an optimum

$$J_3 X^*_1 + {}_3B_1 = 0, \tag{13}$$

where J is the Jacobean matrix of the first order conditions (e.g. the Hessian), x^* are the endogenously optimized output variables, and finally B the total differential of exogenous demand and supply parameters. The latter matrix is

$$B = \begin{array}{l} - q_{z,1}\underline{d}\gamma \; - \; q_{x,1}\underline{d}\beta \; + \; \underline{d}\alpha_y \; - \; (q_{x,1}+q_{x,2})\underline{d}\beta \; - \; (q_{z,1}+q_{z,2})\underline{d}\gamma \; + \; q_{z,1}\underline{d}d \;\; - \; q_{x,1} \; \underline{d}b \; - \; \underline{d}a_x\text{-} \\ (q_{x,1}+q_{x,2})\underline{d}b \; - \; (q_{z,1}+q_{z,2})\underline{d}d, \\[2mm] -q_{z,1}\underline{d}\beta + \; \underline{d}\alpha_v \; - \; (q_{z,1}+q_{z,2})\underline{d}\beta \; - \; (q_{x,1}+q_{x,2})\underline{d}\gamma \; -q_{x,1}\underline{d}\gamma \; - \; q_{z,1}\underline{d}b \; - \; \underline{d}a_z \; - \; (q_{z,1}+q_{z,2})\underline{d}b \; - \\ (q_{x,1}+q_{x,2})\underline{d}d \; - \; q_{x,1}\underline{d}d. \end{array} \tag{14}$$

where $\underline{d}$ is the differential operator.

Consequently, the system of equations to consider is

$$X^* = - J^{-1}B. \tag{15}$$

where the vector $-J^{-1}B$ predicts the optimal changes in output quantities of conventional, certified used in conventional markets, and certified products marketed in the certified markets, respectively, as demand and supply parameters changes. Moreover, imposing symmetry implies that the impact on the endogenous variables of changes in the exogenous parameters for both firms is identical.

We can now evaluate how an increase in α_v, ceteris paribus, affects the optimal output levels (note that a decrease has the same magnitude as an increase, but with an opposite sign),

$$\begin{array}{l} \dfrac{dq_{x,1}}{d\alpha_v} \\[2mm] \dfrac{dq_{z,1}}{d\alpha_v} \end{array} = \frac{\alpha_v}{2D}\begin{bmatrix}(d-\gamma)\\(\beta+b)\end{bmatrix}=\begin{bmatrix}<>\\>\end{bmatrix}, \tag{16}$$

The effect of an increase in consumer willingness to pay for the certified increase the certified output increases the certified output, but has an ambiguous impact on the conventional production. Conventional output increases if $d > \gamma$. The magnitude of the quantity and price changes depends on values of the demand parameters.

Because of symmetry restrictions, the effects of changing the consumer willingness to pay for the conventional good has an equal but opposite effect,

$$\begin{array}{c} \dfrac{dq_{x,1}}{d\alpha_y} \\ \dfrac{dq_{z,1}}{d\alpha_y} \end{array} = \frac{\alpha_y}{2D}\begin{bmatrix} (b+\beta) \\ (d-\gamma) \end{bmatrix} = \begin{bmatrix} > \\ <> \end{bmatrix}. \tag{17}$$

That is, the conventional output increases for a positive demand shock, but the effect is ambiguous for certified good production. The certified output level increases if $\gamma < d$.

A change in the own-price parameter yields the following matrix,

$$\begin{array}{c} \dfrac{dq_{x,1}}{d\beta} \\ \dfrac{dq_{z,1}}{d\beta} \end{array} = \frac{3\beta}{2D}\begin{bmatrix} q_{z,1}(\gamma-d)-q_{x,1}(b+\beta) \\ q_{x,1}(\gamma-d)-q_{z,1}(b+\beta) \end{bmatrix} = \begin{bmatrix} <> \\ <> \end{bmatrix}, \tag{18}$$

The effect on conventional production is positive if $q_{z,1}(\gamma-d) > q_{x,1}(b+\beta)$, and also positive for certified production if the converse holds, i.e. $q_{x,1}(\gamma-d) > q_{z,1}(b+\beta)$.

