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Kenneth Njoroge
University of Nebraska - Lincoln

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Kenneth Njoroge*

*University of Nebraska-Lincoln, USA, k_njoroge@hotmail.com

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Abstract

This paper develops a conceptual model that analyzes the impact of increasing market transparency under the Livestock Mandatory Reporting Act of 1999 on the incentives for collusion in the U.S. meatpacking industry. More than likely, meatpackers will have asymmetric priors regarding the distribution of livestock prices. Moreover, they lack the incentives to voluntarily reveal their real priors. Thus, the enforcer of the Act faces a problem of asymmetric information regarding the informativeness of publicly disclosed market reports relative to that of packers' priors. Analytical results predict that divergent priors of Bayesian packers can be updated by more informative market reports, so that the resultant posteriors converge, enabling packers to identify a more efficient, unanimous trigger price. This enhances observability of deviations from collusive behavior, and increases the internal policing efficiency by a cartel that employs trigger price strategies to monitor deviations by its members. Contrary to the Act's well-intended objectives, this is consistent with promoting collusion and decreasing market efficiency.

KEYWORDS: Mandatory price reporting, collusion, livestock, oligopsony, trigger pricing

1. Introduction

The industrialization of agriculture has led to significant changes in the structure of U.S. livestock and meat markets. Of particular importance is increased backward vertical integration and coordination through packer ownership of livestock, use of marketing arrangements and forward contracts, resulting in a large proportion of livestock transactions going unreported[1]. As a consequence, livestock producers believe markets have become less and less transparent, making it more and more difficult to discover the "right" price for their product. In response, U.S. Congress enacted the Livestock Mandatory Reporting Act 1999 (hereafter the Act). The Act was passed with the stated objectives of providing easily understandable market information with greater precision, scope and reliability to all market participants so that they can make informed decisions; and increasing transparency in the livestock and meat price discovery process, thereby enhancing competition in the market place for livestock and livestock products.

The Act differs from voluntary reporting in three ways[2]. First, under voluntary reporting, the Agricultural Marketing Service (hereafter AMS)[3] collected only negotiated spot trade information. Under the Act, AMS now collects all types of transactions. Second, under voluntary reporting, AMS employed self-discretion to preserve confidentiality. Under the Act, AMS now sets the confidentiality guidelines for disclosure. Third, under voluntary reporting, AMS collected information from packers and feeders throughout the day. Now, reporting packers are required to electronically submit information to AMS at scheduled times.

Only packers who slaughter above 125,000 cattle, 100,000 swine and 75,000 lambs and importers with annual average imports of 5,000 metric tons of lamb must report to AMS. Packers must report entire transactions but are exempt from reporting livestock purchases from public auction markets. The Act also specifies the schedule of reporting. To preserve confidentiality, AMS restricts disclosure of the reported data through confidentiality guidelines. The Act stipulates civil penalties of up to $10,000 per misreporting violation and requires a quarterly audit and reviews that could be more frequent if necessary.

As of this writing, the Act has been in place for two years, and it took as many years for its supporters to get it through Congress. However, with the exception of one study (Azzam, 2003), the agricultural economics literature has yet to evaluate the claims that led to its enactment. Those claims are well summarized by a question in a larger questionnaire sent out in August 2002 by Agricultural Committee Chairman Larry Combest (R-Texas) to farm and producer groups, agricultural economists, and the

[1] As much as 35-40% of all cattle transactions, 75% of all hog transactions, and 40% of all lamb transactions are by private marketing arrangements..

[2] The Livestock Mandatory Reporting Act of 1999 amended the voluntary market news program instituted by the Agricultural Marketing Act of 1946.

[3] AMS enforces the Act and discloses the reported data subject to confidentiality guidelines. The current confidentiality guideline is the 3/70/20 rule. This means that over a 60-day period, at least 3 packers have to submit data at least 50% of the time; (2) No one reporting packer can account for more than 70% of the data in a report; (3) The same reporting packer cannot be the only reporting packer for more than 20% of the time.

secretary of Agriculture. Specifically, the question reads: "Mandatory price reporting was advocated as necessary to improve market transparency and price discovery. Implicit in the arguments of individuals advocating mandatory price reporting was the idea that this improvement would lead to higher prices for producers. What has been the effect of mandatory price reporting on producer prices?"

While extensive literature on voluntary information sharing exists, literature on mandatory information reporting is limited. In a study of the Danish ready-mixed concrete industry, Albaek, Mollgaard and Overgaard (1997) show that disclosure of data from mandatory information reporting led to collusive behavior in which prices increased and the variance in prices across firms diminished. Since there were no significant changes in costs, inputs or technology, the study predicts that firms exploited the government information sharing program to enhance collusive behavior and raise prices.

