Price Transparency in the Voluntary Price Reporting System for Live Cattle: Theory and Empirical Evidence from South Dakota

by

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ABSTRACT

The ability of the former federal voluntary price reporting system to facilitate market efficiency in the cash markets for U.S. livestock was questioned by producer groups and academic researchers prior to implementation of federal mandatory price reporting regulations. In the cash market for slaughter cattle, concerns raised in the literature centered on the effect of thinning cash markets and strategic price reporting behavior on the robustness of voluntary cash price reports issued by the USDA-Agricultural Marketing Services.

A theoretical framework is developed describing the interregional spatial linkages between cash markets and price reporting regimes (mandatory versus voluntary). Data from South Dakota and Nebraska cash markets for live cattle are used to test if the conditions necessary for interregional price transparency did exist prior to implementation of federal price reporting regulations. A set of testable hypotheses, based on the theoretical framework, is developed to test if the concerns raised in the literature about the voluntary price reporting system can be empirically verified.

The empirical results do not support the literature's proposition that the voluntary price reporting system for live cattle failed to provide timely and accurate market price information to the cash market prior to the implementation of the federal mandatory price reporting system in South Dakota and Nebraska. Furthermore, empirical evidence does not support the supposition that a thinning cash market or strategic price reporting had a significant negative effect on the AMS voluntary price reporting system's accuracy or timely transmission of price information. Therefore, we conclude that the AMS voluntary price reporting system provided price transparency for South Dakota and Nebraska producers selling in the cash market and contributed to the price discovery process.

Price Transparency in the Voluntary Price Reporting System for Live Cattle: Theory and Empirical Evidence

Passage of mandatory livestock price reporting (MPR) legislation at the federal level is the direct result of concerns raised over the reliability of the voluntary price reporting (VPR) system to provide accurate and timely information to market participants.[1] This legislation ended individual state mandatory livestock price reporting regimes and discontinued the voluntary reporting of slaughter cattle sales by the Agricultural Marketing Service (AMS).[2]

Structural change occurring in the livestock industry over the last fifty years has often been cited as the reason for reforming the public price reporting mechanism for livestock markets. The literature on public price reporting suggests that increased concentration has contributed to a thinning of cash transaction information available to the public and provided packers and feedlots a potential opportunity to engage in strategic price reporting under the AMS-VPR system. The general conclusion arrived at in the literature is that the AMS-VPR system's ability to provide timely and accurate price reports had been significantly degraded before its demise in 2001.

However, recent evidence in the literature suggests that the VPR system may not have lost its ability to function as an efficient price transmission mechanism. In a recent paper by Fausti and Diersen (2004), the robustness of the VPR system as a price transmission mechanism was empirically verified in

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[1] Increased concentration in both the packing and feedlot industries and the use of alternative marketing arrangements (marketing agreements, forward contracts, etc.), have resulted in the movement away from terminal market transactions by market participants over the last 30 years. In the spot market for cattle, the use of terminal markets has declined from 30% in 1977 to 13% in 1999 (GIPSA 2002). Furthermore, the four largest packers control 82% of steer and heifer slaughter but only purchase 3.7% of total slaughter from terminal markets. A number of economists have concluded that these structural changes in the cattle industry has resulted in thinning markets. Possible consequences include hampering price discovery, reducing market transparency, and degrading the effectiveness of the voluntary price reporting system. See for example Bastian et al. (2001) or Azzam (2003).

[2] National mandatory livestock price reporting legislation was passed in October 1999 and supplanted state legislation. The first federal publicly issued mandatory price report was released on April 2, 2001, ending individual state reporting activity. Regional AMS voluntary livestock reports also ended at this time, e.g. Montana Direct, Washington/Oregon Direct, etc.

the South Dakota and Nebraska cash markets for dressed weight steers. The existence of price transparency prior to federal MPR regulations raises questions about the validity of the concerns raised in the literature advocating reform of the public price reporting system because the VPR system's price transmission mechanism was severely flawed. This issue does have policy implications because the MPR legislation is due to expire in September of 2005.

We propose a simple interregional spatial equilibrium model which incorporates a VPR system. From the model, the necessary conditions for the existence of spatial equilibrium and spatial price transparency are derived.[3] It is demonstrated that a significant presence of a thinning market effect and/or strategic price reporting behavior will distort the spatial price relationship being transmitted by the VPR system. The consequence of this distortion is the loss of spatial price transparency, rendering the VPR system inefficient. An empirical model consistent with the theoretical framework is proposed. A set of hypotheses are derived from the theoretical framework and tested to determine if the VPR system was rendered inefficient because of thinning markets and/or strategic price reporting as asserted in the earlier literature.

Literature Review

Two related issues raised in the public price reporting literature which cast doubt upon the ability of the VPR system to provide accurate and timely price reports are 1) the failure of industry participants to report an estimated 35 to 40 percent of all cattle transactions (USDA-GIPSA 1998) and 2) the use of captive supply mechanisms by packers reduces cash market transactions.[4] The literature contends that

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[3] Fausti and Diersen (2004) define price transparency as "a market condition where all relevant information on transaction prices is publicly available to all market participants." They define spatial price transparency as " price transparency existing between spatially linked interregional markets."