The last parameter in the demand equation is γ, which indicates how differentiated the products are in the eyes of the consumers. As the two product lines become more homogeneous in the eyes of the consumer, the parameter γ increases (Shy, 1993). Thus, the $J^{-1}B$ matrix is

$$\begin{array}{c} \dfrac{dq_{x,1}}{d\gamma} \\ \dfrac{dq_{z,1}}{d\gamma} \end{array} = \frac{3\gamma}{2D}\begin{bmatrix} q_{x,1}(\gamma-d)-q_{z,1}(b+\beta) \\ q_{z,1}(\gamma-d)-q_{x,1}(b+\beta) \end{bmatrix} = \begin{bmatrix} <> \\ <> \end{bmatrix}, \tag{19}$$

and the firm's conventional output increases if $q_{x,1}(\gamma-d) > q_{z,1}(b+\beta)$, and the certified output increases if $q_{z,1}(\gamma-d) > q_{x,1}(b+\beta)$.

It is now appropriate to consider exogenous shifts in the supply curve. Similar to changes in demand intercepts, the effects of shifting the supply curves have the same

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affects, but with opposite signs. First, consider a change in the conventional supply intercept, a_x,

$$\frac{\dfrac{dq_{x,1}}{da_x}}{\dfrac{dq_{z,1}}{da_x}} = \frac{a_x}{2D}\begin{bmatrix} -(b+\beta) \\ (\gamma-d) \end{bmatrix} = \begin{bmatrix} < \\ <> \end{bmatrix}. \qquad (20)$$

Thus, if the conventional supply shifts upwards, the firm output decreases. However, for $(\gamma-d)>0$, the certified output is increasing. A positive shock in the certified supply intercept,

$$\frac{\dfrac{dq_{x,1}}{da_z}}{\dfrac{dq_{z,1}}{da_z}} = \frac{a_z}{2D}\begin{bmatrix} (\gamma-d) \\ -(b+\beta) \end{bmatrix} = \begin{bmatrix} <> \\ < \end{bmatrix}, \qquad (21)$$

the output effects of changing the certified intercept are in opposition to that of changes in the conventional supply intercept.

Next, consider a change in the supply slope coefficient, b.

$$\frac{\dfrac{dq_{x,1}}{db}}{\dfrac{dq_{z,1}}{db}} = \frac{3b}{2D}\begin{bmatrix} q_{z,1}(\gamma-d)-q_{x,1}(b+\beta) \\ q_{x,1}(\gamma-d)-q_{z,1}(b+\beta) \end{bmatrix} = \begin{bmatrix} <> \\ <> \end{bmatrix}. \qquad (22)$$

Thus, the impact of changes in the supply slope coefficient have the same impact on firm output levels, as changes in the demand slope. The last case to consider is a change in the cross product term in the supply function, d.

$$\frac{\dfrac{dq_{x,1}}{dd}}{\dfrac{dq_{z,1}}{dd}} = \frac{3d}{2D}\begin{bmatrix} q_{x,1}(d-\gamma)+q_{z,1}(b+\beta) \\ q_{z,1}(b+\beta)-q_{x,1}(d-\gamma) \end{bmatrix} = \begin{bmatrix} <> \\ <> \end{bmatrix}, \qquad (23)$$

Conventional output increases if $q_{x,1}(d-\gamma)>-q_{z,1}(b+\beta)$, and certified output increases if the converse holds, i.e. $q_{z,1}(d-\gamma)>-q_{x,1}(b+\beta)$.

Empirical Application

Agribusinesses in the U.S. pork sector are implementing a variety of certification schemes. At the upstream live-animal stages, the National Pork Board has instituted

voluntary programs such as the Pork Quality Assurance program (PQA), as well as the Swine Welfare Assurance Program (SWAP). The PQA was instituted in 1989 to address proper antibiotic use on farms. SWAP started in 2003 as an effort to guarantee ethical live animal treatment on farms and in slaughter plants. However, the compelling question is whether NPB's SWAP has the potential to guarantee quality for animal-welfare concerned consumers and add value for compliant farmers.