Wachenheim and Devuyst (WD) (2001) conclude that the three most important issues regarding the Livestock Mandatory Reporting Act are: the benefits of price data at a national or even regional level of aggregation, whether the USDA can report these data at a more localized basis and maintain confidentiality, and whether mandatory price reporting will lead to collusive pricing by meat packers. Without a formal model, and relying mostly on findings from previous theoretical studies and evidence from other industries, WD posit that, if AMS discloses disaggregated data, the likelihood of collusive pricing will increase.

Defining an increase in transparency as the degree to which the volatility of livestock and meat prices is reduced as more information is provided by the Act, Azzam (2003) constructed a theoretical model to study the consequences of such transparency for the structure, conduct and performance of the livestock industry. He concluded that "the usefulness of the Act to the livestock industry may not be in the value of the reported information to feeders, as the supporters of the Act claim. Rather, by forcing packers to pool information at negligible marginal cost, the Act may foster more competitive conduct in the procurement of livestock." However, Azzam's results are based on the assumption that packers hold consistent conjectures in equilibrium. Since consistent conjectures do not accommodate conduct that is less competitive that Cournot, Azzam's model assumes the Act does not afford packers the opportunity to use information from the Act as a vehicle for collusion.

Serious concerns regarding fair competition and trade practices in the meatpacking industry go back to the turn of the last century. Back then; Congress enacted the Packers and Stockyards (hereafter P&S) Act in 1921. These concerns have persisted, motivating numerous reviews of the P&S Act. GIPSA[4] is the USDA agency that administers the P&S Act. Thus, concern about the potential for collusion is crucial and highly relevant in the meatpacking industry. The ideas presented here should only be considered a starting-point into which extensions may add additional institutional and theoretical detail in the hope of providing better tools for scrutinizing industry conduct.

[4] Grain Inspection, Packers and Stockyards Administration (GIPSA) is part of USDA's Marketing and Regulatory Programs, whose mandate is to enforce fair and competitive trading practices. GIPSA has a regulatory program known as the Packers and Stockyards Program, under which fair and open competitive practices are enforced.

The contribution of this paper is to develop a conceptual model to analyze the impact of the Act on the potential for non-cooperative collusion through trigger price strategies. The paper is organized as follows: Section 2 shows how asymmetric priors can generate interest disparity amongst packers and impede the potential for trigger price strategies. Section 3 shows how AMS market reports can update asymmetric priors of Bayesian packers so that the resultant posteriors converge, enabling packers to identify a more effective unanimous trigger price. Section 4 presents the concluding remarks.

2. Asymmetric Priors and Non-Cooperative Collusion

To motivate a conceptual framework, I follow Azzam (2003) and consider a homogenous, risk-neutral oligopsony of n packers, whose objective is to maximize the expected utility of individual profits. Let the oligopsony face a common supply function:

$$W = \overline{W}(Q) + e\,, \tag{1}$$

where W is the observable stochastic component of the price of livestock and $\overline{W}(Q)$ is the non-stochastic component given by:

$$\overline{W}(Q) = a + bQ = a + bq_i + bQ_{-i}\,, \tag{2}$$

where a and b are the intercept and the slope of the supply curve respectively, q_i is the quantity procured by packer i, and Q_{-i} is the aggregate livestock quantity by all other packers except packer i. Finally, e is the random additive noise that consists of both the random shock to the factors of livestock production, and the random noise from the noisiness of the market signals. It is assumed that e, is identically and independently distributed with zero mean, a CDF, $F(e)$ and an associated PDF, $f(e)$. Both $f(e)$ and $F(e)$ are assumed to be continuously differentiable, and $F(e)$ is a non-decreasing function, with $F(-\infty) = 0$ and $F(+\infty) = 1$. Thus, W is a random variable with a CDF, a corresponding PDF and an associated parameter vector, θ.

As a prelude to the description of the packer game, I specify the meaning of incomplete and imperfect information as it applies in this paper. First, imperfect information refers to uncertainty in the history of the game up to the decision-making point. Thus, before she makes a move, a packer with imperfect information faces uncertainty regarding the other packers' past actions thus far. Second, incomplete information refers to uncertainty regarding the game's payoffs.

To be consistent with an incomplete and imperfect information structure, we adopt the model developed by Spence (1978). In this model, the stochastic supply function captures incomplete information by introducing event uncertainty into the game's payoffs. Further, this model captures imperfect information by restricting the best response functions of packers, so that they only observe noisy market signals and not each other's actions.

Effectively, at each move in the game, each packer decides whether or not to cheat on the cartel. Owing to a stochastic livestock supply, each packer faces uncertainty regarding the game's payoffs (including individual payoffs). Since she exclusively depends on noisy market signals to detect past rival behavior up to her decision making point, each packer faces uncertainty regarding her rivals' past livestock quantities. Thus, if packers observe an unexpectedly high price of livestock, they face uncertainty regarding whether this was caused by cheating, or by a stochastic shift of the livestock supply. To begin with, we deliberately assume the distribution of the observable price of livestock is common knowledge, thus imposing symmetric priors across packers.

