Market and Welfare Effects of the U.S. Livestock Mandatory Reporting Act

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This paper analyzes the market and welfare effects of the United States Livestock Mandatory Reporting Act enacted in 2001. The act mandates meat packers to report their transactions daily to a government agency and requires the agency to make a summary of those transactions available to the public through the Mandatory Livestock Meat Market News Reports. Considering the case of an imperfect packer cartel that uses trigger price strategies, this paper examines the impact of market information provided by the reports on equilibrium livestock slaughter and the welfare of the groups involved and identifies the determinants of the socially optimal level of information. A key result of the paper is that, even when facilitating collusion among packers, increased market information can be social welfare enhancing.

JEL Classification: L13, L15, L66

1. Introduction

The Livestock Mandatory Reporting Act (the Act) was enacted in 2001 to provide market participants with information on all cash and noncash transactions reported by packers to the Agricultural Marketing Service (AMS) on a daily basis. The information is aggregated under specific confidentiality guidelines1 to preserve the anonymity of the source2 and published in the Mandatory Livestock and Meat Market News Reports (Reports).3 AMS is responsible for setting the confidentiality guidelines as well as for enforcing the Act. As stated in the Act

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1 The current confidentiality guideline is known as the "3/70/20." It allows AMS to publish price reports if, during the most recent 60-day time period, at least three packers provide data at least 50% of the time, no single packer provides more than 70% of the data, and no single packer may be the sole reporting entity for a report more than 20% of the time. The "3/70/20" replaced the "3/60" guideline. The "3/60" guideline required that, in order for AMS to report price information, there should be at least three packers reporting with no single packer accounting for 60% or more of the total livestock procured.

2 Since among the packers who are on the reporting as well as the receiving end of information are the top four packers who slaughter more than 70% of the cattle, 60% of the hogs, and 67% of the lamb, aggregation is viewed as necessary in order not to foster collusion.

Effects of Livestock Mandatory Reporting (Federal Register 2000), the Reports intend to provide information “that can be readily understood by producers, packers, and other market participants, ... [improve] the price and supply reporting services of the Department of Agriculture and [encourage] competition in the marketplace for livestock and livestock products.” The rationale is that “as more animals have been purchased under marketing arrangements, neither the arrangements nor the final purchase prices are publicly disclosed.”

About two years after the Act went into effect, Schroeder, Grunwald, and Ward (2002) reviewed the early literature on livestock mandatory reporting (LMR). A consensus appeared to be forming that, while LMR could be beneficial by reducing uncertainty and increasing competition in cattle markets, revealing too much information about rival pricing could facilitate collusion (and reduce competition) among packers (Schroeder, Grunwald, and Ward 2002, p. 11).

The uncertainty-reducing effect of LMR was deduced from two experimental studies by Anderson et al. (1998) and Bastian, Koontz, and Menkhaus (2001). In the first experiment, price and quantity information in the fed cattle market, simulated through the Fed Cattle Market Simulator (FCMS), was varied, and market outcomes were observed. Uncertainty, measured by price dispersion, was found to increase with the amount and type of information withheld. In the second experiment, also using the FCMS, market participants were provided with price and quantity information on cattle sold through the spot markets as well as through forward contracts. The authors observed a substantial reduction in the variance of forward contract prices. The effect of the forward-market information on the variance of spot prices was negative but not statistically significant.

Maintaining the hypothesis that mandatory reporting reduces uncertainty through the provision of more information, Azzam (2003) studied the effects of the reduction in uncertainty on the structure, conduct, and performance of livestock markets. Azzam’s theoretical findings suggest that, in a setting where cattle feeders and packers are risk-averse and packers hold consistent conjectures, increased transparency due to mandatory reporting promotes competition and results in higher livestock prices. However, since increased transparency can make it easier for packers to collude (Wachenheim and DeVuyst 2001), Azzam’s assumption of consistent conjectures is restrictive because it rules out the possibility of collusion.

Njoroge (2003) provides a formal model of collusion that is in line with the arguments in Wachenheim and DeVuyst (2001). In Njoroge’s study, collusion arises because risk-neutral oligopsonistic packers, who have divergent priors about the distribution of livestock and meat prices before the Act, have convergent posteriors after updating their priors with the Reports. In that setting, packers are better able to identify a unanimous trigger price and, as a result, find it easier to monitor each other’s deviations from a (tacitly) collusive agreement. Risk neutrality, however, rules out gains to firms from the profit variance-reducing effect of increased transparency, and in this context, Njoroge’s work focuses on the collusive effect.

The collusive effect of the Act has been tested empirically by Azzam and Salvador (AS) (2004). The test by AS is based on the theoretical model by Jin (1996), who shows that if the squared sales of risk-averse Cournot firms decline after the introduction of an information-

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4 The legislation was passed in 1999 with a sunset clause requiring Congress to reauthorize the Act after five years. In the fall of 2004, Congress authorized a one-year extension ending in October 1, 2005. As of this writing, separate legislations introduced by the House and by the Senate aiming at extending the Act beyond October 1, 2005, are being held up in committee.

5 Information on the FCMS is available at http://agecon.okstate.edu/fcms.
sharing arrangement, collusion is likely. AS found that, of all the regions AMS uses to report the data (Texas–Oklahoma, Kansas, Nebraska, Colorado, and Iowa–Minnesota), the Act was noncollusive only in Nebraska.

The focus on either the risk effect or the collusive effect of transparency represents a major limitation of the preceding studies. Clearly, by reducing the perceived volatility of livestock prices, transparency generates a risk effect. The risk effect reduces the risk-averse packers' perceived cost of uncertainty and provides economic incentives for increased cattle procurement. Also, by increasing the observation of deviations from collusive behavior among packers, increased transparency may generate a collusive effect. The collusive effect provides economic incentives for packers to restrict livestock procurement toward the monopsony level. Specifically, an increase in transparency can reduce the noise of market signals used by an imperfect cartel to detect deviations from collusive conduct. As a result, transparency can increase the cartel's efficiency in policing the behavior of its members, and, hence, it can increase the expected payoffs from collusion. In this context, the effect of increased transparency on the quantity of procured livestock and social welfare can be determined only by analyzing the trade-off between the risk and collusive effects.

The objective of this paper is to analyze the impact of market information provided by the Reports on equilibrium livestock slaughter, taking into account both the risk and the collusive effects of increased transparency. In addition, our paper seeks to identify the welfare implications of the Act and the determinants of the socially optimal level of information when the Reports are more informative than the packers' priors and have an influence on the behavior of the members of an imperfect cartel (i.e., a market structure where a small number of firms decide between collusive and noncollusive conduct).

To analyze the market and welfare effects of the Act, we develop a stylized model of transparency, risk, and collusion that includes elements from the models by Azzam (2003) and Njoroge (2003). This enables us to focus on the analysis of the Act without the added complexity of considering the idiosyncrasies of any particular livestock market. Our model extends the Green and Porter (1984) framework of optimal trigger price strategies for collusion among risk-neutral firms by allowing for packer aversion toward risk. Relaxing the assumption of risk neutrality allows for the explicit consideration of the trade-off between the risk and collusive effects of transparency, facilitating a more comprehensive economic analysis of the Act. In particular, while increasing the transparency in the Green–Porter setting

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6 This is a well-known result in the industrial organization literature (see Stigler 1964). Albaek, Mollgaard, and Overgaard (1997), in a study of the effects of mandatory publication of firm-specific prices in the ready-mixed concrete sector in Denmark, found that the publication of price information fostered collusion.

7 It should be noted that the change in the information in the Reports and, hence, a change in transparency can be seen as corresponding to one of two scenarios. The first could be a change in the amount of information after the switch from voluntary reporting (which represents the situation prior to the Act) to mandatory reporting. The second could be a change in the amount of information under alternative AMS confidentiality guidelines since the Act went into effect. As mentioned previously (see footnote 1), USDA has worked with two guidelines: the original “3/60” and the “3/70/20.” The latter was instituted four months after the Act because the “3/60,” which was intended to ensure that proprietary data were not made public, resulted in many AMS reports having missing data—denying the market information and, consequently, undermining the very intent of the Act. By implication, the intent of the “3/70/20” confidentiality guideline is to provide the market with more information and, hence, more transparency than what was provided under the “3/60” guideline. Since the two scenarios are analytically indistinguishable, the discussion in the rest of the paper is in terms of increased transparency under the Act.