[4] The number of studies in the literature on public price reporting have questioned the accuracy of the AMS VPR system relative to a MPR regime (Anderson et al 1998, Bastian et al 2001, Azzam 2003). These studies assert that moving to a mandatory price reporting system will improve the availability of public information dramatically by prohibiting the nonreporting of transactions. The implementation of mandatory price reporting in the market for slaughter cattle has improved public reporting of non-spot market transactions.

these developments in the slaughter cattle market has contributed to a thinning market phenomenon and degraded the VPR system for fed cattle.[5] A common theoretical linkage in this literature is that if you increase price uncertainty, you decrease market efficiency. These studies basically assume Tomek's thinning market phenomenon was occurring in the voluntary price reporting mechanism, increasing price uncertainty.[6] Critics of VPR conclude that a full information system is more efficient because it reduces price uncertainty and improves market efficiency relative to an incomplete information system. However, this branch of the literature does not provide any insight on if the AMS-VPR system actually reached the point where thinning market information had materially effected market transparency.

A third issue, raised by Koontz (1999), is the potential for packers and feedlots to engage in strategic price reporting during periods of sharp price movements in the market when transaction prices are voluntarily reported. Koontz suggests that packers will not report transaction prices higher than the average price paid when price is rising. On the other hand, feedlots will not report sale prices below the average when price is falling. Given the AMS did not report a transaction price unless it could confirm both sides of the trade, in periods of sharp price movements the weighted average price reported by the AMS would not reflect the actual weighted average price in the market if buyers and sellers behaved strategically. Conclusive empirical evidence has been not reported in the literature supporting the presence of strategic price reporting behavior. However, strategic price reporting, if it were widespread during periods of sharp price movements, would exacerbate the thinning market problem during these periods.

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[5] The concept of a thin market in this context refers to the decline in reported transactions as a percentage of total transactions (Tomek 1980).

[6] Azzam (2003, p.388) discusses increased transparency in terms of reduced uncertainty over livestock prices under a mandatory system relative to voluntary price reporting system. The underlying premise of Azzam's assumption is that increased uncertainty is the result of fewer transactions being reported under a voluntary system, resulting in increased price dispersion relative to actual dispersion of market transaction prices. In simple terms, Azzam refers to the issue as analogous to a sampling issue.

Empirical evidence in support of the proposition that the AMS-VPR system was an efficient price transmission mechanism in the period just prior to the implementation of federal MPR regulations is presented in a paper by Fausti and Diersen (2004). Fausti and Diersen adopt the methodology found in the recent literature on the relationship between competitive spatial equilibrium and market integration (Barrett and Li 2002, McNew 1996, McNew and Fackler 1997) . They provide empirical evidence that the spatial price relationship between South Dakota and Nebraska cash markets for dressed weight steers fulfills the conditions necessary for the existence of spatial price transparency.

Recent literature on the relationship between competitive spatial equilibrium and market integration (Barrett and Li 2002, McNew 1996, McNew and Fackler 1997) provides an alternative methodology for analyzing the robustness of price transparency within the context of mandatory versus voluntary price reporting. When interregional trade is nonnegative, Barrett and Li note that a long-run competitive spatial equilibrium condition holds when marginal profit from arbitrage activity is equal to zero. Under this condition, when trade is positive, regional price differentials move "one-for-one with the costs of spatial arbitrage" in the long-run (Barrett and Li p.293). Market integration, however, as discussed in the contestable market literature "implies the transfer of Walrasian excess demand from one market to another, manifest in the physical flow of a commodity, the transmission of price shocks from one market to another, or both" (Barrett and Li p.293). Market integration implies an efficient short-run market adjustment mechanism restoring a market to its long-run equilibrium condition.

The concept of spatial price transparency discussed in the paper by Fausti and Diersen is analogous to Barrett and Li's concept of "perfect integration." The necessary conditions for the existence of spatial price transparency are 1) interregional competitive spatial equilibrium, and 2) interregional market integration. Jointly, these two conditions are sufficient for the existence of spatial price transparency. An example of an application of Barrett and Li's work for livestock markets begin with the assumption that there are two spatially related regional markets. If one of the spatially related markets

relies on a VPR system to provide market information, then it is possible either a thinning market or a

strategic price reporting effect can result in marginal profits from spatial arbitrage being non-zero in the

long run. This implies competitive spatial equilibrium will not exist between these two markets. In this

case, according to Barrett and Li, the interregional market relationship would be defined as "imperfect

integration" when trade is positive. This implies that price shocks are transmitted from one market to

another, but the price signal from the VPR system would also contain a non-zero marginal arbitrage profit

component (economic rent) that some proportion of market participants would not be aware of. Thus, the

full information condition of spatial price transparency, as defined by Fausti and Diersen, is violated.

In the framework developed below, we investigate the efficiency of the AMS-VPR system. The

focus will be on determining the nature of the spatial relationship between two spatially related cash

markets for live slaughter cattle (South Dakota and Nebraska) and their respective price reporting regimes.

The conclusion will be based on if there is evidence of either thinning markets or strategic price reporting

affecting the interregional spatial price relationship in these markets.

Regional Mandatory Price Reporting Regimes

The purpose of regional livestock MPR laws is to require all livestock transactions to be reported to the

designated government agency.[7] In theory, this implies complete price transparency in cash markets. The

price revealed in a MPR (P_t^{MA}) for region A, in period t, equals the actual weighted average market price

(P_t^A) for cash sales in period t for the reporting region plus a random error:

(1) $P^{MA}(I_t^A) = P_t^A + \varepsilon_t.$[8]

The symbol I denotes the information set containing all transaction data generated in region A and

collected by the price reporting agency. The variable (ε) denotes random error occurring in the data

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[7] Several states passed MPR regulations prior to implementation of federal MPR regulations in 2001 (IA, MN, MO, NE, and SD).