Having specified the game's information structure, the next step is to consider an infinite horizon game, one in which each packer's objective is to maximize her expected present discounted value of profits under this information structure.

Following Porter (1983), suppose packers employ the Green-Porter enforcement mechanism, in an infinite horizon game. In this case, they revert to Cournot-Nash equilibrium levels of livestock for a finite number of $(T-1)$ periods whenever the observable market price of livestock W rises above a predetermined, unanimous trigger price $\hat{W}$.

Specifically, under the Green-Porter enforcement mechanism, we describe packers' strategies as follows:

1) In the initial period $t=0$, each packer extends a goodwill gesture by purchasing a suggestively collusive quantity of livestock q_i^{NC}. This results in a collusive vector of livestock quantities, $\mathbf{q}^{\mathbf{NC}} = \left(q_1^{NC},......,q_n^{NC}\right)$, that is smaller than the Cournot-Nash Equilibrium (hereafter CE) quantity vector $\mathbf{q}^{\mathbf{CE}}$, such that $\mathbf{q}^{\mathbf{NC}} < \mathbf{q}^{\mathbf{CE}}$.
2) In any subsequent period t, each packer extends the collusive period by purchasing q_i^{NC}, as long as $W \le \hat{W}$ in the previous period $(t-1)$.
3) If in any period $t-1$, $W > \hat{W}$, regardless of the apparent cause, each packer shifts to the punishment period by purchasing a punitive CE quantity, q_i^{CE}, resulting in the quantity vector $\mathbf{q}^{\mathbf{CE}} = \left(q_1^{CE},....,q_n^{CE}\right)$ in period t, and continues purchasing this quantity for T periods until period $[t+(T-1)]$ and then reverts to the collusive quantity q_i^{NC} in period $(t+T)$.

Since the Cournot-Nash equilibrium is self-enforcing, no packer has an incentive to deviate from the punishment phase. If we assume that packers face a common, discount factor β within the range $0<\beta<1$, then the expected present discounted value of packer i's profits is:

$$V_i\left(\mathbf{q}^{\mathbf{NC}}\right) = \Pi_i\left(\mathbf{q}^{\mathbf{NC}}\right) + \Pr\left(W > \hat{W}\right)\left[\sum_{t=1}^{T-1} \beta^t \Pi_i\left(\mathbf{q}^{\mathbf{CE}}\right) + \beta^T V_i\left(\mathbf{q}^{\mathbf{NC}}\right)\right] + \Pr\left(W < \hat{W}\right)\beta V_i\left(\mathbf{q}^{\mathbf{NC}}\right), \tag{3}$$

Inserting $W = \overline{W}(Q) + e$ from equation (1) into equation (3), we obtain:

$$V_i\left(\mathbf{q}^{\mathbf{NC}}\right) = \Pi_i\left(\mathbf{q}^{\mathbf{NC}}\right) + \Pr\left(\overline{W}(Q) + e > \hat{W}\right)\left[\sum_{t=1}^{T-1} \beta^t \Pi_i\left(\mathbf{q}^{\mathbf{CE}}\right) + \beta^T V_i\left(\mathbf{q}^{\mathbf{NC}}\right)\right]$$
$$+ \Pr\left(\overline{W}(Q) + e < \hat{W}\right)\beta V_i\left(\mathbf{q}^{\mathbf{NC}}\right)$$

Noting that:

$$\Pr\left\{\overline{W}(Q) + e \ge \hat{W}\right\} = \Pr\left\{e \ge \hat{W} - \overline{W}(Q)\right\} = 1 - \Pr\left\{e < \hat{W} - \overline{W}(Q)\right\} = \left[1 - F_e\left(\hat{W} - \overline{W}(Q)\right)\right]$$

$$\Pr\left\{\overline{W}(Q) + e < \hat{W}\right\} = \Pr\left\{e < \hat{W} - \overline{W}(Q)\right\} = F_e\left(\hat{W} - \overline{W}(Q)\right),$$

we obtain:

$$\begin{aligned} V_i\left(\mathbf{q}^{\mathbf{NC}}\right) &= \Pi_i\left(\mathbf{q}^{\mathbf{NC}}\right) + \left[1 - F_e\left(\hat{W} - \overline{W}(Q)\right)\right]\left[\sum_{t=1}^{T-1} \beta^t \Pi_i\left(\mathbf{q}^{\mathbf{CE}}\right) + \beta^T V_i\left(\mathbf{q}^{\mathbf{NC}}\right)\right] \\ &+ \left[F_e\left(\hat{W} - \overline{W}(Q)\right)\right]\beta V_i\left(\mathbf{q}^{\mathbf{NC}}\right), \end{aligned} \tag{4}$$