At the downstream levels, the National Council of Chain Restaurants (NCCR), and the Food Marketing Institute (FMI) launched the Animal Welfare Audit Program (AWAP) in 2003 to meet the public concerns about the housing and treatment of animals on farms and in slaughter plants. Individual food service providers are responding to animal welfare issues, and to concerns about consumer nutrition. In the summer of 2003, the McDonald's Corporation launched both an antibiotics policy as well as a new menu with an expanded variety of healthy meal choices for customers. The objective of the antibiotics policy is to prevent development of antibiotic resistant bacteria strains (Mc Donald's 2003). The objective of the new menu is to attract health conscious consumers and reduce the risk of losing their patronage as well as that of those who might accompany them to a meal. An important issue to address is how programs like these affect upstream suppliers' and consumers' welfare. The intriguing question is if these aforementioned programs can enhance the downstream suppliers' potential for market power, or provide a source for alleviating market power.

Public policy makers have also taken an active interest in implementing certification programs. Golan et al (2001) discussed the public role of creating initiatives and forming rules for food-certification program rules in the U.S. food chain. Moreover, the USDA agencies currently provide oversight for the National Organic Program (NOP), the Process Verification Programs (PVP), and the Country of Origin Labeling Act (COOL). The NOP sets the standards for organic food products, and uses an independent auditor to certify compliance with the NOP guidelines. Compliance with the PVP's also uses third party auditors. COOL is a mandatory labeling scheme to inform the consumer about country of origin of food commodities such as meat, fish, fresh fruit, vegetables, and peanuts among others. Consequently, from a normative perspective the problem is to design a certification program that can enhance the overall economic efficiency.

The previously presented model may be useful in providing some quantitative answers to the aforementioned issues. As this study is similar to a counterfactual study, it imposes a few limitations in the empirical data application (e.g. see discussion in Hall 2003 and references therein). Other than current marketing information, there is no value chain wide certification program implemented for pork products in the U.S. for which data exists. Consequently, this study focuses on two reference points: an ex-ante and an ex-post certification situation, where both situations refer to long-run equilibrium conditions. The comparative analysis can yield insight into how the ex-post equilibrium adjusts due to changes in demand substitutability and the cost structures of firms.

Thus, in addressing these issues, a number of empirical assumptions are invoked. The first assumption concerns the relationship between upstream and downstream suppliers in the industry. This model assumes that upstream and downstream suppliers are separate entities. Thus, this approach ignores issues related to completely vertically integrated meat packing plants, as well as contracting and captive supplies. In forthcoming research, this assumption will be relaxed, to account for varying degree of contracting relationship in the pork value chain. According to GIPSA *Packers and Stockyards Statistical Report*, the four firm hog-slaughter industry concentration ratio is 82 percent (2001). The USDA Agricultural Outlook Statistical Indicator database has information about current production levels and prices, which are displayed in Table 1 below.

Table 1. Base Line Data (in Live Weight Equivalent).

Quantity	C4	Farm Gate Price	RetailPrice
17.64	14.43	0.48	1.44
Million lb		$/lb	$/lb
Source:			
GIPSA			
and USDA			

Business and Company Resource Center reports that Tyson, ConAgra, Cargill, and Smithfield are the industry leaders in the U.S. meat packing industry (note that these firms are not only multi-specie, but also provide an array of other food products, marketed under national brands). These four firms have a number of desirable traits. First, the firms have a national scope, and as such are suitable firms that could potentially implement a food system wide certification scheme. Second, the four largest firms carry brands that are recognized by the consumers, who are wiling to pay a premium for these

products. Lusk, Nilsson, and Foster (2004) found that consumers are willing to pay a premium for nationally branded pork products over store branded and no branded pork products. The model makes three further assumptions regarding the downstream supplier's behavior: (a) that the firms are symmetric; (b) the firms have market power at the consumer stages; (c) the firms have market power at the upstream stages. A forthcoming study will analyze the impact on the results from these assumptions.

By using the optimality conditions from the analytical model, it is possible to solve for equilibrium prices and quantities ex-ante and ex post certification era. The ex-ante equilibrium rates are displayed in Table 1, and are intended to reflect current economic situation in the U.S. pork value chain. Consequently, the exogenous parameters in this calibration exercise are market shares, prices, and quantities. Note that all prices are measured in live weight pounds (to get to retail weight, divide by 1.869). The endogenous parameters are thus the structural parameters in demand and supply, and subsequently the demand and supply elasticities.

Table 2. The Ex-Ante Equilibrium with Imperfect Competition in the Upstream and Consumer Market.

	Total Output	Farm price	Retail price	Firm Output	Profit	Profit (%)
	11.41	0.51	1.48	2.85	2.77	143
Units	M Lbs	$/lbs	$/lbs	M Lbs	M$	sales value

The profit rate is somewhat more arbitrarily though. Since the cost of production is normalized to zero, other input costs are forgone in the analysis, so this figure represents only a partial economic rent.

