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# Public Price Reporting in the Cash Market for Live Cattle: A Spatial Market Approach

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Legislative authorization for the Livestock Mandatory Reporting Act of 1999 was renewed in October of 2006. One of the cited justifications for implementing mandatory reporting was that the voluntary reporting system for the slaughter cattle cash market was unable to provide accurate and timely market information. We extend the spatial market analysis literature by developing a methodology for detecting distortions in spatial relationships across related price series. Using spatially linked regional markets, we compare state-level mandatory price-reporting data to the U.S. Department of Agriculture voluntarily reported state data to determine if the spatial relationship between price-reporting mechanisms was disrupted by market distortions prior to implementation of federal mandatory price reporting. We found no empirical evidence of system failure; therefore, we conclude that market thinning or noncompetitive behavior had not reached the level necessary to disrupt the ability of the voluntary price-reporting system to provide timely and accurate price information.

**Key Words:** public price reporting, spatial markets, market integration, price transparency, price discovery, livestock markets

On October 1, 2006, mandatory price reporting (MPR) of livestock prices was renewed in the United States (the White House 2006). Prior to renewal, the legislation was allowed to expire October 1, 2005, under a sunset provision inserted into the original legislation passed in October of 1999 (Economic Research Service 2005, U.S. Government Accountability Office 2005). The MPR system has generated debate among producers, politicians, and economists because of issues associated with implementation problems, unrealistic expectations for improved transparency, and market data aggregation (Ward 2006b).

The Agricultural Marketing Services (AMS), a branch of the U.S. Department of Agriculture, is responsible for collecting and disseminating MPR livestock market information (Economic Research

Service 2005). Prior to MPR, these reports were prepared from information voluntarily supplied by market participants or collected by market reporters. Some of these reports focused on local and regional cash markets, detailing the quantities of different types of livestock products sold, with ranges for weights, yields, and grades as well as prices. Other reports were more aggregated and summarized market activity across a wide geographic area for a week, month, or year.

In this study, we investigate whether the voluntary price-reporting (VPR) system's ability to provide accurate and timely market information was diminished due to market distortions (e.g., Anderson et al. 1998, Koontz 1999, and Azzam 2003). According to this literature, the movement of market participants away from cash transactions in public markets to direct sale cash transactions and alternative marketing arrangements (marketing agreements, forward contracts, etc.) resulted in a thinning of cash market information. The consequence of a thinning of cash market information as discussed in the MPR literature is similar to the concerns raised by Tomek (1980) for terminal markets. If thinning markets did re-

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duce transparency in the cash market for slaughter cattle, then price discovery and market efficiency would suffer. We investigate this supposition of market distortions disrupting the ability of VPR to provide timely and accurate market information in a smaller regional cash market for slaughter cattle.

Our primary objectives are (i) to introduce a methodology for detecting certain types of distortions in spatial price relationships within a cointegration framework, and (ii) to use this methodology to empirically test for the presence of market distortions in the VPR system at a regional level. We first provide a review of the literature and the debate over the perceived failure of the VPR system. Next, we define the econometric conditions produced by a thinning market effect and then discuss how market distortions would affect the VPR system's ability to generate transparency. We then empirically test for the presence of distortionary effects during the period just prior to MPR implementation. The source for mandatory livestock price-reporting data is the transaction records on all slaughter livestock sales in the state of South Dakota collected for the 19-month period prior to the implementation of the federal MPR.

The structure of South Dakota's livestock industry, the existence of state-level MPR transaction data, and the spatial relationship between South Dakota's feedlot industry and Nebraska's packing industry provide a unique environment where the regional spatial market for live cattle is divided artificially by state lines. Thus, the spatial price relationship between the AMS's "Nebraska voluntary price report" and South Dakota's mandatory price report provides an excellent case study candidate for investigating the efficacy of VPR.