8 In essence, our model nests the Green–Porter model as a special case. As will be shown later in the paper, when the Arrow–Pratt coefficient of absolute risk aversion is zero, our model collapses to the Green–Porter model.
would enhance the effectiveness of trigger price strategies and would reduce the quantity of livestock slaughter, increasing transparency in our setting would also reduce packer uncertainty, prompting an increase in the quantity of procured livestock. Thus, by allowing for packer aversion toward risk, our model explicitly accounts for the counteractive risk and collusive effects of the Act. A key result of our paper is that increasing the information in livestock markets can be social welfare enhancing even if it promotes collusion among packers.

The rest of the paper is structured as follows. Section 2 determines the equilibrium livestock slaughter under an imperfect cartel market structure. The effect of increased information on the equilibrium quantity procured by the imperfect cartel is examined in section 3. Section 4 identifies the welfare effects of increased transparency and the determinants of a socially optimal level of information. Section 5 summarizes and concludes the paper.

2. The Optimal Livestock Slaughter

The starting point of the analysis is the same as that considered in Azzam (2003), namely, a homogeneous, risk-averse oligopsony of $N$ symmetric packers,\(^9\) whose objective is to maximize the expected utility of profits. For simplicity, it is assumed that packers face zero processing costs and that the production technology between procured livestock and processed meat is fixed proportions. The livestock supply function facing each packer is given by

\[ W = W(Q) + e, \]  
where $W$ is the observable stochastic component of the price of livestock and $W(Q)$ is the nonstochastic component given by

\[ W(Q) = a + bQ = a + bq_i + bQ_{-i}. \]

The parameters $a$ and $b$ are the intercept and the slope of the livestock-supply curve, respectively; $q_i$ is the livestock quantity procured by packer $i$; and $Q_{-i}$ is the aggregate livestock quantity procured by all other packers except for packer $i$. The parameter $e$ is the random additive noise that consists of both the random shock to the factors of livestock production and the random noise of the market signals. It is assumed that $e$ is identically and independently distributed with zero mean, PDF $f(e)$ and CDF $F(e)$, where $f(e)$ is symmetric around zero,

\[ F(-\infty) = 0, \text{ and } F(+\infty) = 1. \]

The volatility of livestock prices is measured by the variance of the random additive shock, $\sigma_w^2$. Following Azzam (2003), market transparency is defined as the degree to which the volatility of livestock and meat prices is reduced as the Reports become more informative. Given that livestock prices are stochastic and packers are assumed to be risk averse, maximization of expected utility of profits is analogous to maximization of the corresponding certainty equivalent (CE) of stochastic profits. The CE of packer $i$ is given by

\[ \text{As pointed out by Azzam (2003), one justification for the assumption of risk-averse behavior is that a high-volume/low-margin industry, like the meat industry, would be quite sensitive to price variability. On the issue of risk aversion in pork and beef packing, see Schroeter and Azzam (1991) and Holt (1993), respectively.} \]

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where \( P \) is the price received by packers for processed meat. The first term on the right-hand side (RHS) of Equation 3 represents the expected profit of the \( i \)th packer, while the second term is her risk premium given her average absolute risk aversion, \( \lambda_i \), and volatility of livestock prices, \( \sigma^2_{W} \).

**The Imperfect Cartel Market Equilibrium**

The imperfect cartel considered in this paper consists of packers who employ trigger price strategies in an infinite horizon game under incomplete and imperfect information. The analysis focuses on infinite horizon interaction between packers, where the packers involved do not know when the strategic interaction will end. The feasibility of noncooperative collusion (NCC) depends on the packers’ discount factors and the game’s information structure. According to the Folk theorem, if packers are sufficiently patient, then almost any strategy can be supported as a Nash equilibrium, and therefore collusion can be a subgame perfect Nash equilibrium.

To avoid undue complications arising from interest disparity, potential side payments, and quota allocations, symmetry is assumed regarding the level of risk aversion, \( \lambda_i \); discount factors, \( \beta_i \); and posterior conjectures on the distribution of livestock prices, \( \mathcal{f}(\theta|W) \), across all participating packers. It is further assumed that packers’ discount factors are high enough and their posteriors sufficiently informative for NCC to be feasible in the first place.

The objective of each packer is to maximize the expected utility of the present discounted value of idiosyncratic profits in the infinite horizon game. As mentioned above, this is analogous to maximizing the present discounted value of the idiosyncratic CE. Thus, individual packers can have economic incentives to deviate from collusive behavior depending on their discount factors and the game’s information structure.

The model of incomplete and imperfect information developed by Spence (1978) is used to capture the information structure of the strategic interaction outlined above. The stochastic supply function captures the information incompleteness by introducing event uncertainty into the game’s payoffs. Thus, packers face uncertainty regarding the game’s payoffs (including individual payoffs). Effectively, a packer’s profit is a function of her own behavior, the actions of her rivals, and the stochastic shifts of the livestock supply function.

In addition, this model captures the imperfection of information by restricting the best response functions of the packers, so they detect noisy market signals but not actual competitor behavior. Thus, packers cannot directly observe each other’s livestock purchases, resulting in uncertainty about a rival’s past behavior. Specifically, under the Act packers must imperfectly interpret the history of their rivals’ behavior by observing noisy market signals generated by AMS Reports. In this context, the game’s information structure can be influenced by AMS as it changes the amount of information in its Reports; that is, changes in the information provided can alter the packers’ ability to observe deviations from collusive behavior.

The starting point of the conceptual framework is the identification of the imperfect cartel quantity \( q_{IC} \in [q_{PC}, q_{CN}] \) as the feasible range of the imperfect cartel’s vector of livestock quantities, where \( q_{PC} \) and \( q_{CN} \) are, respectively, the perfect cartel and the Cournot Nash equilibrium (CNE) vectors of procured livestock. The CNE quantity of livestock procured by packer \( i \) (derived by maximizing the \( i \)th packer’s CE in Equation 3 and solving simultaneously...
the best response functions of the $N$ packers) is given by

$$q_i^{CN} = \frac{P - a}{(N + 1)b} - \frac{\lambda \sigma_w^2(P - a)}{b(N + 1)[(N + 1)b + \lambda \sigma^2_w]},$$

with the first term on the RHS of this expression being the CNE outcome under risk neutrality.

The livestock quantity procured by each member of a perfect cartel (derived by maximizing the expected utility of the cartel's joint profits in a single period—which is equivalent to maximizing the cartel's joint $CE$ in a single period) is

$$q_i^{PC} = \frac{(P - a)}{2Nb + \lambda \sigma^2_w} \Rightarrow q_i^{PC} = \frac{(P - a)}{2Nb} - \frac{\lambda \sigma^2_w(P - a)}{2bN(2Nb + \lambda \sigma^2_w)},$$

with the first term on the RHS of this expression being the quantity that would be procured by packer $i$ if the purchase price of livestock were noiseless or if packers were risk neutral, that is, $\lambda = 0$.

Under an imperfect cartel, packers lack profit incentives to collude outside the range $q^{IC} \in [q^{PC}, q^{CN}]$. This is because, on the one hand, restriction of livestock quantities below vector $q^{PC}$ is suboptimal since packers could always increase their $CE$ by procuring more livestock. On the other hand, procurement of livestock at a level above the CNE vector of livestock quantities, $q^{CN}$, is irrelevant. This is so because the CNE is, by definition, a self-sustaining equilibrium whose outcome would be preferable to such conduct (i.e., packers would have no incentive to deviate). Thus, at any given level of information, the feasible range of NCC is bounded by the corresponding perfect cartel and CNE vectors of procured livestock quantities.