In this situation, the downstream supplier buys at the elastic portion of the input supply $\eta \approx 1.1$, and markets the product at the inelastic portion of the consumer demand curve, $\varepsilon \approx .43$. Recall that the inverse schedules yield flexibilities, so we need to invert the matrix to obtain the direct elasticities (Hoeck, 1967).The supply price elasticity is reasonable since production technology is variable in the long-run. The demand price elasticity, however, is somewhat in contrast to the classical textbook example of monopoly pricing, where the firm prices at the elastic portion of the demand curve. This result may arise in part because the functional form of demand wherein there is no substitution to other food products taking place.

In the case where the firm has market power in the output markets only, holding farm price constant, increase firm output and consequently decrease price, and profits.

The scenario with imperfect competition only at the consumer markets is shown in the Table 3 below.

Table 3. Ex-Ante Equilibrium with Imperfect Competition in the Consumer Market only.

	Total Output	Farm price	Retail price	Firm Output	Profit	Profit (%)
	11.72	0.51	1.39	2.93	2.57	122
Units	M Lbs	$/lbs	$/lbs	M Lbs	M$	sales value

Here, the supply price elasticity is lowered slightly due to increased total production, $\eta \approx 1.0$, whereas the demand elasticity decreases, $\varepsilon \approx .39$. Because the supplier cannot suppress market power in the input stages, the output level increase, and prices decrease, which decrease the profit rates by nearly 20 percent units.

In the case where a pork certification program is certified, the certified live animal supply is created by developing a supply curve that lies slightly above the conventional supply curve. The cost of supplying certified live animals is hypothesized to exceed that of the conventional. Here, the certified supply intercept shifts up by forty percent units, so that ceteris paribus, the cost of supplying certified products exceeds the conventional production costs by forty percents. The demand is shifted upwards by two percent units. That is at identical consumption levels, the certified pork retail price exceeds the conventional retail price by two percent. Although these shifts are symbolic, these shifts presents cases in which there is a sustainable certified hog and pork product market. Due to the high nonlinearity in the first order conditions, there is somewhat of a challenge in finding a numerical equilibrium where the firms produce both quantities as well as obtain positive profits. Still, although the optimality conditions come from a strictly convex programming problem, the optimal solution can lie in the negative variable quadrant. The ex-post equilibrium is given Table 4 below.

Table 4. Ex-Post Equilibrium with Imperfect Competition in the Upstream and Consumer Market.

	Total Output	Farm price	Retail price	Firm Output	Profit	Profit (%)
Certified	9.58	0.60	1.57	2.40	2.31	151
Conventional	7.45	0.54	1.49	1.86	1.77	142
Total	17.03	0.57*	1.53*	4.26	4.08	147*
Unit	M Lbs	$/lbs	$/lbs	M Lbs	M$	of sales value
* = weighted average						

Here we note that radical changes in the value chain occurred. Total demand has increased, but this has occurred at decreased demand for conventional products. With

decreased conventional output, the price has increased compared to the ex-ante scenario. However, the prices are and contribution margin are higher for the certified product.

The weighted average farm (upstream) price is higher than the ex-ante conventional price but lower at the consumer-end market. That is, an analysis of aggregate data could wrongfully indicate that the consumer is worse off, because of the price increase. However, taking into account the new product introduction, there are consumers who demand the certified product. Thus, this example illustrates that considering the certified product in the same bundle as the conventional product group may overstate, or understate the true welfare changes.

The new product introduction has increased demand price elasticities sharply: the demand own price elasticities are high, $\varepsilon \approx 8\text{-}10$. There is also an increase in the supply elasticities, which have increased by a magnitude of two.

With a perfectly competitive live animal market, the economic impact of the certification is displayed below.

Table 5. Ex-Post Equilibrium with Imperfect Competition in the Consumer Market.

	Total Output	Farm price	Retail price	Firm Output	Profit	Profit (%)
Certified	10.27	0.60	1.46	2.57	2.21	1.26
Conventional	7.28	0.54	1.39	1.82	1.55	1.19
Total	17.56	0.58	1.43	4.39	3.76	1.23
Unit	M Lbs	$/lbs	$/lbs	M Lbs	M$	of sales value
* = weighted average						

As with the previous scenario, total output increases and so does the farm prices. The retail price for conventional, however, is unchanged at 1.39 per live weight pound. Moreover, the composition of the firm's profit is similar to the previous case in which the contribution margin is higher for the certified commodity. Note also that the average weighted prices have increased due to the product introduction.