where the first term on the RHS is packer i 's expected profit in the initial period, $(t = 0)$, and the next two terms capture her expected present discounted value of profits in the next period. The probability that the observable market price of livestock will exceed the predetermined unanimous trigger price serves as the weight for the punishment period, while the probability that it remains below this trigger price serves as the weight for the collusive period. We can proceed to solve for the expected present discounted value of packer i 's collusive profits (hereafter V_i) to get:

$$V_i\left(\mathbf{q}^{\mathbf{NC}}\right) = \frac{\Pi_i\left(\mathbf{q}^{\mathbf{NC}}\right) + \left[1 - F_e\left(\hat{W} - \overline{W}(Q)\right)\right]\left[\sum_{t=1}^{T-1} \beta^t \Pi_i\left(\mathbf{q}^{\mathbf{CE}}\right)\right]}{\left[\mathbf{1} - \beta^T - \left(\beta - \beta^T\right)F_e\left(\hat{W} - \overline{W}(Q)\right)\right]}$$

$$V_i\left(\mathbf{q}^{\mathbf{NC}}\right) = \frac{\Pi_i\left(\mathbf{q}^{\mathbf{CE}}\right)}{(1-\beta)} + \frac{\Pi_i\left(\mathbf{q}^{\mathbf{NC}}\right) - \Pi_i\left(\mathbf{q}^{\mathbf{CE}}\right)}{\left[1 - \beta^T - \left(\beta - \beta^T\right)F_e\left(\hat{W} - \overline{W}(Q)\right)\right]}. \tag{5}$$

At this juncture, it is crucial to note that Porter's model deals with symmetric firms that share a common discount factor, β, and a commonly observed cumulative density function (CDF) of the price of livestock, $F_W(w)$. Thus, the model assumes the distribution of livestock prices is common knowledge, and thus, packers have symmetric priors. Porter gives two reasons for imposing symmetry. The first is that the resultant symmetric equilibrium enables a detailed examination of the nature of the effects of the probability distribution function of the stochastic "supply" element, $F(e)$, on the optimal equilibrium solution. The second is "to abstract from problems the cartel may face in trying to reconcile disparate interests". Clearly, Porter acknowledges that heterogeneity across firms could indeed impede collusion but this is obviously not the focus of his paper and hence the assumption.

Given that interest disparity is a factor that determines the potential for non-cooperative collusion by a cartel of asymmetric packers, a more detailed scrutiny on whether the Act could reconcile such disparity amongst packers should be very interesting and useful in studying the impact of the Act on the potential for collusion.

Predictably, asymmetric discount factors are the most important source of interest disparity amongst packers. However, since discount factors are exogenous to AMS, the Act is unable to reconcile such disparity. As a result, the subsequent analysis will deliberately impose symmetry across discount factors.

Recall that in the infinite horizon game described above, after the initial period, if in any period $t-1$, $W > \hat{W}$, each packer shifts to the punishment period by purchasing q_i^{CE} in period t. Each packer detects the consequence of the cartel's actions in the previous period by using her idiosyncratically perceived distribution of W to test the hypothesis that the vector of livestock quantities in the previous period was consistent with the collusive vector $\mathbf{q}^{\mathbf{NC}} = \left(q_1^{NC},..,q_n^{NC}\right)$. Effectively, the trigger price $\hat{W}$ is an upper tail critical value of this hypothesis test, based on each packer's idiosyncratic priors and yet, it must be unanimous across the cartel. Obviously, divergent priors amongst packers will impede and could render the identification of this unanimous trigger price infeasible.

It is more plausible that, in practice, packers possess asymmetric priors. If a packer's priors are more precise than those of her counterparts, she has the opportunity to unilaterally cheat on the cartel without detection. Predictably, packers would lack the incentive to voluntarily reveal their real priors to each other. It is therefore highly unlikely that the previous voluntary reporting program could have significantly mitigated prior asymmetries across packers. Accordingly, asymmetric priors are a second source of interest disparity across packers. To the extent that imposing symmetric priors sacrifices a model's ability to predict the impact of the Act on interest disparity, this simplification is unnecessarily restrictive for the intended analysis and therefore inadmissible.