[8] This assumption assumes full compliance with price reporting regulations by all market participants. It is assumed transaction costs associated with price reporting are zero and so the intercept term is dropped.

collection and reporting process. If one assumes full industry compliance (complete information), then:

$E(\varepsilon_t|I_t^A)=0$, $VAR(\varepsilon_t|I_t^A) = \sigma^2\varepsilon_t$, and $E(P_t^{MA}|I_t^A) = P_t^A$.[9] Assuming the government's data collection

procedures adhere to standardized collection and evaluation practices, then a unidirectional,

instantaneous, and complete integrated relationship between P_t^A and P_t^{MA} exists in the context of a price

reporting relationship.[10]

Voluntary Price Reporting Regimes

The information set (I_t^B) contains transaction price information for region B, voluntarily reported to the

price reporting agency. The information set determines the price revealed in the VPR system (P_t^{VB}), at

time t, plus a random error:

(2) $P^{VB}(I_t^B) = P_t^B + v_t$.

P_t^B is the actual market weighted average transaction price in region B, and v_t is the random error term

resulting from random error in the data collection and reporting process. Next, let it be assumed that the

VPR system draws a large enough sample when constructing I_t^B that the sample is representative of the

market.[11] Hence, the VPR system is an efficient conduit for the transmission of market information on

slaughter cattle transactions in region B. This implies: $E(P_t^{VB}|I_t^B)= P_t^B$, given that $E(v_t|I_t^B)=0$ and

$VAR(v_t|I_t^B)=\sigma^2 v_t$. Assuming the government's data collection procedures adhere to standardized

collection and evaluation practices, then an unidirectional, instantaneous, and complete integrated

relationship between P_t^B and P_t^{VB} exists in the context of a price reporting relationship.[12]

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[9] Note that the mathematical operators E and VAR are conditional expectation and variance operators, respectively.

[10] The integrated relationship exists if there is no systematic component associated with the error term.

[11]. The assumption is that the expected value of collected transaction prices is an unbiased estimate of equilibrium price and is consistent with Tomek (1980).

[12] The requirement for an integrated relationship between actual and reported market prices is that the error term is stationary. Stationary is imposed by the assumptions: that $E(v_t|I_t^B)=0$ and $VAR(v_t|I_t^B)=\sigma^2 v_t$. This implies that there is not a systematic component affecting the mean and variance of the error term.

A thinking market or strategic price reporting effect will alter the information set and effect the first and second moments of the distribution of the error term. With respect to $E(v_t | I_t^B) = 0$ and $VAR(v_t | I_t^B) = \sigma^2 v_t$ assumptions, one or both could be violated. This implies that either $E(v_t | I_t^B) \neq 0$ or $VAR(v_t | I_t^B)$ changes as the content of the information set changes. These types of potential flaws in the AMS-VPR system have been alluded to by the proponents of federal mandatory price reporting. For example: 1) If buyers and sellers of slaughter cattle are behaving strategically when reporting transaction prices, then v_t will not have a constant mean over time[13], and 2) if the volume of transactions being reported is diminished to the point of affecting the distribution of the VPR then v_t will experience an increase in its variance over time.[14] If either one of these conditions or both are present, then the relationship between P_t^{VB} and P_t^B will not be stationary. This implies that VPRs will not have a long-run equilibrium relationship with actual market transactions. In this case, it is not possible for the two price series to achieve price transparency. This implies the VPR system is fundamentally flawed in region B. This is the basic argument made in the earlier literature.

Interregional Slaughter Cattle Production and Interregional Spatial Equilibrium: A Simple Model

Assume regions A and B are two spatially related regions for the production of slaughter cattle. Assume the production capacity of slaughter cattle in region A is defined as being small relative to B. Assume region B is defined as a centralized market and region A as a decentralized market.[15] The difference between the two regions is slaughter cattle production capacity and: a) region B has processing facilities and a voluntary public price reporting regime, and b) region A has a mandatory price reporting regime and

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[13] If $E(v_t | I_t^B) \neq 0$ then $E(P_t^{VR} | I_t^B) \neq P_t^B$. This implies the voluntary price report is biased. This problem could arise if buyers and sellers are engaged in strategic price reporting. Strategic price reporting will result in the mean of the error term shifting whenever the market experiences sharp price movements.

[14] If there are transactions not reported, then the content of the information set declines as the proportion of transactions reported declines (thinning markets), resulting in the variance of the error term $(VAR(v_t | I_t^B))$ increasing over time as markets become thinner (Tomek 1980).

[15] The term centralized infers the ability of a region to produce, market, and process slaughter cattle internally.

no processing facilities. Assume region A produces an excess supply of slaughter cattle because of a lack of processing facilities. Assume region B has excess demand for slaughter cattle due to processing facilities having excess capacity. Producers in region A have a choice of selling their live cattle to a field representative of a processing firm located in region B or selling their cattle in region A to an intermediary (independent order buyer). The intermediary will assume the risk of delivering the cattle to the processing facility in region B and profit from any short-run arbitrage activity. Therefore, all slaughter cattle flow from region A to region B.[16]
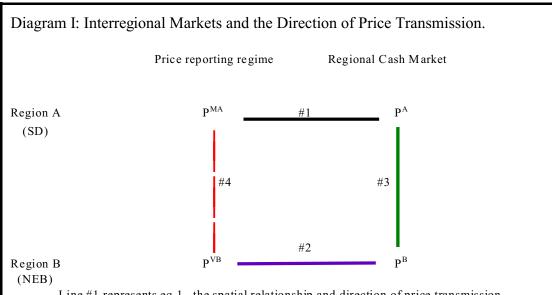
Next, assume the market for slaughter cattle is competitive in regions A and B. This implies that opportunities for interregional arbitrage dissipate quickly.[17] This infers that the cash markets for slaughter cattle in regions A and B are spatially integrated and this relationship can be defined as:

(3) $P_t^A = \alpha + P_t^B + \psi_t$, where α is the intercept term capturing transactions cost and ψ_t is the random error term and $E(\psi_t) = 0$ and $Var(\psi_t) = \sigma^2{}_{\psi_t}$. It is assumed that the cash markets in regions A and B adhere to zero marginal profit condition associated with competitive spatial equilibrium.