There are two rather stark shortcomings with this empirical application. First, the model does not currently incorporate the economic impact of vertically aligned hog processors that do not acquire supply of live animals through open market transactions. Nevertheless, the analytical model could be extended in a future study to incorporate the aspects of multiple stage ownership in the hog value chain. Second, a slight perturbation of the numerically calibrated model produces ex-post results that are challenging to interpret. For example, in the ex-post situation, the resulting own price demand

elasticities are high, $\varepsilon \approx 10$, with lower valued cross price elasticities. The supply price elasticities are elastic, but smaller in magnitude than the demand elasticities, $|\eta| \approx 2$. The supply cross price elasticities is positive, however, indicating that the products are aggregate complements. The issue with the elasticities reveals a more challenging problem with the numerical optimization model. The optimization problem is highly nonlinear in the demand and supply parameters, and because the elasticities are endogenous, and only prices and quantities exogenously given, the ex ante calibration may actually be an unstable saddle point in the parameter space and with small perturbations thereof may result in negative optimal quantities. Thus, it is warranted to extend the analysis by constraining the model to yield only economically tractable results.

Nevertheless, this exercise has proven to be a valuable exercise on two counts. First, there seems to be some support of the fact that the demand for the conventional product will not be discontinued despite the introduction of the certified product. Although the demand and supply functions are sensitive for the chosen parameter values, there is still confidence that the conventional product is not automatically discontinued. Second, adverse price movements in the conventional market are likely to occur. Consequently, aggregate price indices may actually misrepresent the welfare impact on consumers and producers. Although this study does not provide estimate welfare changes for consumers and producers, there are some indications that the certification scheme provides a better match between consumer preferences and product attributes.

Conclusions

This study attempted to provide an economic model that could potentially quantify the economic distributional impact of a certification program in the U.S. pork value chain. There are two rather stark conclusions from this study, which all have important implications for both agribusinesses and policy markets.

The first conclusion is that the economic effects of a certification program depend vastly on assumptions regarding consumer and producer behavior. If the firm's decision to become multiproduct suppliers are endogenized, rather than exogenously given, market environments may arise in which the suppliers do not certify their product despite the fact that the certified consumer end demand exists. Although the analytical model is a strict convex programming problem, corner solutions are still present since the solutions can lie in negative variable quadrants. Hence, endogenizing the product choice can yield situations that are in sharp contrast to previous studies, where the firm's quality choice is given exogenously (e.g. see Marette et al). Thus, from a policy perspective, the absence of a certified product may indicate presence of market power, as well as situations in which the potential certified live animal supply curve is located well above the conventional supply curve, or that there is weak consumer willingness to pay for certified pork products. Furthermore, if there are consumers who are willing to consume the uncertified product in an ex post certification era, the certified and conventional products cannot be considered as perfect substitutes.

Secondly, certification in imperfectly competitive industries may actually lessen competition if firms use the certification program as a mean to differentiate the product lines. In our analytical model, we showed that when the differentiation parameter, γ, increases, there is an unequal effect the markets: thus there are situations in which an increase of the differentiation parameter actually lowers quantities and increases the market prices. Moreover, our numerical model showed that in the ex post scenario, the firm with no market power at the upstream stages have higher equilibrium output levels than the firm with double market power.

Hitherto, the economic impact of a certification scheme across the whole value chain remains somewhat unclear. For the farmer the certification program may be a profitable strategy that ensures market access, alleviates market power, and expands the consumer-end market. For the packer-retailer the program may be a profitable strategy that matches heterogeneous consumer demand preferences with extensive certified and conventional product diversification. Thus, stakeholders in the value chain are implementing food certification programs to meet consumers concerns about product and process control, such as animal welfare and antibiotic usage. Downstream suppliers provide product guarantees and expand the product lines to attract bundles of consumers that would otherwise not patronize their product line. Hence, by supplying products with different product attributes, suppliers differentiate among different consumers on basis of their willingness to pay for product attributes while consumers, in aggregate, benefit from greater choice.

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