To analyze the impact of increased information on livestock procured by the imperfect cartel, consider the Green and Porter (1984) enforcement mechanism for the risk-averse, homogeneous packer oligopsony described above. To detect deviations from collusive conduct by other participants, each packer employs her posterior conjectures, $f_i(\theta|W)$, to test the hypothesis that the observable price of livestock, $W$, is drawn from a population characterized by an expected mean and variance. Once the observable price of livestock $W$ exceeds a trigger price, $\bar{W}$, packers enter a punishment period regardless of the apparent source of the higher $W$. They do this by procuring livestock at the CNE level, $q^{CN} = (q_1^{CN}, \ldots, q_N^{CN})$ for a finite number of periods, $T \in (0, \infty)$, before reverting to the collusive vector $q^{IC} = (q_1^{IC}, \ldots, q_N^{IC})$.

Any threat of a punishment that exceeds $q^{CN} = (q_1^{CN}, \ldots, q_N^{CN})$ is not credible because the CNE becomes an appealing self-enforcing option. There are two necessary conditions for this threat of punishment to be credible. First, each packer's $CE$ during punishment must be smaller than this same packer's $CE$ during collusion. Second, the $CE$ of a packer who purchases the collusive quantity when all other packers are cheating must be less than the $CE$ of this same packer if she also deviates. Thus, this threat is credible only if

$$CE_i(q^{CN}) < CE_i(q^{IC}) \text{ and } CE_i(q_i^{IC}, q_i^{CN}) < CE_i(q_i^{CN}, q_i^{CN}).$$

(4)

If either of these conditions is not satisfied, then the threat of such punishment is not credible, and the cartel cannot sustain collusion.

Subject to the above conditions, the oligopsony could employ the Green–Porter enforcement mechanism to facilitate NCC under incomplete and imperfect information in an infinite horizon game as follows:
(a) In period $t = 0$, each packer extends a goodwill gesture by purchasing a collusive quantity of livestock $q^i_C$. This results in a collusive vector $q^C = (q^C_1, \ldots, q^C_N)$ such that $q^C_i < q^C_N$.

(b) In any subsequent period $t + 1$, each packer continues to purchase $q^i_C$, as long as in the previous period the market price of livestock is less than a trigger price, that is, as long as $W \leq \tilde{W}$.

(c) If in any period $t, W > \tilde{W}$, then, regardless of the apparent cause, each packer shifts to the CNE quantity resulting in the vector $q^{CN}$ in period $t + 1$ and continues purchasing this quantity for $T - 1$ periods (i.e., until period $[t + (T - 1)]$ before reverting to $q^i_C$ in period $(t + T)$.

Based on this enforcement mechanism, the expected present discounted value of the $CE$ of an imperfect cartel's member is given by

$$V_i(q^C) = CE_i(q^C) + \Pr\{W \geq \tilde{W}\} \left[ \sum_{t=1}^{T-1} \beta^t CE_i(q^{CN}) + \beta^T V_i(q^C) \right] + \Pr\{W < \tilde{W}\} \beta V_i(q^C).$$

Substituting for $W$ from Equations 1 and 2 and noting that

$$\Pr\{\tilde{W}(Q) + e \geq \tilde{W}\} = \Pr\{e \geq \tilde{W} - \tilde{W}(Q)\} = 1 - \Pr\{e < \tilde{W} - \tilde{W}(Q)\} = 1 - F(\tilde{W} - \tilde{W}(Q))$$

and

$$\Pr\{\tilde{W}(Q) + e < \tilde{W}\} = \Pr\{e < \tilde{W} - \tilde{W}(Q)\} = F(\tilde{W} - \tilde{W}(Q)),$$

we obtain

$$V_i(q^C) = CE_i(q^C)$$

$$+ \left[ 1 - F_e(\tilde{W} - \tilde{W}(Q)) \right] \left[ \sum_{t=1}^{T-1} \beta^t [CE_i(q^{CN})] + \beta^T V_i(q^C) \right]$$

$$+ F_e(\tilde{W} - \tilde{W}(Q)) \beta V_i(q^C).$$

Rearranging Equation 5 results in

$$V_i(q^C) = \frac{CE_i(q^{CN})}{(1 - \beta)} + \frac{CE_i(q^C) - CE_i(q^{CN})}{1 - \beta^T + (\beta^T - \beta)F(\tilde{W} - \tilde{W}(Q))}. \quad (6)$$

Equation 6 shows that a packer's expected payoff, $V_i(q^C, \tilde{W}, T, \beta)$, is equal to the $CE$ generated by Cournot competition plus the difference between the $CE$ generated by NCC periods and that generated by the CNE periods, $[CE_i(q^C) - CE_i(q^{CN})]$, both appropriately discounted. The greater $[CE_i(q^C) - CE_i(q^{CN})]$ is, the greater the packer's payoff, $V_i(q^C)$, is and the more attractive collusive behavior is relative to Cournot behavior among packers. Following Porter, an NCC equilibrium is characterized by an equilibrium vector of livestock quantities, $q^{CN*} = (q^{CN*}_1, \ldots, q^{CN*}_N)$; a unanimous trigger price, $\tilde{W}$; and a punishment period $T$ if
\[ V_i(q^{IC}) = \text{Max}\{ V_i(q^{IC}) \mid q_j = q_j^*, \forall j \neq i, q_i \geq 0 \}. \] (7)

The solution to the maximization problem in Equation 7 is a Nash equilibrium vector of livestock quantities, \( q^{IC}(W, T) \), which is a function of the trigger price \( W \) and a punishment period \( T \). Effectively, the noncooperative equilibrium is characterized by the trigger price, \( W^* \); the punishment period, \( T^* \); and the resultant collusive equilibrium vector of livestock quantities, \( q^{IC} = (q_1^{IC}, \ldots, q_N^{IC}) \), when, given the symmetric discount factor \( \beta \), no participant can increase her expected \( V_i(q^{IC}) \) by unilateral deviation from the collusive agreement. The equilibrium present discounted value of packer \( i \) is thus a function of \( W \) and \( T \), that is, \( V^*_i(W, T) \) for \( i = 1, \ldots, n \).

Note that there exists a range of potential levels of the trigger price, \( W \) (and an associated range of potential symmetric noncooperative equilibria), available to the cartel. Within this range of trigger prices, each packer perceives an optimal trigger price as the one that maximizes her present discounted value. Because of symmetry, the optimal trigger price is common across all packers.

Porter's model can now be extended to a general case in which the packers' degree of risk aversion is given by \( \lambda \). As shown in Appendix A, when the optimal trigger price \( W^* \) is chosen from the range of potential trigger prices to maximize \( V_i(q^{IC}) \), the equilibrium quantity of livestock procured by each packer under an imperfect cartel is given by

\[ q_i^{IC} = \frac{(P - a)}{(2Nb + \lambda\sigma_w^2)} + \frac{1}{\beta e} \left[ \frac{(N + 1)b + \lambda \sigma_w^2}{2Nb + \lambda \sigma_w^2} \right], \] (8)

where \( e = \frac{|f'(e)/f(e)|^{-1}}{f(e)} \). When \( \lambda = 0 \), the general case described by Equation 8 collapses to the special case of risk-neutral packers.

At this point, it is useful to clarify the relationship between the term \( e \) and packers' posteriors regarding the distribution of livestock prices. Based on each packer's posterior distribution, for a given value of the random additive noise to the supply of livestock, \( e \), an increase in \( e = |f'(e)/f(e)|^{-1} \) corresponds to an increase in \( f'(e) \) relative to \( f(e) \). This implies an increase in the absolute slope of the packer's posterior PDF, \( f(e) \), relative to that of its associated CDF, \( F(e) \), at this particular point. This is consistent with a mean-preserving contraction of the PDF that reduces the associated variance, \( \sigma_w^2 \), by shifting probability from the tails to the middle part of the density function while holding the mean constant.