## Literature Review

### *Trends in the Marketing of Slaughter Cattle and the Voluntary Price-Reporting System*

Increased concentration in both the packing and feedlot industries and the use of alternative marketing arrangements (marketing agreements, forward contracts, etc.) have resulted in a movement away from terminal market transactions by mar-

ket participants over the last 30 years. In the spot market for cattle, the use of public markets (auction markets, terminal markets, etc.) declined from 30 percent in 1977 to 12.8 percent in 2003 (Grain Inspection and Packers and Stockyards Administration 2005). Furthermore, the four largest packers accounted for 83.2 percent of steer and heifer slaughter but purchased only 6.9 percent of total cattle slaughter in public markets. A number of economists have looked at the issue of structural changes in the cattle industry and the potential negative effect on price discovery, reducing market transparency, and degrading the effectiveness of the voluntary price-reporting system (e.g., Anderson et al. 1998, Wachenheim and DeVuyst 2001).

The government response to declining terminal markets for fed cattle was to increase its reliance on voluntarily reported transaction information for direct sales. During this period, however, direct sales information collected on a voluntary basis by government market reporters also began to thin. By the end of the 1990s the USDA estimated that nationally 35 to 40 percent of all negotiated transactions in the fed cattle market were not being reported (Agricultural Marketing Service 2000). An additional shortcoming alluded to in the literature was the AMS's inability to report on captive supply transactions (marketing agreements, forward contracting, and packer ownership) occurring in the slaughter cattle market. For beef producers, this was seen as a critical shortcoming of the VPR system.

Concerns were also raised over local market transparency. With a decline in aggregate spot market volumes, local market coverage by daily market news releases became much more sparse. For example, in the early 1990s local daily fed cattle cash price reports for Kansas and Texas were not released for about 10 percent of the days due to lack of sufficient trading volume. By year 2000, the AMS was unable to release 60 percent of these daily market reports. With the increased volume of cattle moving outside the spot market, coverage of these daily market reports became a major concern of market participants (Grunewald, Schroeder, and Ward 2004). The prospect of a public price-reporting system relying on regional cash market data that continued to thin had many industry participants believing that the VPR system had become ineffective.

### *Early Producer Reaction to Mandatory Price Reporting*

Prior to the implementation of MPR, it appears that producer expectations, especially in the feedlot sector, were raised to an unrealistic level concerning the ability of MPR to improve market transparency. Producers appear to have been initially disappointed with MPR because they perceived a lack of improvement in transparency (Grunewald, Schroeder, and Ward 2004, Ward 2006a).

Schroeder et al. (2002) conducted a survey of feedlot operators located in the key fed cattle production areas of Texas, Oklahoma, Nebraska, and Iowa one year after MPR was implemented. They found that operator perceptions indicate a belief that MPR did not improve regional information on fed cattle cash prices and that operators indicated a propensity to have a greater reliance on private information sources. However, these private firms also rely on public price-reporting sources for data collection purposes (e.g. Cattle-Fax, etc.). The survey results reported by Schroeder et al. (2002) suggest that feedlot producers perceived that MPR reduced market transparency at the local and regional level.

Grunewald, Schroeder, and Ward (2004) provide econometric analysis of the Schroeder et al. (2002) survey data and concur with the conclusions of Schroeder et al. (2002). Grunewald, Schroeder, and Ward (2004) speculated that producers' perception of MPR not increasing transparency suggests that it is possible that the VPR system was providing transparency in the cash market. Fausti and Diersen (2004) presented empirical evidence suggesting that the VPR system was providing transparency in the South Dakota cash market for dressed weight steers. Pendell and Schroeder (2006) reported that AMS's aggregate weekly VPR series were cointegrated. These studies suggest that producer disappointment with MPR may be due to raised expectations based on the belief that the VPR system had lost its ability to provide timely and accurate market information. Ward (2006b) suggests that this initial disappointment has begun to dissipate as both the AMS and the industry have adapted to the realities of the new reporting environment.

### *Mandatory Price Reporting: Benefits and Concerns*

As a consequence of MPR implementation, transparency increased dramatically for captive supply transactions (Ward 2006a, 2006b). It is the general consensus among economists that the addition of non-spot market transactions to public price reports corrects an important deficiency associated with the VPR system. In a recent study, Pendell and Schroeder (2006) reported empirical results suggesting that MPR had strengthened the long-run price relationships between AMS weekly regional aggregate reports.