Diagram I depicts the spatial relationships across interregional markets as discussed above.

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[16] The discussion reflects the production and marketing of slaughter cattle in South Dakota. There are no modern commercial beef packing plants in South Dakota. A majority of South Dakota slaughter cattle are shipped out of state for processing.

[17] This implies the long-run competitive spatial equilibrium is consistent with marginal profit from arbitrage activity being equal to zero This assumption is consistent with Barrett and Li, and McNew and Fackler.

The MPR and VPR systems depicted in diagram I reflect information on transaction prices from their respective cash markets. The cash markets are assumed to be in equilibrium as a result of competitive spatial arbitrage. Therefore, if information on transaction prices in region B is not distorted by a thinning market phenomenon or a strategic price reporting effect, then the information contained in the MPR from regional A will mirror the information contained in the VPR from region B. The interregional spatial relationship between region A's mandatory price report and region B's voluntary price report depicted in diagram I is defined as follows:

(4) $P_t^{MA} = a + P_t^{VB} + e_t$, where (a) denotes the intercept term reflecting transaction cost, and e_t is the

random error term. Assuming no market distortions, then $E(e_t) = 0$, and $Var(e_t) = \sigma^2_{e_t}$ is constant over

time. This implies the spatial relationship between MPR and VPR reflects the competitive spatial equilibrium that exists between the cash markets in regions A and B.

However, the literature contends that this competitive spatial equilibrium relationship in the cash market is not reflected in the AMS-VPR system because of market distortions. The economic implications of three market distortions on the reliability of the information contained in a VPR is investigated next.

Case I: Positive Marginal Profit from Spatial Arbitrage in the Long Run

The first case assumes that competitive spatial arbitrage breaks down in the cash markets between regions A and B. Assume long-run marginal profit to arbitrage is positive. That implies region B buyers of slaughter cattle can earn positive economic rent by purchasing region A's cattle. If positive profit persists in the long run and is stationary, then it is possible for a noncompetitive spatial equilibrium to exist between the cash markets in regions A and B.[18] Positive marginal profit would be captured in the intercept term (α) defined in eq. 3. The intercept term would then capture transaction cost and positive economic rent.[19] This relationship would also be reflected in the spatial equilibrium relationship between the MPR and VPR as defined in equation 4.

If long run marginal profit to spatial arbitrage is positive and stationary, then this situation would be consistent with Barrett and Li's case of "imperfect integration." We can describe this situation as noncompetitive spatial equilibrium. However, if long-run economic profit from arbitrage is positive and nonstationary, then linear cointegration techniques would no longer be a robust method for estimating the

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[18] There is no empirical evidence that the price differential between live cattle prices paid in South Dakota and live cattle prices paid in Nebraska is greater than the transport and handling cost of delivering South Dakota live cattle to the Nebraska market.

[19] This can be easily demonstrated by rewriting eq.4 as $E[P_t^{MA}] - E[P_t^{VB}] = E[a] + E[e_t]$ and assuming β denotes positive economic rent occurring in the cash market. Thus, in the cash market equation (eq.3) transaction cost is denote by α and economic rent is denote by β: $P_t^A = \alpha + \beta + P_t^B + \psi_t$. Substituting in equations 1&2 for $E[P_t^{MA}]$ and $E[P_t^{VB]}$, and then substituting $\alpha + \beta + P_t^B + \psi_t$ for P_t^A you have $E[\alpha + \beta + P_t^B + \psi_t] - E[P_t^B + \nu_t] = E[a] + E[e_t]$. Taking the realization of the expected values on both sides of the equality sign and you have: $a = \alpha + \beta$. Thus, the intercept term of the cointegrating equation (eq.4) captures transaction cost and economic rent.

spatial price relationship between interregional markets. The problem arises because combining

stationary transaction cost with nonstationary economic rent from arbitrage would render the error term in

eq.4 non stationary.[20] As a consequence, linear cointegration estimation techniques would fail to find a

cointegrated relationship between P_t^{MA} and P_t^{VB}. In either case, spatial price transparency will not exist

because full information on market transactions will not be available to all market participants.

Case II: Thinning Markets

The second market distortion to be discussed is thinning market information. If the amount of transaction

information voluntarily reported declines over time in region B, then sampling variability associated with

the VPR system for region B will increase. This implies the variance of the interregional spatial price

relationship will increase as market information becomes thinner. If the variance increases as market

information becomes thinner, then the error term in eq. 4 will not be stationary.[21] As a consequence,

linear cointegration estimation techniques would fail to find a cointegrated relationship between P_t^{MA} and

P_t^{VB}. In either case, spatial price transparency will not exist because full information on market

transactions will not be available to all market participants.

Case III: Strategic Price Reporting

The third market distortion to be discussed is strategic price reporting behavior. If buyers and sellers

behave strategically during periods of sharp price movements, then the average transaction price in the

cash market will not equal the average transaction price reported to and by the VPR agency in region B.