To illustrate, consider the general class of exponential power distributions:

\[ f(e) = \omega(\delta)\sigma^{-1} \exp \left[ -c(\delta) \left( \frac{e - \mu}{\sigma} \right)^{2/(1 + \delta)} \right], \]

with \( -1 < \delta \leq 1 \), where the normal distribution represents a special case in which \( \delta = 0 \).\(^{10}\) It can be shown (see Appendix B) that, given a location parameter \( \mu = 0 \),

\[ e = \frac{f'(e)}{f(e)} = \frac{2c(\delta)}{(1 + \delta)} e^{(1 - \delta)/1 + \delta} [\sigma^2]^{-1/(1 + \delta)}. \]

\(^{10}\) According to Box and Tiao (1973), the parameter \( \delta \) is a measure of kurtosis indicating the extent of "nonnormality," that is, the extent to which the parent population is leptokurtic or platykurtic.
If a packer’s prior belongs to this class of distributions, then an increase in \( \varepsilon = |f'(e)[f(e)]^{-1}| \) corresponds to a decrease in the perceived volatility of livestock prices by a packer, \( \sigma^2_{\text{W}} \), in the posterior. This corresponds to an increase in the information of a packer’s posterior relative to that of her prior.

Utilizing Bayesian updating, Njoroge (2003) shows that the shape of a packer’s posterior distribution converges to that of the market signal generated by the information in a Report. Accordingly, if we consider the information in the Reports and that of the packer’s posteriors to be convergent, then \( \varepsilon = |f'(e)[f(e)]^{-1}| \) can serve as an information indicator for both.\(^{11}\) The greater is \( \varepsilon \), the more informative are the Reports and the greater is the information of packer’s posteriors.

We have seen that the information in the Reports can alter a packer’s perception of the volatility of livestock prices. Although the specific functional form is inconspicuous, we do know that increasing the information in AMS Reports reduces the perceived volatility of livestock prices by packers. Indeed, it can be shown that for the general class of exponential power distributions, this impact is such that \( \partial \sigma^2_{\text{W}} / \partial \varepsilon < 0 \) and \( \partial^2 (\sigma^2_{\text{W}}) / \partial \varepsilon^2 > 0 \) (see Appendix B). The effect of information contained in the Reports on the perceived volatility of livestock prices by packers can be accounted for by including the information indicator, \( \varepsilon \), as an argument, that is, \( \sigma^2_{\text{W}}(\varepsilon) \). Equation 8 can then be rewritten as

\[
q_i^{IC^*} = \frac{(P - a)}{2Nb + \lambda \sigma^2_{\text{W}}(\varepsilon)} + \frac{1}{2b^2} \left[ \frac{(N + 1)b + \lambda \sigma^2_{\text{W}}(\varepsilon)}{2Nb + \lambda \sigma^2_{\text{W}}(\varepsilon)} \right],
\]

where the first RHS component is the optimal livestock quantity that would be procured by packer \( i \) if the imperfect cartel were devoid of cheating (hereafter the compliance component), and the second RHS component is the optimal deviation quantity by each participant in response to imperfect observation of cheating within the imperfect cartel (hereafter the cheating component). Thus, the difference between the perfect and the imperfect cartel is that the perfect cartel is, by definition, devoid of the cheating component.

After having derived the equilibrium quantity of livestock procured by each member of the imperfect cartel as a function of the information in the Reports, we can now examine the impact of changing that information on \( q_i^{IC} \).

### 3. Transparency and Equilibrium Slaughter

Consider first the extreme case of an increase in information to full transparency. If a packer’s posterior PDF, \( f(e) \), is symmetric around a zero mean, that is, \( f'(e) > 0 \) when \( e < 0 \), and \( f'(e) < 0 \) when \( e > 0 \), then the feasible range for the information indicator \( \varepsilon = |f'(e)[f(e)]^{-1}| \) is \( 0 < \varepsilon < \infty \) (recall that a packer’s posterior CDF, \( F(e) \), is a nondecreasing function of \( e \)). As the slope of the PDF approaches infinity (\( f'(e) \to \infty \)), so does the information indicator (\( \varepsilon \to \infty \)); that is, full transparency is approached. Increasing the information to full transparency results in the collapse of the density function \( f(e) \) into a vertical line of infinite slope.

\(^{11}\) The normal conjugate framework predicts that convergence is attained in a few iterations. Since packers have unlimited access to publicly disclosed market reports, their posteriors will converge to the distribution of the signal generated by the Reports.
RESULT 1. As information increases to full transparency, the procured livestock quantity under an imperfect cartel is reduced to that of a perfect cartel; that is, as \( \varepsilon \rightarrow \infty \), the optimal cheating component approaches zero, and \( q^C_{\varepsilon} \rightarrow q^C \) (see Equation 9).

Result 1 confirms that, under perfect observation of deviations from collusive behavior, trigger price strategies will generate the benchmark outcome of a perfect cartel.

While approaching full transparency results in reduction of procured livestock to the level of a perfect cartel, there are levels of information, \( \varepsilon \), at which the packers will revert to the benchmark case of Cournot behavior. The effect of the level of information on the optimal behavior of packers under an imperfect cartel is summarized in Proposition 1.

PROPOSITION 1. There exists a threshold level of information, \( \varepsilon^* \), above which packers prefer trigger price strategies to Cournot competition, below which they reverse this preference, and at which they are indifferent between the two.

PROOF. A proof of Proposition 1 is given in Appendix C, where it is shown that \( \varepsilon^* \) exists irrespective of whether the collusive effect dominates the risk effect or not.

Proposition 1 implies that it is not always optimal for members of an imperfect cartel to engage in trigger price strategies. When information provision generates posteriors that are less informative than \( \varepsilon^* \), packers are unable to sustain trigger price strategies at a level that generates smaller-than-CNE quantities of procured livestock, and the imperfect cartel reverts to the benchmark case of Cournot behavior.

When information provision generates posteriors that are sufficiently informative for participating packers to prefer trigger price strategies to Cournot behavior (i.e., when \( \varepsilon > \varepsilon^* \)), the net procurement effect of information provision can be determined by evaluating \( \partial q^C_{\varepsilon} / \partial \varepsilon \) from Equation 9 as follows:

\[
\frac{\partial q^C_{\varepsilon}}{\partial \varepsilon} = \frac{(P - a)\lambda \frac{\partial [\sigma^2_W(\varepsilon)]}{\partial \varepsilon}}{[2Nb + \lambda \sigma^2_W(\varepsilon)]^2} + \left\{ \frac{(N - 1)\lambda \frac{\partial [\sigma^2_W(\varepsilon)]}{\partial \varepsilon}}{\varepsilon [2Nb + \lambda \sigma^2_W(\varepsilon)]} - \frac{(N + 1) + \lambda \sigma^2_W(\varepsilon)}{\varepsilon^2 [2Nb + \lambda \sigma^2_W(\varepsilon)]} \right\}.
\]

(10)

The impact of increased transparency on the optimal compliance and cheating components is captured by the first and second terms on the RHS of Equation 10, respectively, and is summarized in Proposition 2.

PROPOSITION 2. Increasing the information in the Reports has two countervailing effects on the quantity of livestock procured by packers. First, an increase in transparency leads to a reduction in the cost of uncertainty and provides economic incentives for packers to procure more livestock (risk effect). At the same time, an increase in transparency enhances the observation of deviations from collusive behavior, leading to greater internal policing efficiency by an imperfect cartel that employs trigger price strategies, and provides economic incentives for participating packers to procure less livestock (collusive effect).

PROOF. The proof of Proposition 2 is straightforward. The first term on the RHS of Equation 10 comprises the risk effect, and it is positive (recall that \( \partial [\sigma^2_W(\varepsilon)] / \partial \varepsilon < 0 \)). The second term on the RHS of Equation 10 comprises the collusive effect, and it is negative. Note that, to determine the collusive effect, it is sufficient to evaluate the impact of increasing the information in the Reports on the cheating component.
It follows that the net procurement effect depends on which of the two countervailing effects dominates. If the risk effect outweighs (is outweighed by) the collusive effect, then an imperfect cartel that employs trigger price strategies to deter deviations from collusive behavior will procure more (less) livestock in response to an increase in the information in the Reports. The question that arises then is how information provision affects economic welfare in the livestock market. The effect of information provision on total economic surplus and the determinants of the socially optimal level of information in the Reports are considered in the next section of the paper.