The divergence of priors determines the feasibility of a unanimous trigger price by packers. If priors are too divergent, the identification of a unanimous trigger price is clearly infeasible. It is crucial to emphasize that a unanimous trigger price is by definition, a necessary condition for a sustainable trigger price strategy. From the outset, we emphasize that subject to discount factors β_i, packers with asymmetric priors could feasibly identify a unanimous trigger price $\hat{W}$, employ trigger price strategies, and reach a non-symmetric collusive equilibrium. To show how packers can achieve this, let us consider asymmetric priors, and thereby rewrite equation (4) as:

$$V_i\left(\mathbf{q}^{\mathbf{NC}}\right) = \Pi_i\left(\mathbf{q}^{\mathbf{NC}}\right) + \left[1 - F_e^i\left(\hat{W} - \overline{W}(Q)\right)\right]\left[\sum_{t=1}^{T-1}\beta^t \Pi_i\left(\mathbf{q}^{\mathbf{CE}}\right) + \beta^T V_i\left(\mathbf{q}^{\mathbf{NC}}\right)\right]$$
$$+ \left[F_e^i\left(\hat{W} - \overline{W}(Q)\right)\right]\beta V_i\left(\mathbf{q}^{\mathbf{NC}}\right),$$

where $F_e^i\left(\hat{W} - \overline{W}(Q)\right)$ is packer i's idiosyncratically perceived probability of the observable market price of livestock staying below the trigger price, based on her private idiosyncratic priors. Thus, depending on her idiosyncratic priors, each packer will now assign idiosyncratic weights to the punishment and collusive periods. Effectively, each packer will perceive an idiosyncratic present discounted value of profit depending on her priors (Thus, under asymmetric priors, V_i is no longer symmetric across packers). As a result, we can now rewrite equation (5) as:

$$V_i\left(\mathbf{q}^{\mathbf{NC}}\right) = \frac{\Pi_i\left(\mathbf{q}^{\mathbf{CE}}\right)}{(1-\beta)} + \frac{\Pi_i\left(\mathbf{q}^{\mathbf{NC}}\right) - \Pi_i\left(\mathbf{q}^{\mathbf{CE}}\right)}{\left[1 - \beta^T - \left(\beta - \beta^T\right)F_e^i\left(\hat{W} - \overline{W}(Q)\right)\right]}.$$

Following Porter, a non-cooperative equilibrium is characterized by an equilibrium vector of livestock quantities, $\mathbf{q}^{\mathbf{NC*}} = \left(q_1^{NC*},......,q_n^{NC*}\right)$, a unanimous trigger price $\hat{W}$, and a punishment period T if:

$$V_i\left(\mathbf{q}^{\mathbf{NC*}}\right) = Max\left\{V_i(\mathbf{q})\middle| q_j = q_j^*, \forall j \neq i, q_i \geq 0\right\}$$

The first order necessary condition for this maximization problem is:

$$0 = \partial V_i\left(\mathbf{q}^{\mathbf{NC}^*}\right)/\partial q_i = \left[1-\beta^T + \left(\beta^T - \beta\right)F_e^i\left(\hat{W} - \overline{W}(Q)\right)\right]\left\{\partial\Pi_i\left(\mathbf{q}^{\mathbf{NC}^*}\right)/\partial q_i\right\}$$
$$+\left[\Pi_i\left(\mathbf{q}^{\mathbf{NC}*}\right) - \Pi_i\left(\mathbf{q}^{\mathbf{CE}}\right)\right]\left(\beta^T - \beta\right)f_e^i\left(\hat{W} - \overline{W}(Q)\right)b. \tag{6}$$

We can derive the Cournot-Nash Equilibrium (CE) profit by packer i, $\Pi_i\left(\mathbf{q}^{\mathbf{CE}}\right)$ as follows: $\Pi_i(\mathbf{q}) = [P - a - (q_i + Q_{-i})b]q_i \Rightarrow \partial\Pi_i(\mathbf{q})/\partial q_i = [P - a - (2q_i + Q_{-i})b]$
$\partial\left[\Pi_i\left(q_i^{CE}, Q_{-i}\right)\right]/\partial q_i = P - a - 2bq_i^{CE} - bQ_{-i} = 0 \Rightarrow q_i^{CE} = (P - a - Q_{-i})/2b$,
where P is the price packers receive for their output. If we assume packers are otherwise symmetric in all other aspects except in their priors, the resultant q_i^{CE} and associated $\Pi_i\left(\mathbf{q}^{\mathbf{CE}}\right)$ are:

$$q_i^{CE} = (P-a)[(n+1)b]^{-1} \Rightarrow \Pi_i\left(\mathbf{q}^{\mathbf{CE}}\right) = (P-a)^2[(n+1)b]^{-1}.$$

To allow for asymmetric quantities, let $q_j^{NC*} = \delta_j q_i^{NC*}$, where δ_j is a coefficient of symmetry, (so that perfect symmetry is a special case in which $\delta_j = 1, \forall j = (1,....,n)$, and $Q^* = nq^{NC*}$). The aggregate quantity of livestock quantities in collusive periods is $Q^* = \sum_{j=1}^{n}\delta_j q_i^{NC*}$. We can now rewrite equation (6) above in terms of q_j^{NC*} as:

$$\left[1-\beta^T + \left(\beta^T - \beta\right)F_e^i\left(\hat{W} - \overline{W}(Q)\right)\right]\left\{P - a - \left(\sum_{j=1}^{n}\delta_j + 1\right)bq_i^{NC*}\right\}$$
$$= -\left[\left[P - \left(a + \sum_{j=1}^{n}\delta_j\right)bq_i^{NC*}\right]q_i^{NC*} - \frac{(P-a)^2}{(n+1)b}\right]\left(\beta^T - \beta\right)f_e^i\left(\hat{W} - \overline{W}(Q)\right)b. \tag{7}$$