Specifically, strategic price reporting will result in the average transaction price in the cash market being

above (below) the voluntarily reported average price during periods of sharp upward (downward) price

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[20] The literature (Barrett and Li, McNew, McNew and Flacker, etc) indicates that linear cointegration techniques are inadequate when transactions cost are not stationary. The linear combination of a stationary and nonstationary time series is nonstationary (Gujarati, p.805).

[21] We are assuming a mean preserving increase in dispersion. This increase in variance can easily be shown by using the definition: $\text{Var}(P_t^{MA} - P_t^{VB}) = \text{Var}(P_t^{MA}) + \text{Var}(P_t^{VB}) - 2\text{Cov}(P_t^{MA}, P_t^{VB}) = \text{Var}(e_t)$. If $\text{Var}(P_t^{VB})$ increases, then $\text{Var}(e_t)$ increases.

movements. Strategic price reporting could also affect dispersion because it will reduce the proportion of cash transactions reported during sharp market moves, contributing to the thinning of market information. If this market distortion only occurs during sharp price movements and sharp price movements are random events, then the first and second moments of the distribution of the error term equations 2 and 4 will be affected as discussed in footnotes 13 and 21.

Empirically, spatial equilibrium is a long-run concept which requires certain conditions to be present in the spatial relationship of two time series variables. Statistical evidence of a cointegrated relationship between P_t^{MA} and P_t^{VB} is necessary to conclude a long-run spatial equilibrium exists between the cash markets and the associated price reporting systems.[22] A cointegrated relationship between P_t^{MA} and P_t^{VB} is present if e_t is stationary.[23] The concerns raised in the literature about thinning market information, strategic price reporting, and non-competitive spatial arbitrage on market efficiency can be interpreted as the literature being concerned that these market distorting effects are disrupting the spatial equilibrium relationship between AMS-VPR and actual cash market transactions.

This discussion leads to a set of testable propositions:

A) If the spatial price relationship estimated by regressing P_t^{MA} on P_t^{VB} is found to be cointegrated, then there is evidence of a long run competitive spatial equilibrium. The implication of the presence of a long run competitive equilibrium is that if market distortions did exist during the era of VPR, they did not have a material effect on the ability of the VPR to reflect the equilibrium relationship between the Nebraska and South Dakota cash markets.

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[22] If a cointegrated relationship is not empirically verified then there are two possibilities: a competitive spatial equilibrium does not exist between the two cash markets or the VPR system in region B is fundamentally flawed.

[23] The literature (Barrett and Li, McNew, McNew and Flacker, etc) indicates that linear cointegration techniques are inadequate when transactions cost are not stationary, trade is bidirectional, or trade is discontinuous. Only the issue of nonstationary transaction cost poses a potential problem. The other two potential problems are not relevant to the theoretical framework developed in this paper. However, empirical results discussed later indicate that transaction cost are stationary.

B) If the spatial price relationship estimated by regressing P_t^{MA} on P_t^{VB} is found to be cointegrated and the empirical estimate of the intercept term of the cointegrating regression, α, is found to be stationary, significant, and of a magnitude consistent with a reasonable estimate of transactions cost for shipping cattle from South Dakota to Nebraska, then we can conclude that the assumption of zero marginal profit to spatial arbitrage is reasonable.

These propositions will be revisited during the discussion of the empirical results.

Interregional Spatial Integration and Price Transparency

According to the recent literature (e.g. Barret and Li), market integration is defined as the ability of linked markets to transfer changes in market supply and demand conditions from one market to another via the transmission of price shocks, commodity movements, or both. Efficient transmission of price shocks is consistent with the definition of price transparency requiring the market mechanism to provide accurate and timely price information to market participants.

To test if the AMS-VPR system did fully transmit price shocks from one region to another in a timely fashion, an error correction model (ECM) is proposed. The purpose of the ECM is to test the robustness of the short-run-equilibrium price-shock-adjustment-mechanism, to determine if the MPR series in region A (South Dakota) and the VPR series in region B (Nebraska) are spatially integrated.

Adopting the ECM framework to model the price transmission process across interregional markets will allow us to define the price transmission process (eq. 5). According to Granger (1981, 1983), two cointegrated series (eq. 4) can be expressed as a simple error correction model:

(5) $\Delta P_t^{MA} = \gamma_0 + \gamma_1 \Delta P_t^{VB} + \gamma_2 e_{t-1}$.

The change in the equilibrium price of slaughter cattle from period t-1 to t in region A is reflected in ΔP_t^{MA}. The change in the equilibrium price of slaughter cattle from period t-1 to t in region B is reflected in ΔP_t^{VB}. The intercept term γ_0 ($\gamma_0 = \Delta a$) reflects changes in the long-run equilibrium

relationship due to the effect of the price shock on transaction cost levels.[24] The slope parameter γ_1 ($0 \leq \gamma_1$ ≤ 1) captures the transmission of the price shock occurring in region B, in time period t, to region A. If $\gamma_1 = 1$, then this would indicate "instantaneous perfect integration" as defined by Barrett and Li. However, a weaker condition discussed by Barrett and Li is "perfect integration," which only requires that the entire price shock be transmitted without a specific duration-of-time constraint. The variable e_{t-1} reflects the deviation from parity remaining to be transmitted from region B to region A as a result of the price shock at time t. The deviation from parity adjustment parameter γ_2 ($0 \leq \gamma_2 \leq 1$) captures the transmission of the price shock residual to region A.