4. Welfare Effects of Transparency

In the context of this paper, the socially optimal level of information in AMS Reports is the one that maximizes total economic surplus (TES). If increased information translates into increased TES, then it is deemed to be socially desirable. While it might appear that the level of information that maximizes TES will also maximize the quantity of livestock procured by packers, this intuition can be misleading. As will be shown below, maximizing TES is not always equivalent to maximizing the procured quantity of livestock. To motivate this counterintuitive result, consider the way in which packers’ livestock purchasing decisions are affected by changes in the information in the Reports.

Consider first the case where the risk effect dominates the collusive effect of transparency. In this case, if the information in the Reports increases, packers will procure more livestock. Thus, increasing the information in the Reports will generate a positive net procurement effect, in which case the more informative are the Reports, the greater is TES. Effectively, by disseminating more informative Reports, AMS can increase the aggregate quantity of procured livestock and TES while promoting the incentives for collusion.

Figure 1 illustrates the effects of increased transparency when the risk effect dominates the collusive effect. Specifically, panel (a) depicts the disaggregated welfare effects (i.e., changes in consumer surplus, livestock producer surplus, and packer profits), and panel (b) depicts changes in TES caused by increased transparency. D is the consumer demand for processed meat, while AE and ME are the average and marginal expenditure schedules (inclusive of the average and marginal cost of uncertainty) faced by the oligopsonistic packers, respectively. $S_L$ is the supply of livestock. Although $S_L$ is a part of the AE schedules faced by packers, it is included in panel (a) to illustrate the effect of increased transparency on the surplus of livestock producers. At the initial market equilibrium, $P$ is the consumer price for processed beef, $W$ is the price received by livestock producers, and $Q$ is the industry slaughter. The average expenditure per unit of livestock is $W + C_U$, where $C_U$ denotes the (average) cost of uncertainty.

As shown in Figure 1, the reduction in the cost of uncertainty due to increased transparency (i.e., the risk effect of increased transparency) causes a clockwise rotation of the average and marginal expenditure schedules faced by packers (compare AE and ME to AE’ and ME’ in Figure 1, panel [b]). At the same time, the collusive effect of increased transparency rotates the marginal expenditure schedule faced by the imperfect cartel counterclockwise from

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12 This can happen both when packers switch from Cournot competition \textit{ex ante} to trigger price strategies \textit{ex post} and when they prefer trigger price strategies both \textit{ex ante} and \textit{ex post}.
Panel (a): Disaggregated welfare effects

Panel (b): TES

Figure 1. Market and Welfare Effects of Increased Transparency When the Risk Effect Dominates the Collusive Effect

$ME'$ to $ME''$ in Figure 1, panel (b). Since the risk effect dominates the collusive effect in the case depicted in Figure 1, the aggregate quantity of procured livestock increases from $Q$ to $Q'$. The above changes lead to a reduction in consumer price, an increase in the price received by livestock producers, and welfare gains for all groups involved.
The gains in consumer surplus, producer surplus, and packer profits are given, respectively, by areas $P_1bP', \ W'fgW$, and $cbe(W'+C_{U'})d$-PacP' in Figure 1, panel (a). The vertically hatched area in Figure 1, panel (b), depicts the increase in TES caused by an increase in transparency when the risk effect dominates the collusive effect.

**RESULT 2.** When the risk effect dominates the collusive effect of transparency, increased market information under the Act results in increased quantity of livestock procured by packers and welfare gains for consumers, livestock producers, and meatpacking firms.

Consider next the case where the collusive effect dominates the risk effect of transparency. In this case, if the information in the Reports increases, packers will procure less livestock. Hence, increasing the information in the Reports generates a negative net procurement effect. As a result, dissemination of more informative Reports can reduce an imperfect cartel's aggregate quantity of procured livestock in spite of simultaneously reducing the cost of uncertainty perceived by packers. Figure 2 illustrates the effects of increased transparency when the collusive effect dominates the risk effect. Similar to Figure 1, panel (a) of Figure 2 depicts the changes in consumer surplus, livestock producer surplus, and packer profits, while panel (b) depicts changes in TES caused by increased transparency.

As illustrated in Figure 2, since the collusive effect dominates the risk effect in this case, the aggregate quantity of procured livestock falls from $Q$ to $Q'$. This leads to an increase in the consumer price, $P$, and a reduction in the price received by producers, $W$. These changes result in losses in consumer and producer welfare given by the areas $P_1bP$ and $WhgW'$ in Figure 2, panel (a), respectively. At the same time, the reduced costs of uncertainty and the increased effectiveness of trigger price strategies to foster collusion increase packer profits by the area $(P'acP_1)\text{df}(W'+C_{U'})cb$. 

Interestingly, even though the reduced quantity of livestock procured by packers when the collusive effect dominates the risk effect causes an unambiguous reduction in consumer and producer welfare, TES can still increase as the increase in packer profits can outweigh consumer and producer losses (this case is depicted in Figure 2). Put a different way, TES will increase in this case when the social benefits from the risk effect of increased information (shown by the vertically hatched area in Figure 2, panel [b]) outweigh the social costs due to the collusive effect of increased information (shown by the dotted area in Figure 2, panel [b]). Thus, despite promoting collusion and reducing the quantity of livestock procured by packers, the increase in the information in the Reports can result in net social welfare gains. These findings are summarized in Results 3 and 4.

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12 Note that, while our analysis assumes that packers are price takers downstream (i.e., in the markets they sell their products), our results also hold for the case where the oligopsonistic packers are able to exercise market power when selling their products. In such a case, the equilibrium quantity of procured livestock is determined by the intersection of the marginal expenditure schedule and the marginal revenue schedule (and not the demand). Even though the existence of oligopolistic packer power would change our results quantitatively (i.e., would reduce the equilibrium quantity of livestock slaughter, increase the consumer price, and reduce the price received by livestock producers), the qualitative nature of our results on the market and welfare effects of increased market information under the Act would remain unaffected.

13 An analogous result is reported by Marette and Crespi (2003) in a paper that examines the relationship between the formation of legal cartels and quality certification. Their paper shows that consumer welfare may increase under a cartel that provides information about product quality when the information effect associated with the formation of the cartel outweighs its collusive effect.
RESULT 3. When the collusive effect dominates the risk effect of transparency, increased market information under the Act results in reduced quantity of livestock procured by packers. Even though the reduced quantity of livestock procured by packers causes an unambiguous reduction in consumer and livestock producer welfare, total economic surplus can still increase as the increase in packer profits can outweigh consumer and producer losses.
RESULT 4. Even when facilitating collusion among oligopsonistic packers, increased transparency can be social welfare enhancing.

The socially optimal level of information in the Reports is then the level that equates the marginal benefits to the marginal costs of information provision. Counterintuitively, the socially optimal level of information does not always maximize the aggregate quantity of livestock procured by packers.

The conditions under which the risk effect dominates the collusive effect and vice versa depend on factors like the number of packers, the level of their risk aversion, the information of their priors (which determines their perceived volatility of prices), and the rate at which increasing the information in the Reports reduces packers’ perceived volatility of livestock prices. The greater is the number of packers and/or the greater is their risk aversion and/or the less informative are their priors, the greater is the likelihood that the risk effect dominates the collusive effect, and the greater is the socially optimal level of information.

Overall, we have identified two instances in which increased information can increase TES in spite of promoting collusion. In the first case, provision of more informative Reports can promote collusion, but at the same time it increases the procured quantity of livestock. In the second case, even though provision of more informative Reports reduces the procured quantity of livestock, the social benefits generated by the risk effect can outweigh the social costs generated by the collusive effect making the provision of market information welfare enhancing and, thus, socially desirable.