The solution to the FOC in equation (7) is the Nash equilibrium quantity vector $\mathbf{q}^{\mathbf{NC}*}\left(\hat{W}, T\right)$, which is a function of a <u>unanimous</u> trigger price $\hat{W}$, and a punishment period T. The equilibrium present discounted value of packer i is thus a function of $\hat{W}$ and T i.e. $V_i^*\left(\hat{W}, T\right)$ for $i = 1,....,n$. Effectively, there exists a range of potential levels of the trigger price, $\hat{W}$, and an associated range of potential non-symmetric equilibria available to a cartel whose members have asymmetric priors. Within this range of trigger prices, each packer idiosyncratically perceives her optimal trigger price as the one that maximizes her present discounted value.

If we retrace Porter's derivations, we can show that in the absence of interest disparity, if an optimal trigger price, $\hat{W}^*$, is chosen from the range of potential trigger prices to maximize the V_i, the resultant optimal equilibrium quantity of livestock by each packer is common across all packers and is given by:

$$q_i^{NC*} = \left\{(P-a) + (n+1)\left[f_e\left(\hat{W}^* - \overline{W}(Q)\right)\right]\left[f_e^/\left(\hat{W}^* - \overline{W}(Q)\right)\right]^{-1}\right\}(2bn)^{-1}. \tag{8}$$

However, in the case of asymmetric priors, it is questionable whether interest disparity could permit a single optimal trigger price to be common across all packers. Predictably, the greater is the divergence of priors, the smaller is the range of potential unanimous trigger prices and the smaller is the range of the associated enforceable equilibria. Thus, the greater is the divergence of priors, the less likely that a cartel will identify a trigger price that is commonly optimal across its members. As a result, the greater is the divergence of priors, the smaller is the scope for sustainable trigger price strategies.

In sum, the impact of asymmetric priors on the potential for non-cooperative collusion has two possible outcomes. First, if priors are too divergent, packers are unable to identify a unanimous trigger price, in which case sustainable non-cooperative collusion is infeasible. Second, even when packers can feasibly identify a unanimous trigger price, divergence of priors limits the scope of non-cooperative collusion by restricting packers from identifying a commonly optimal trigger price and its associated optimal non-cooperative equilibrium.

The present study is not the first to consider the potential for non-cooperative collusion amongst firms with asymmetric information. Radner (1986) posits a model for games in which players do not discount future utility. In one class of these games, players lack a commonly observed consequence (e.g. price, profit or output) to detect cheating. The model posits an enforcement mechanism in which, at each period, each player tests the hypothesis that all other players have not been cheating based on the successive observations of her own utilities, but is also able to announce the outcome of her tests to the others. The model uses a convexity assumption to bound the expected achievable utility from cheating (by any one player) by a linear function of the observed statistics. The study shows that by using this mechanism, players could achieve a supergame equilibrium. A follow-up study by Radner, Myerson and Maskin (1986) provides an example, where players do discount future utilities.

In addition to the monitoring mechanism posited by Radner (1986), a cartel could also detect cheating through monitoring market shares; exploiting most favored party clauses or monitoring geographically allocated markets among other strategies. Thus, trigger price strategies are not the only enforcement mechanism that is available to a cartel of packers. However, most of the other mechanisms that a cartel can employ to detect cheating besides trigger price strategies are exogenous to the Act. Specifically, the Act involves increasing the informativeness of AMS market reports, potentially providing a commonly observed statistic to the cartel. Thus, the Act's impact on other collusive strategies besides trigger price strategies is predictably not as profound. For this reason, the scope of this paper is specifically limited to how the Act could impact the potential for trigger price strategies.

I shall show that, by increasing the informativeness of AMS market reports, the Act can provide a commonly observed distribution of livestock prices on the basis of which cartel members can test their hypotheses. This can reconcile the interest disparity that arises from asymmetric priors amongst packers and thus increase the policing efficiency of trigger price strategies. Thus, contrary to its intended objectives, the Act can potentially promote collusion rather than competition. This is the primary motivation for the subsequent analysis.

3. Bayesian Updating: How Asymmetric Priors Converge

In the context of the Act, packer's priors refer to idiosyncratic conjectures about the distribution of W before that packer gains access to the market reports that are publicly disclosed by AMS under the Act. Likewise, a packer's posterior distribution describes that packer's knowledge about W conditional on AMS market reports. Assume all packers are Bayesian decision makers. Let $f^i(\theta)$, be packer i's idiosyncratic prior PDF of the parameter vector θ, that contains the mean and variance of W.