The interregional ECM modeling of the price shock transmission process is done in a discrete time framework to determine if the time-path of the adjustment process is consistent with Barrett and Li's definition of perfect integration. First, assume that the spatial relationships outlined in diagram I adhere to the conditions necessary for competitive spatial equilibrium. Next, assume a fixed portion of the price shock ($\gamma_1 = \gamma_2$) is transmitted from region B to region A each period, and $\gamma_0 = 0$.[25] Now, assume that a price shock at time t occurs in region B. The price shock disrupts the long-run equilibrium between regional transaction prices P_t^A and P_t^B. This disruption will be reflected in the respective price reports P_t^{MA} and P_t^{VB}. In period t, the proportion of the price shock transmitted to region A and reflected in P_t^{MA} is:

(6) $\Delta P_t^{MA} = \gamma_1 \Delta P_t^{VB}$.

Where $e_t = \Delta P_t^{VB} - \gamma_1 \Delta P_t^{VB}$ is the residual of the price shock not yet transmitted to region A.

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[24] Barrett and Li discuss the effect of nonstationary transaction costs on the robustness on linear ECM models. We assume $\gamma_0 = 0$, and empirical evidence presented later in the paper support this assumption.

[25] We assume the market mechanism for the transmission of price shocks across regions is time invariant. Empirical evidence presented later indicates the fixed proportion assumption is robust.

In period t+1, the proportion of the price shock transmitted to region A is the residual e_t multiplied by γ_1. The transmission process continues until the entire shock is transmitted to region A. Rewriting the price shock transmission process in a compact form allows us to define the *spatial price transmission equation*:

$$(7) \quad \sum_{i=0}^{n} \Delta P_{t+i}^{MA} = \Delta P_t^{VB} \sum_{i=0}^{n} \gamma_1 (1 - \gamma_1)^i \ .$$

Equation 7 confirms that the proposed ECM framework is consistent with Barret and Li's definition of perfect integration occurring between regions A and B whenever $\gamma_0 = 0$, and $0 < \gamma_1 < 1$.[26] Instantaneous perfect integration occurs whenever i=0, $\gamma_0 = 0$, $\gamma_1 = \gamma_2$, and $\gamma_1 = 1$. This type of integration is the type one would associate with financial markets. Barret and Li's segmented equilibrium would occur if $\gamma_0 = 0$, $\gamma_1 = 0$, and there was no movement of slaughter cattle from region A to B.

Empirical estimation of parameters γ_1 and γ_2 in eq. 5 will provide statistical evidence of whether spatial integration existed between P_t^{MA} and P_t^{VB}. If both γ_1 and γ_2 are statistically significant we can conclude that the spatial relationships in diagram I are integrated. The implication under this scenario is that the AMS Nebraska voluntary price report did engender spatial price transparency in Nebraska and South Dakota cash markets.

Methodology

For South Dakota and Nebraska, we intend to empirically investigate the spatial relationships hypothesized in diagram I. The time period selected is the 19-month period just before federal mandatory price reporting rules went into effect. A test for the presence of cointegration will provide empirical evidence on the possible existence of long-run spatial equilibrium relationships discussed above (diagram I). If a long-run equilibrium relationship is found, then an error correction mechanism (ECM) modeling

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[26] Given that $\displaystyle\lim_{i \to \infty} \sum_{i=0}^{n} \gamma_1 (1 - \gamma_1)^i = 1$, and thus $\displaystyle\lim_{i \to \infty} \sum_{i=0}^{n} \Delta P_{t+i}^{MA} = \Delta P_t^{VB}$. Therefore, Barret and Li's requirement of complete price shock transmission for perfect integration is met.

approach will be used to investigate the short-run disequilibrium adjustment process to determine if there is empirical evidence of spatial integration between regional price reporting systems.

First, unit root tests will be conducted to determine which of the selected price series are non-stationary.[27] Engle and Granger (1987) state that if two series are I(1) then it is possible that a linear combination of the two series is I(0). Engle and Granger propose a *cointegrating regression*: regressing one I(1) series on another I(1) series. The residual series generated by the cointegration regression will be tested for the existence of a unit root to determine if the two price series are cointegrated. Next, based on the work by Granger (1981, 1983), the Granger Representation Theorem states that if two time series variables are cointegrated, then the relationship between them can be expressed as an error correction mechanism (ECM).

Data

In July of 1999 South Dakota Codified Law: Chapter 40-15B (SDCL 2000) required mandatory livestock price reporting in South Dakota to begin on Sept 1, 1999. The legislation required that all private livestock transactions were to be reported to the South Dakota Department of Agriculture. The Department of Agriculture collected data until federal mandatory price reporting began. The Secretary of Agriculture's office supplied all of the collected mandatory reporting data used in this study.[28] The South Dakota mandatory price reporting data were used to construct a daily weighted average price series for all live weight steer transactions occurring in the state during the 19-month period prior to implementation of federal mandatory price reporting. The data provide a unique opportunity to test if the AMS-VPR system reflected actual market conditions during the period just prior to the implementation of federal MPR.

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[27] For a discussion of unit root testing procedures and testing for cointegration between non-stationary time series variables see Gujarati (2003).

[28] In contrast to the dressed weight transaction data used in the study by Fausti and Diersen (2004), we use live cattle transaction data. Additional information on the characteristics of the South Dakota MPR data set can be found in the paper by Fausti and Diersen.