5. Concluding Remarks

The market information contained in the Mandatory Livestock and Meat Market News Reports can influence packers' strategic behavior. By increasing the information in its Reports, AMS can alter the quantity of livestock procured by packers. In this context, AMS faces a trade-off. On one hand, increasing the information in the Reports reduces the cost of uncertainty faced by packers. This generates a risk effect, which reduces the average expenditure schedule faced by packers, creating social benefits. On the other hand, increasing the information in the Reports may enhance the internal policing efficiency of a cartel that employs trigger price strategies to monitor deviations by its members, which fosters collusive behavior that results in social costs.

The analysis in this paper identified two cases under which provision of more information under the Act can increase total economic surplus in spite of promoting collusion among packers. First, if the risk effect outweighs the collusive effect to generate a positive net procurement effect, then information provision will generate increased quantities of procured livestock and welfare gains for consumers, livestock producers, and meatpacking firms. In this case, a positive net procurement effect is consistent with an increase in total economic surplus.

Second, even if the collusive effect outweighs the risk effect to generate a negative net procurement effect (whereupon dissemination of more informative Reports facilitates packers to collude and procure reduced quantities of livestock), this does not necessarily imply a reduction in total economic surplus. Even though the reduced quantity of livestock procured by packers causes an unambiguous reduction in consumer and livestock producer welfare, total economic surplus can still increase as the increase in packer profits can outweigh consumer and
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producer losses. In other words, economic surplus increases in this case if the social benefits from reduced uncertainty outweigh the social costs from collusion.

An important implication of these results is that if information provision increases the quantity of livestock procured by packers, then total economic surplus will always increase and, in spite of the inherent promotion of collusion, disclosure of information is socially desirable. Alternatively, one can speculate that the structure of the U.S. meatpacking industry suggests judicious mandatory disclosure if the outcome of information provision is a reduction in the quantity of livestock procured by packers because of three reasons.

First, the number of dominant packers is such that the observation of deviations from collusive behavior is possible. This implies that if disclosure leads such packers to restrict livestock slaughter relative to the competitive level, then, ceteris paribus, the associated social costs are likely to outweigh the social benefits. In addition, packers have taken alternative measures to minimize their exposure to factor input risk (e.g., backward vertical integration and coordination through ownership, marketing arrangements, and forward contracts). Given these measures, a level of disclosure that leads packers to procure less livestock is likely to stifle the social benefits generated by the risk effect while allowing the countervailing social costs generated by the collusive effect to dominate.

Finally, packers are likely to employ their own resources to acquire costly information on the distribution of livestock prices. Packers may obtain such signals by employing experienced local field buyers or by rewarding loyal feeders in exchange for market intelligence. Accordingly, one could expect packers to be well informed about the distribution of livestock prices. The more informed are packers' priors, the smaller is the risk effect and the greater is the efficiency of policing deviations from collusive conduct. Provision of informative Reports to such packers can lead to convergence of posteriors, facilitating the identification of a more efficient trigger price, thereby increasing the observation of deviations even further. Ceteris paribus, if information provision leads well-informed packers to procure less livestock, then the social costs of such disclosure are likely to outweigh the social benefits.

While the structure of U.S. livestock markets can lead one to speculate that information disclosure that leads packers to restrict slaughter is likely to generate social costs that outweigh social benefits, this is ultimately an empirical question worthy of further study. Suffice it to say that in this case, information provision through the Act should be judicious.

While our analysis has focused on the role of the government in determining the level of information in the Reports, one could argue that the government should also target the relative magnitude of the risk and collusive effects in order to affect the qualitative nature of the market and welfare effects of increased transparency. By battering collusion, for instance, the government could ensure that the risk effect dominates the collusive effect and have the welfare of all stakeholder groups increase with an increase in transparency, as suggested in this paper.

It turns out that the government could make headway against collusion if the information collected by AMS could be used to monitor packer competitive behavior in livestock markets. However, the authority to monitor competitive behavior in livestock markets lies not with AMS but with the Grain Inspection, Packers and Stockyards Administration (GIPSA), which is responsible for the enforcement of the Packers and Stockyards Act.

While, in theory, the two government agencies could coordinate their efforts to ensure the "judicious" use of information (and the dominance of the risk effect of increased transparency), coordination between AMS and GIPSA is limited because of the legal framework within which the two agencies operate (US GAO 2005). According to GIPSA officials, "individual packer
data held by AMS would be useful for monitoring competitive behavior in livestock markets. However, because GIPSA could not obtain that confidential information unless the Attorney General or the Secretary directed disclosure of the information for enforcement purposes, GIPSA is making do with the publicly available AMS livestock market report data. This monitoring effort is limited because AMS reports do not include the company-specific transaction data that might reveal anti-competitive behavior (p. 20).

In this context, for the government to ensure that the risk effect dominates the collusive effect of increased information (so that increased market transparency due to the Act is social welfare enhancing and Pareto improving), it should either adjust the regulatory framework to facilitate GIPSA’s access to AMS information on packers’ conduct, delegate the monitoring of packers’ conduct to AMS, or merge the two agencies. Under the current regulatory framework, AMS can affect the quantitative effects of the Act only through the amount of information contained in the Reports.

Before concluding this paper, it is important to emphasize that, while extensive literature about trigger price strategies exists, they are not the only mechanism that could be used to enforce collusion. Packers who wish to collude have a range of other viable options, including the monitoring of market shares and geographic allocation of markets. In addition, this paper assumes that all packers truthfully reveal all their transactions to AMS in full compliance with the Act and does not therefore consider the possibility of strategic misrepresentation by packers. Both the impact of the Act on alternative collusion mechanisms and the analysis of strategic misrepresentation by packers could provide insights that further our understanding on the impact of the Mandatory Reporting Act on livestock markets.

Appendix A

This Appendix derives the equilibrium quantity of livestock procured by each risk-averse member of a symmetric imperfect cartel when a trigger price is chosen to maximize the member’s \( V(q^{IC}) \) in an infinite horizon game under incomplete and imperfect information.

The starting point is the first-order-condition (FOC) of Equation 6 in the text:

\[
\frac{\partial V(q^{IC})}{\partial q_i} = \frac{[1 - \beta T + (\beta T - \beta)F(.)] \left( \frac{\partial [CE_i(q^{CN})]}{\partial q_i} \right) - (CE_i(q^{IC}) - CE_i(q^{CN}))[( - b)(\beta T - \beta)f(.)]}{[1 - \beta T + (\beta T - \beta)F(.)]^2} = 0.
\]

This is equivalent to

\[
[1 - \beta T + (\beta T - \beta)F(.)] \left\{ \frac{\partial [CE_i(q^{CN})]}{\partial q_i} \right\} + \Delta b(\beta T - \beta)f(.) = 0,
\]

where \( \Delta = [CE_i(q^{IC}) - CE_i(q^{CN})] = \left\{ [P - (a + Nbq^{IC})]q^{IC} - (1/2)\lambda \sigma_w (q^{IC})^2 - CE_i(q^{CN}) \right\} \) since \( \frac{\partial [CE_i(q^{CN})]}{\partial q_i} = P - a - q^{CN}(N + 1)b + \lambda \sigma_w \). Recalling the assumption of symmetric imperfect cartel, that is, \( q_i^{IC} = q_j^{IC} = q^{IC} \forall i,j \in \{1, \ldots, N\} \), we can rewrite Equation A1 in terms of \( q^{IC} \):

\[
- \left\{ [P - (a + Nbq^{IC})]q^{IC} - \frac{1}{2} \lambda \sigma_w (q^{IC})^2 - CE_i(q^{CN}) \right\} [b(\beta T - \beta)f(.)] = 0
\]

\[
\frac{[1 - \beta T + (\beta T - \beta)F(.)]}{[1 - \beta T + (\beta T - \beta)F(.)] \left\{ P - a - q^{IC}((N + 1)b + \lambda \sigma_w) \right\}}.
\]