If a random sample of k iid observations $\mathbf{W} = (W_1,....,W_k)$ is drawn from AMS market reports, it generates a noisy market signal that constitutes the likelihood function $L(\theta|\mathbf{W})$. The likelihood function is of the form: $L(\theta|\mathbf{W}) = \prod_{j=1}^{k} f(W_j|\theta)$. Depending on its informativeness relative to that of a packer's priors, a market signal can update the packer's priors. Once a packer accesses this signal, her posterior PDF, $f^i(\theta|\mathbf{W})$, will contain both her prior PDF, $f^i(\theta)$, and the entire evidence from the signal.

To motivate intuition regarding how a signal generated by AMS market reports could update a packer's priors, let us consider the well-known, normal-conjugate framework[5]. According to Box and Tiao (1973 p.20) and Zellner (1987 p. 46), if the distribution of a prior is locally uniform over the range in which the distribution of a given likelihood assumes appreciable values, then such a likelihood function dominates the prior in the posterior. Effectively, the normal-conjugate framework predicts that as long as the precision of the market signal is considerably greater than that of a packer's priors, then the packer will learn from the signal and update her priors. Moreover, in this particular case, as the sample size and the precision of the signal increase, the packer assigns a weight that approaches zero to her priors (thus disregarding her prior prejudices), so that the shape of her posteriors approaches that of the signal.

However, according to Schlaifer, Raiffa, and Pratt (1995 p.221), if a prior is considerably more precise than a given likelihood, then the prior dominates, and the shape of the posterior will in this case be similar to that of the prior. Effectively, such a signal is relatively non-informative since it reveals nothing that the packer did not already know. Thus, a packer does not learn from such a signal, and she assigns a weight that approaches zero to its evidence irrespective of the number of observations. As a result, the prejudice that is inherent in such a packer's priors will dominate her posteriors.

To illustrate, consider AMS market reports obtained through the voluntary reporting program. Suppose that these market reports consist of weekly averages of nationally aggregated data. Further, consider a packer who perceives her priors from daily data (obtained through private market intelligence by the packer's local field buyers) at, say, the Texas Panhandle. In this case, it is indeed highly questionable whether nationally aggregated weekly data from voluntary reports could generate a market signal that reveals anything that the packer does not already know. As a result, far from updating her priors, a signal that is less informative than a packer's priors is likely to be assigned a zero weight in her posterior. Since the signal is relatively non-informative, it is unable to eclipse the packer's prejudiced priors in the posterior. Effectively, this signal is highly unlikely to alter the packer's strategic decisions or her subsequent actions.

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[5] I thank an anonymous referee for the correction that movement of prices is best modeled after a lognormal distribution. While it is important to keep this in mind, I nevertheless use the normal-conjugate framework to motivate intuition owing to its well-known simplicity. This simplification does not compromise the usefulness of the analytical approximation, and it circumvents cumbersome concepts like the logarithms of trigger prices. Obviously, an empirical study must take this useful fact into account.

In sum, the precision of a market signal relative to that of a packer's priors determines whether or not the signal will dominate her posteriors. On one hand, if the precision of a signal is less than that of a packer's priors, then irrespective of its sample size, such a signal is unlikely to alter her strategic decisions or actions. On the other hand, if a signal is more informative than a packer's priors, it eclipses the prejudice from her priors in the posterior, and could potentially influence both her decisions and actions.

Proposition I

To update the priors or to influence the strategic decisions and actions of a packer, AMS market reports must generate a market signal that is at least as precise as the packer's priors.

Consider two Bayesian packers who have divergent priors, such that the priors of packer A are more precise than those of packer B. Suppose both packers gain access to a market signal that is more precise than their priors. The normal-conjugate framework predicts that given the relative precision of both priors, packer B's posterior will weight the information from this market signal more heavily than will packer A's posterior. Hence, both posteriors will converge upon exposure to a market signal that is commonly more precise than both priors. Effectively, from a commonly more precise signal, packer B, the less informed packer, learns faster than packer A.

Eventually, as the sample size and the precision of AMS market reports increase, the resultant market signal updates the priors of both packers so that both posteriors converge to a more precise joint posterior whose variance approaches that of the corresponding market signal.[6] The implication of this interesting result for mandatory price reporting leads to the following proposition:

Proposition II

If two packers possess divergent initial priors regarding the price of livestock, then their respective posterior distribution regarding this factor input price would be almost identical if both packers are provided with a high number of observations from more precise data. Moreover, the weight that a packer puts on her (idiosyncratic) prior tends to zero when the number of observations becomes large or when the variance of the observations becomes small, and the resultant convergent posterior is more precise relative to the initial priors.