The South Dakota MPR data set contains 80 weeks of daily transaction data. There are 142 transaction days recorded for the direct sale of live steers in South Dakota. The data set contains 59,614 head and 300 recorded transactions.[29] The AMS-VPR series selected is the Nebraska Daily Direct Weighted Average report. The two price series were matched with respect to transaction dates.

Empirical Results: Testing for Unit Roots and Cointegration

In Table I the Dicky-Fuller (DF) and Augmented Dicky-Fuller (ADF) test statistics are provided for each of the price series. The test statistic for detecting the presence of serial correlation is either the Durbin-Watson d or Durbin's t, depending on if a lagged dependent variable was needed to whiten the error structure of the unit root test. Lagged terms were added to the ADF equation until the error structure was empirically verified as whitened. The unit root tests are based on the null hypothesis that a price series has a unit root and is non-stationary versus the alternative that the series does not have a unit root and is stationary.[30] The unit root hypothesis test indicates that both price series are non-stationary (Table I). The cointegration results are presented in Table II.

TABLE I
UNIT ROOT TEST RESULTS

Price Series	Obs.	Tau Statistic	P-Value
Nebraska Daily Direct Weighted-Average report.[1]	142	-0.80	0.81
South Dakota Mandatory Price Reporting Data.[2]	142	-1.34	0.61

1. The order of the autoregressive model selected for the ADF test is AR(0). DW d test stat=1.68
2. The order of the autoregressive model selected for the ADF test is AR(1). Durbin's t= -1.27

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[29] The mandatory price reporting data set supplied to the Dept. of Economics at SDSU by the State of South Dakota contains transaction data on over 600,000 head of cattle. Dressed weight sales, grid sales, forward contract sales, marketing agreement transactions, heifer and holstein transactions were excluded from the sample. Voluntary price report data were collected from various issue of the AMS Livestock, Meat and Wool Weekly Summary and Statistics report (1999-2001).

[30] If serial correlation was not detected in the initial DF test, then the autoregressive order is zero. If serial correlation was detected then the appropriate ADF test was used.

TABLE II
SDMPR COINTEGRATION TEST RESULTS

Price Series Cointegrating Regressions	Number Of Obs.[31]	Cointegrating Regression		Tau Statistic	P-Value
		Intercept Estimate	Parameter Estimate		
SDMPR & Nebraska Daily Dir. Wt. Avg.[1]	142	5.14	0.917	-9.27	0.001

1. The order of the autoregressive model selected for the ADF test is AR(0). DW d test stat = 2.025.

The empirical evidence (Table II) suggests a long-run spatial equilibrium relationship did exist between the South Dakota Mandatory price report series and the Nebraska Direct series and supports proposition A. The intercept term in Table II can be interpreted as the long-run equilibrium level of transactions cost associated with selling South Dakota slaughter cattle in the Nebraska market. The estimate of $5.14 cwt. is reasonable and we conclude the statistical evidence does support the assumption that marginal profit to spatial arbitrage is zero if the intercept term is empirically verified as being stationary.

We conclude that there is strong empirical evidence to support the proposition that there was a robust competitive spatial equilibrium relationship between South Dakota and Nebraska cash markets for live slaughter cattle, and their associated price reporting mechanisms, in the period just prior to implementation of federal mandatory price reporting.

Empirical evidence of the existence of long-run equilibrium relationships, however, does not tell us anything about short-run deviations away from equilibrium. Short-run divergence from the long-run equilibrium relationship between the price reporting mechanisms may result from the alleged flaws in the AMS-VPR system. The literature clearly indicates that interregional integration occurs only if price shocks are completely transmitted from one region to another. To investigate this issue, an error

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[31] Statistical analysis was conducted using SAS (1993).

correction mechanism will be employed to investigate the effect of short-run anomalies on the long-run relationship just established.

ERROR CORRECTION MODEL

In the last section we established empirically that there is statistical evidence of long-run spatial equilibrium relationship linking the South Dakota and Nebraska cash markets and the associated regional price reports. While the estimated long-run equilibrium relationships are statistically significant, there is still the question of whether price integration exists across these spatial relationships. Sustained short-run deviations would be evidence of the failure of the AMS-VPR system to act as an efficient mechanism or conduit for the transmission of changing market conditions to the public.

An error correction modeling procedure is therefore utilized with the following set of premises concerning price determination in the cash market for slaughter steers. It is assumed here that the equilibrium cash price of slaughter steers is determined by regional market conditions outside of South Dakota. Packers engaged in the direct cash purchase of live slaughter steers in South Dakota are aware of the current regional market conditions for beef and the transaction costs associated with placing South Dakota steers into the supply channel. It is also assumed here that the trends in transaction and transport costs were relatively flat during the time period covered by this study.[32] Given these assumptions, a price shock to the live slaughter steer cash market at the regional level will eventually be reflected in the direct price paid to South Dakota producers. Simply stated, a price shock of x dollars per cwt. at time t at the regional level will disrupt the long-run equilibrium between the regional market price and the price paid to South Dakota producers. The disequilibrium condition will persist until the South Dakota market fully adjusts to the price shock in some future period t+n, where n is the number of periods (transaction days) needed for full adjustment to take place (eq.7). It is during this period of disequilibrium that price

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[32] During the time period covered by this study the average Midwest retail weekly #2 diesel price per gallon was $1.41 and the standard deviation was 12 cents (U.S. Dept. Of Energy, Energy Information Administration).

transparency can be affected.[33] The length of time (n) it takes for the transmission of a price shock opens a window of opportunity for profitable arbitrage activities to occur in smaller decentralized markets like South Dakota.[34]