The solution to the FOC described by Equation A2 is \( q^{IC}(\hat{W}, T) \). This equation shows that there exist multiple collusive equilibria and an associated range of possible equilibrium quantity vectors, \( q^{IC}(\hat{W}, T) \), depending on the values.
of \( \hat{W} \) and \( T \). This implies that each participant packer’s optimal \( V_i(q^*(\hat{W}, T) ; \hat{W}, T) \) is a function of \( \hat{W} \) and \( T \), that is, \( V_i^*(\hat{W}, T) \). Since multiple equilibria exist, each participant packer has economic incentives to identify the optimal trigger price \( \hat{W}^* \), which can be enforced to maximize her \( V_i^*(\hat{W}, T) \). In other words, packers have a profit incentive to identify a feasible \( \hat{W}^* \) that maximizes expected payoffs from NCC. Through symmetry, \( \hat{W}^* \) is unanimous to all members of the imperfect cartel. An optimal trigger price, \( \hat{W}^* \), satisfies the FOC:

\[
\frac{\partial V_i(q^*(\hat{W}, T) ; \hat{W}, T)}{\partial \hat{W}} = 0. \tag{A3}
\]

Following Porter (1983), Equation A3 can be expressed more informatively as

\[
\sum_{j=1}^N \frac{\partial V_j^*}{\partial \hat{q}_j^*} \frac{\partial \hat{q}_j^*}{\partial \hat{W}} + \frac{\partial V_i^*}{\partial \hat{W}} = 0. \tag{A4}
\]

However, this FOC is evaluated at the equilibrium \( q^{*\text{C}} = (q_1^{*\text{C}}, \ldots, q_N^{*\text{C}}) \), and, at equilibrium, \( \partial V_i^*/\partial q_i = 0 \). Thus,

\[
(N - 1) \frac{\partial V_i^*}{\partial \hat{q}_j^*} + \frac{\partial V_i^*}{\partial \hat{W}} = 0, \forall j \neq i. \tag{A5}
\]

The remaining task is to solve Equation A5 and obtain the optimal quantity of procured livestock that can realistically be enforced. The first step is to determine how a change in \( \hat{W} \) shocks an existing collusive equilibrium quantity vector of procured livestock \( q^{*\text{C}} \). To capture this shock, one can derive \( \partial \hat{q}_j^* / \partial \hat{W} \) by totally differentiating the FOC in Equation A2:

\[
-\Delta b(\beta^T - \beta)f(\cdot) \Delta \hat{W} + \Delta b^2(\beta^T - \beta)f(\cdot) N \Delta \hat{q}^{*\text{C}} - (\beta^T - \beta) h f(\cdot) [P - a - q(2N b + \lambda \sigma_w)] \Delta \hat{q}^{*\text{C}}
\]

\[-\Delta b f(\cdot) \beta \log \beta \Delta T = -[1 - \beta^T + (\beta^T - \beta) F(\cdot)] \frac{\partial V_i^*}{\partial q_i^*}
\]

\[-[P - a - q^{*\text{C}}((N + 1)b + \lambda \sigma_w)] \Delta \hat{q}^{*\text{C}} + \left[ P - a - q^{*\text{C}}((N + 1)b + \lambda \sigma_w) \right] \frac{\partial \hat{W}}{\partial \hat{W}}.
\]

Equation A6 can be simplified to

\[
\frac{\partial \hat{q}_j^*}{\partial \hat{W}} = \left\{ \frac{\left[ \Delta b f(\cdot) \beta \frac{\Delta q^{*\text{C}}((N + 1)b + \lambda \sigma_w)}{f(\cdot)} \Delta \hat{W} - \frac{\Delta q^{*\text{C}}((N + 1)b + \lambda \sigma_w)}{f(\cdot)} \Delta \hat{W} \right]}{\left[ P - a - q^{*\text{C}}((N + 1)b + \lambda \sigma_w) \right] \Delta \hat{W}} \right\} \tag{A7}
\]

The second step is to determine how a change in the livestock quantities procured by all other packers except packer \( i \) can influence \( V_i^* \). By symmetry, this can be evaluated by \( (N - 1) \partial V_i^*/\partial q_i \). From Equation 6, we obtain

\[
\frac{\partial V_i^*}{\partial q_i} = \frac{[1 - \beta^T + (\beta^T - \beta) F(\cdot)] \left( \frac{\partial \Delta}{\partial q_i} + \Delta \frac{\partial (\beta^T - \beta) \beta}{\partial q_i} \right)}{[1 - \beta^T + (\beta^T - \beta) F]^2}.
\]

Since

\[
\frac{\partial \Delta}{\partial q_i} = \frac{\partial [CE_i(q^{*\text{C}}) - CE(q^{\text{CN}})]}{\partial q_i} = \frac{\partial CE(q^{*\text{C}})}{\partial q_i}
\]

and

\[
CE_i(q) = \left[ P - (a + bq_i + bQ_{-i}) \right] q_i - \frac{1}{2} \lambda (\sigma_w q_i)^2
\]

(from Equations 1 and 2), then \( \partial \Delta / \partial q_i = -bq_i \), whereupon \( \partial V_i^*/\partial q_i \) can be rewritten as

\[
\frac{\partial V_i^*}{\partial q_i} = \frac{[1 - \beta^T + (\beta^T - \beta) F(\cdot)] \left( \frac{\partial \Delta}{\partial q_i} + \Delta \frac{\partial (\beta^T - \beta) \beta}{\partial q_i} \right)}{[1 - \beta^T + (\beta^T - \beta) F]^2}.
\]
Noting that \(-\Delta[b(\beta^T - \beta)f(e)] = [(1 - \beta^T + (\beta^T - \beta)F(e)] \left\{ \frac{P - a - q^C((N + 1)b + \lambda \sigma^2_w)}{1 - \beta^T + (\beta^T - \beta)F(e)} \right\} \) from Equation A2, we can rewrite \(\frac{\partial V_i^*}{\partial q_i} \) as:

\[
\frac{\partial V_i^*}{\partial q_i} = \frac{[1 - \beta^T + (\beta^T - \beta)F(e)](-bq_i) - [1 - \beta^T + (\beta^T - \beta)F(e)] \left\{ P - a - q_i((N + 1)b + \lambda \sigma^2_w) \right\}}{[1 - \beta^T + (\beta^T - \beta)F(e)]^2}.
\]

The above expression can be further simplified to obtain:

\[
\frac{\partial V_i^*}{\partial q_i} = -\frac{P - a - q^C((N + 1)b + \lambda \sigma^2_w)}{1 - \beta^T - (\beta^T - \beta)F(e)}.
\] (A8)

The third step is to determine the direct effect of a trigger price change on \(V_i^*(\hat{W}, T)\). From Equation 6 we get:

\[
\frac{\partial V_i^*}{\partial \hat{W}} = \frac{-\Delta[(\beta^T - \beta)f]}{[1 - \beta^T + (\beta^T - \beta)F(e)]^2}.
\] (A9)

By substituting Equation A2 into the numerator, we obtain:

\[
\frac{\partial V_i^*}{\partial \hat{W}} = \frac{P - a - q^C((N + 1)b + \lambda \sigma^2_w)}{b[1 - \beta^T + (\beta^T - \beta)F(e)]}.
\] (A10)

Finally, we can substitute Equations A7, A8, and A10 into Equation A5 and rewrite it as:

\[
\frac{1}{(N - 1)} \left\{ \frac{\partial V_i^*}{\partial \hat{W}} \right\} = \frac{[P - a - q^C((N + 1)b + \lambda \sigma^2_w)]}{b[1 - \beta^T + (\beta^T - \beta)F(e)]} - \frac{\Delta f(e)}{f(e)} \frac{\Delta[(N + 1)b + \lambda \sigma^2_w]}{b\left[P - a - q^C((N + 1)b + \lambda \sigma^2_w)\right]}.
\]

This can be simplified further to obtain:

\[
q^C = \frac{P - a}{\frac{a}{2Nb + \lambda \sigma^2_w} - \frac{f(e)}{b}\left[\frac{(N + 1)b + \lambda \sigma^2_w}{2Nb + \lambda \sigma^2_w}\right]}.
\] (A11)