Proposition I and II imply that increasing the informativeness of AMS market reports can potentially reconcile some of the interest disparity arising from divergent priors amongst packers, and thus increase the scope for non-cooperative collusion through trigger price strategies. Predictably, packers lack the incentive to voluntarily reveal their priors to AMS. As a result, AMS faces asymmetric information, regarding the informativeness of publicly disclosed market reports relative to that of packers' priors, and the impact of such reports on the subsequent actions of packers.

[6] Recall that if the market signal is less precise than both priors, then the packers' priors will dominate in the posterior, and since the priors are asymmetric, the packers' posteriors will remain asymmetric and unlikely to converge irrespective of the number of observations. This is because packers cannot learn and therefore update their priors from a signal that reveals nothing they do not already know. If a signal is only more precise than one of the packer's priors, the outcome is predictable.

If AMS increases the informativeness of its market reports through the Act, the resultant market signals can potentially become more informative than the packers' priors. In this case, AMS market reports can influence non-cooperative collusion through trigger price strategies in two ways. First, as described in proposition 2 above, the ensuing convergence of posteriors can enhance the feasibility of identification of a unanimous trigger price by packers. Second, since priors converge to a more precise common posterior, packers are more likely to identify a commonly optimal trigger price that is closer to the expected collusive price. Effectively, this facilitates participants to lower the trigger price and enhance the observability of deviations. *Ceteris paribus,* this is consistent with improving the policing efficiency of trigger price strategies, hence promoting the potential for non-cooperative collusion. This is a significant potential social cost arising from increasing market transparency through the Act.

The objective of the Act is to increase market transparency and thereby, enhance competition in the meat and livestock industry. However, this study predicts that the Act can make non-cooperative collusion more attractive for packers by increasing the efficiency of trigger price strategies and the resultant expected collusive payoffs for packers. If packers perceive an increase in the benefits from collusion, existing penalties for detected collusion may no longer be deterrent and the Act would effectively promote collusion. Thus, to discourage a potential increase in the appeal for collusion, an increase in market transparency should ideally be accompanied by a corresponding increase in the monitoring and punishment of collusion.

However, in the case of trigger price strategies, it is very challenging for GIPSA to detect and therefore punish tacit collusion. If packers truthfully report all their transactions in full compliance to the Act, the resultant dataset could potentially improve econometric detection of collusion amongst packers. Nonetheless, it is feasible for packers to tacitly exploit noisy market signals to collude. Given the challenges of obtaining incontestable econometric evidence against tacit collusion, it is unlikely that packer's fear of such evidence could significantly deter them from colluding. As a result, in the case of trigger price strategies, it could be prohibitively expensive for GIPSA to implement command and control policies.

A natural extension of this paper is to examine the determinants of the socially optimal level of market transparency that can realistically be enforced through the Act. At this level of transparency, the informativeness of market reports should maximize the total economic surplus in the meat and livestock industry.

4. Concluding Remarks

The Act renders market transparency endogenous to AMS. However, AMS faces asymmetric information: *a priori,* AMS neither knows the informativeness of its market reports relative to the precision of packers' priors, nor whether such reports can influence the strategic decisions and actions of packers. This problem arises because packers lack the incentive to voluntarily reveal their priors to AMS.

It is important to emphasize that while the scope of this analysis is limited to trigger price strategies, other strategies are available to packers. Secondly, there exists a tradeoff between the potentially significant social cost that this analysis identifies and the considerable desirable outcomes that are consistent with the Act. In particular, the Act can reduce the perceived volatility of livestock prices, thus reducing the associated cost of uncertainty. The present study does not conduct a cost benefit analysis. Moreover, the model uses the normal-conjugate framework more for analytical simplicity and intuitive appeal rather than for its accuracy in approximating how packers perceive the movement of livestock prices. Despite the limitations implicit in its model, this analysis could at the very least be considered a useful starting point in studying the impact of increasing transparency under the Act.

The present study has shown that as long as AMS market reports generate a market signal that is more informative than packers' priors, then, by Bayesian updating, divergent priors will converge in the posterior, reconciling interest disparity amongst packers. In this case, the more informative is the market signal and the greater is the number of observations that constitute the signal, the greater is the extent of this convergence. In the limit, packers could feasibly reach complete agreement. Moreover, the priors converge to a more informative joint posterior. This result has two implications.

First, the Act can potentially enhance the feasibility of identification of a unanimous trigger price amongst packers. Second, packers are more likely to identify a lower and hence more efficient trigger price. A lower trigger price increases the observability of cheating and enhances the policing efficiency of trigger price strategies. Effectively, this is consistent with the promotion of collusion and the reduction of market efficiency. Thus, increasing market transparency under the Act could generate a significant social cost.

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The author is an M.S. student in the Department of Agricultural Economics at the University of Nebraska-Lincoln and a graduate assistant at the Center of Agricultural & Food Industrial Organization in the Department of Agricultural Economics. The author's research interests include applied game theory, industrial organization, competition policy, market structure, and economics of information and uncertainty.

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