Based on the work by Granger (1981, 1983), the Granger Representation Theorem states that if two time series variables are cointegrated, then the relationship between them can be expressed as an error correction mechanism (ECM). The ECM defined in eq.5 is estimated using OLS:

8) $\Delta P_t^{MA} = \gamma_0 + \gamma_1 \Delta P_t^{VB} + \gamma_2 e_{t-1} + z_t$,

z_t is the random error term, and the empirical estimates are provided in Table III.[35]

TABLE III
ERROR CORRECTION MODEL OLS ESTIMATES

Price Series ECM Regressions	Number Of Obs.	ECM Regression Estimates [1]		
		Intercept Est.	Slope Est.	Speed of Adjustment Est.
ΔSDMPR & ΔNebraska Daily Dir. Wt. Avg.	142	0.03 (0.29)	0.752 (6.62)	-0.755 (-9.16)

1. Student t test statistics are given in parentheses below the respective parameter estimate.

Table III indicates that the intercept estimate is statistically zero. This result implies that transaction costs were stationary during the period investigated in this study. However, this result is also consistent with our conclusion concerning spatial arbitrage and strategic price reporting. We assert that there is empirical evidence to support the proposition B and conclude that these market distortions, if they

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[33]Koontz (1999) reported that packers and feedlots are more likely to withhold transaction information during periods of sharp price movements. However, empirical evidence does not support this type of market disrupting behavior affecting the interregional spatial relationship in this study.

[34] The possibility of excess profit potential arising in this type of situation has been alluded to by Goodwin and Schroeder (1991) and Tomek (1980).

[35] The first difference variables used to estimate the ECM were screened for serial correlation (DW: 2.042) and stationarity, and no diagnostic problems were detected.

existed, did not materially affect the long-run competitive spatial price relationships between the South Dakota and Nebraska cash markets and their respective price reporting systems.

Empirical evidence presented in Table III indicates the slope parameter estimate is highly significant and has a p-value of less than .001. The "speed of adjustment" parameter estimate is also highly significant and has a p-value of less than .001. The "speed of adjustment" parameter coefficient estimates indicate the proportion of the price-shock-residual remaining after period t that will be transmitted to the SDMPR series in period t+1. The slope and speed of adjustment parameter estimates and their respective standard errors are very consistent with the modeling assumption made earlier that $\gamma_1 = \gamma_2$.[36]

Market integration occurs when a price shock completely passes through from one market to another in a timely fashion. When market integration coexists with competitive spatial equilibrium, then the conditions for Barrett and Li's definition of "perfect integration" are satisfied. Table IV provides evidence of the existence of market integration. The evidence from Tables II and IV support the coexistence of competitive spatial equilibrium and market integration. We therefore conclude that the South Dakota and Nebraska cash markets and the associated price reporting mechanisms meet the conditions for prefect integration and the AMS-VPR system did provide spatial price transparency to market participants in these markets. Table IV provides empirical estimates for the speed of adjustment process.

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[36] This implies the institutional structure of the price transmission mechanism is stable within the spatial equilibrium relationship between South Dakota and Nebraska cash markets, and the AMS-VPR system reflected this stability. Of interest is the implication that while price discovery and price determination are dynamic, the instructional structure of the price transmission mechanism is static. Stability of the price transmission mechanism is a vital component of an efficient market and this issue has not received a lot of attention in the literature.

TABLE IV
SOUTH DAKOTA MANDATORY PRICE REPORTING SERIES:
"SPEED OF ADJUSTMENT" OVER TIME TO A PRICE SHOCK AT TIME t

Cointegrating Regressions	TIME		
	t	t+1	t+2
SDMPR & Nebraska Daily Dir. Wt. Avg.	75.2%	93.98%	98.52%

The ECM estimates indicate that 94% of a price shock occurring in the Nebraska cash market was transmitted to the South Dakota cash market by the next transaction day and 98.5% by day two. The empirical evidence indicates that while the AMS-VPR system did not provide instantaneous spatial price transparency, but spatial price transparency did exist.

Conclusions and Summary

For the period when South Dakota required mandatory livestock reporting, we find the spatial relationship between South Dakota and Nebraska cash markets and their respective price reporting regimes for live slaughter cattle are consistent with Barrett and Li's concept of "perfect integration." The theoretical framework developed allows for the empirical testing of the market distortion hypothesis found in the literature, which raised concern over the efficiency of the AMS-VPR system. We found no evidence that noncompetitive spatial arbitrage, thinning market information, or strategic price reporting had a material effect on the functioning of the AMS-VPR system in the South Dakota and Nebraska cash markets for live slaughter cattle. The conclusion from the empirical evidence presented is that in the case of South Dakota and Nebraska, the former voluntary price reporting system did foster spatial price transparency and was a robust mechanism for promoting price discovery.

While our study only covers one small corner of the livestock sector, this South Dakota case study supports the previously published results of Fausti and Diersen and extends the literature by providing a theoretical and empirical framework for modeling and testing for market distortions in markets where

prices are reported as public information. Our contribution establishes the conditions necessary for a VPR system to provide price transparency and foster price discovery in cash markets based on the work by Barrett and Li, but within a linear cointegration framework. Finally, we are not advocating that the former AMS-VPR system is more robust than the new federal mandatary system, but we are saying there is ample evidence that the former system was not as flawed as previous research has suggested. Therefore, it is not necessarily valid to justify the need for mandatory price reporting based on the assertion that the former voluntary price reporting system degraded price transparency. This last point is relevant, given that federal MPR legislation will expire in September 2005.

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