The interpretation of Equation A11 is as follows. First, recall that this model specifies the PDF, \(f(e) = f(\hat{W} - \hat{W}(Q))\), as a symmetric function about its zero mean, with an upward slope \(f'(e) > 0\) when \(e < 0\) and a downward slope \(f'(e) < 0\) when \(e > 0\). In particular, for an imperfect buyer cartel, participating packers are interested in detecting cheating, whereupon the observed price of procured livestock falls below the trigger price, that is, \(\hat{W}(Q) < \hat{W}\). In this case, the additive noise is positive, that is, \([\hat{W} - \hat{W}(Q)] = e > 0\). Thus, the interval of interest is the downward-sloping interval of the PDF, \(f(e)\), along which \(f'(e) < 0\). By definition, \(f(e) \approx 0\), implying that along the relevant downward-sloping interval of the PDF, \([f(e)/f'(e)] < 0\). Given the above, the optimal equilibrium quantity of livestock by each packer is given by:

\[
q^C = \frac{P - a}{2Nb + \lambda \sigma^2_w} + \frac{1}{\frac{a}{2Nb + \lambda \sigma^2_w}} \left[\frac{(N + 1)b + \lambda \sigma^2_w}{2Nb + \lambda \sigma^2_w}\right], \text{ where } e = \frac{f'(e)}{f(e)}.
\]

**Appendix B**

This Appendix shows that if a packer's posterior or the market signal to which she has been exposed belong to the general class of exponential power distributions, then an increase in the information indicator, \(e\), corresponds to a decrease in her perceived volatility of livestock prices.
Consider the general class of exponential power distributions:

\[ f(x) = \omega(\delta) \sigma^{-1} \exp \left[ -c(\delta) \left( \frac{x - \mu}{\sigma} \right)^{2/(1 + \delta)} \right], \]

where \(-1 < \delta \leq 1\). If \( \mu = 0 \), then

\[ \frac{\partial f(x)}{\partial \mu} = \omega(\delta) \sigma^{-1} \exp \left[ -c(\delta) \left( \frac{x}{\sigma} \right)^{2/(1 + \delta)} \right] \left( -c(\delta) \right) \frac{2}{(1 + \delta)} \left( \frac{x}{\sigma} \right)^{-\delta/(1 + \delta)}. \]

Thus,

\[ c = \frac{|f'(x)|}{f(x)} = \frac{2c(\delta)}{(1 + \delta)} \sigma^{-2/(1 + \delta)} \left[ \frac{1}{1 + \delta} \right] ^{1 - \delta/(1 + \delta)}, \]

which can be rewritten as

\[ c = \frac{|f'(x)|}{f(x)} = \frac{2c(\delta)}{(1 + \delta)} \sigma^{-2/(1 + \delta)} \left[ \frac{1}{1 + \delta} \right] ^{1 - \delta/(1 + \delta)}. \]

It follows that

\[ \frac{\partial \sigma^2(x)}{\partial \mu} = -\left( 1 + \delta \right) \left\{ \frac{2c(\delta)}{2c(\delta)} \left[ \frac{1}{1 + \delta} \right] ^{-2/(1 + \delta)} \right\} = -0 \]

and

\[ \frac{\partial^2 [\sigma^2(x) \mu]}{\partial \mu^2} = (1 + \delta)(2 + \delta) \left\{ \frac{2c(\delta)}{2c(\delta)} \left[ \frac{1}{1 + \delta} \right] ^{-3/(1 + \delta)} \right\} = -0. \]

Thus, for the general class of exponential power distributions, \( \frac{\partial \sigma^2(x)}{\partial \mu} < 0 \) and \( \frac{\partial^2 [\sigma^2(x)]}{\partial \mu^2} > 0 \).

**Appendix C**

This Appendix establishes the existence of an information value, \( \varepsilon^* \), at which a packer procures the same quantity of livestock irrespective of whether she colludes under the imperfect cartel or engages in Cournot competition, that is, at \( \varepsilon^* q^{IC} = q^{CN} \).

Consider the collusive and the Cournot quantities

\[ q^{IC} = \frac{(P - a)}{2Nb + \lambda \sigma^2_v(\varepsilon)} + \frac{1}{b} \left[ (N + 1)b + \lambda \sigma^2_v(\varepsilon) \right], \]

and

\[ q^{CN} = \frac{(P - a)}{2nb + \lambda \sigma^2_w(\varepsilon)} + \frac{(P - a)(N - 1)b}{[(N + 1)b + \lambda \sigma^2_w(\varepsilon)][2Nb + \sigma^2_w(\varepsilon)]}. \]

Note that, even though the specific formulation of the function \( \sigma^2_v(\varepsilon) \) is unknown, for the general class of exponential power distributions, \( \frac{\partial \sigma^2_v(\varepsilon)}{\partial \varepsilon} < 0 \) and \( \frac{\partial^2 [\sigma^2_v(\varepsilon)]}{\partial \varepsilon^2} > 0 \) (see Appendix B).

For comparative purposes, the \( q^{IC} \) and \( q^{CN} \) quantities are multiplied by \( [(N + 1)b + \lambda \sigma^2_v(\varepsilon)]b \) and rewritten as

\[ q^{IC} = R[(N + 1)b + \lambda \sigma^2_v(\varepsilon)]b + \frac{S[(N + 1)b + \lambda \sigma^2_v(\varepsilon)]^2}{\varepsilon}, \]

where \( R, S \) are constants.
\[ q_f^C = R \left[ (N + 1)b + \lambda \sigma_w^2 \right] + S(P - a)(N - 1)b^2, \]

where \( R = (P - a) / [2Nb + \lambda \sigma_w^2(e)] \) and \( S = [2Nb + \lambda \sigma_w^2(e)]^{-1} \). Letting \( g(e) = \left[ (N + 1)b + \lambda \sigma_w^2(e) \right] / e \) and \( h(e) = (P - a)(N - 1)b^2 \) reduces the problem of establishing whether a value \( e^* \) such that \( q_f^C = q_f^CN \) exists to establishing whether the curves \( g(e) \) and \( h(e) \) intersect.

The slope and curvature of \( g(e) \) are given by

\[
\frac{\delta g(e)}{\delta e} = \frac{\epsilon \left[ 2N \left( N + 1 \right) b + \lambda \sigma_w^2(e) \right] \sigma_w^2(e) / \delta e - \left( N + 1 \right) b + \lambda \sigma_w^2(e)^2}{e^2},
\]

and

\[
\frac{\delta^2 g(e)}{\delta e^2} = \frac{\epsilon \left[ 2N \left( N + 1 \right) b + \lambda \sigma_w^2(e) \right] \sigma_w^2(e) / \delta e + 2 \lambda \left( N + 1 \right) b + \lambda \sigma_w^2(e)^2}{e^2} - \frac{\epsilon \left[ 2N \left( N + 1 \right) b + \lambda \sigma_w^2(e) \right] \sigma_w^2(e) / \delta e - 2 \left( N + 1 \right) b + \lambda \sigma_w^2(e)^2}{e^2},
\]

respectively. Since \( \delta g(e) / \delta e < 0 \) and \( \delta^2 g(e) / \delta e^2 > 0 \), it follows that \( g(e) / \delta e < 0 \) and \( \delta^2 g(e) / \delta e^2 > 0 \). Thus, \( g(e) \) is convex.

The slope and curvature of the curve \( h(e) \) are given by \( \delta h(e) / \delta e = 0 \) and \( \delta^2 h(e) / \delta e^2 = 0 \), respectively. Given that as \( e \to 0 \Rightarrow g(e) \to \infty \) and as \( e \to \infty \Rightarrow g(e) \to 0 \) and \( h(e = 0) = (P - a)(N - 1)b^2 \), it follows that there exists a value \( e^* \) at which the curves \( g(e) \) and \( h(e) \) intersect. The above imply that there exists a threshold level of information, \( e^* \), above which \( q_f^C < q_f^CN \) and a packer prefers trigger strategies to Cournot competition, below which \( q_f^C > q_f^CN \) and the packer reverses this preference, and at which \( q_f^C = q_f^CN \) and the packer is indifferent between the two.

References


US GAO. 2005. Livestock market reporting: USDA has taken some steps to ensure quality but additional efforts are needed. United States General Accounting Office Report to Congressional Requesters, GAO/RECED-00-26.