The AMS, however, did eliminate a number of regional slaughter cattle cash market reports (Fausti, He, and Diersen 2003). Fausti, He, and Diersen (2003) suggested that these regional reports provided producers with a source of market information not available under MPR. In support of this conjecture, in the post-MPR period, slaughter cattle producers in Nebraska, New Mexico, and Texas have been instrumental in the development of several non-federal regional voluntary price-reporting regimes. It appears that these voluntary reports evolved to address the timing issue associated with "trading windows" for producers in local markets. Concern over accuracy of MPR reports was raised in a report by the U.S. Government Accountability (GAO) (GAO 2005). The GAO report indicated that not all transactions reported to the AMS were included in MPR price reports, and there were cases of packers not reporting transactions. The USDA has indicated to the U.S. Congress that it is responding to the GAO criticisms (Ward 2006b).

### *Voluntary Public Price Reporting and Thinning Markets*

The price-reporting literature identifies a thinning cash market as being the likely candidate responsible for the purported failure of VPR to provide transparency in the market for slaughter cattle (e.g., Azzam 2003). The thinning market argument asserts that structural change in the packing and feeding industries has caused a thinning market effect in the public reporting of cash market prices for slaughter cattle under the VPR system.<sup>1</sup>

<sup>1</sup> The concept of a thin market in this context refers to the decline in reported transactions as a percentage of total transactions (Tomek 1980).

This view basically assumes that Tomek's (1980) thinning market phenomenon was occurring in the VPR system, which increases price uncertainty and decreases market efficiency (Anderson et al. 1998, Azzam 2003). Ward (2006a, p. 4), however, raises the following issue: "A pertinent question for livestock and meat markets is when does thinning of a market with VPR present such a concern over efficiency and accuracy to merit a major public investment in a mandatory system?"

Fausti and Diersen (2004), using South Dakota MPR data on cash sales of dressed weight slaughter cattle, found empirical evidence of price transparency in the South Dakota cash market for dressed slaughter cattle prior to federal MPR. They define price transparency as "a market condition when 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." Their empirical methodology adopted a number of concepts on spatial integration from Barrett and Li (2002). However, they did not directly test for the presence of a thinning market effect.

Our study extends the work of Fausti and Diersen (2004) by constructing a theoretical framework for modeling interregional competitive spatial markets and their respective price-reporting mechanisms. The theoretical framework permits us to propose an empirical methodology to test if independent price-reporting mechanisms for spatially linked competitive markets are being distorted by market participants or market conditions. The empirical procedure is then used to formally test for the presence of market distortions in the spatial price relationship between the South Dakota and Nebraska cash markets for live weight slaughter cattle prior to federal MPR implementation.

## Theoretical Framework

### *Spatial Market Integration*

The literature on the relationship between competitive spatial equilibrium and market integration (McNew 1996, McNew and Fackler 1997, Barrett and Li 2002) provides a methodology for analyzing the robustness of price transparency within

the context of mandatory versus voluntary price reporting. Barrett and Li (2002) note that when interregional trade is nonnegative, 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 2002, 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 2002, p. 293). Market integration implies an efficient short-run market adjustment mechanism restoring a market to its long-run equilibrium condition. Barrett and Li (2002) assert that when competitive spatial equilibrium and market integration coexist, the market achieves "perfect integration."

Fausti and Diersen (2004) adopted Barrett and Li's definition of market integration to investigate the issue of market transparency in the VPR system for dressed slaughter cattle. The concept of spatial price transparency discussed 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 (i) interregional competitive spatial equilibrium, and (ii) interregional market integration. Jointly, these two conditions are sufficient for the existence of spatial price transparency. However, Fausti and Diersen fail to formally address the empirical issue of directly testing for the presence of a thinning market effect. In the model developed below, a framework is developed to formally test what we call the Thinning Market Hypothesis (TMH).

### *Regional Mandatory Price-Reporting Regimes*

Several states passed MPR regulations prior to implementation of federal MPR regulations in 2001 (Iowa, Minnesota, Missouri, Nebraska, and South Dakota). The purpose of regional livestock MPR laws is to require that all livestock transactions be reported to a designated government agency. In the case of South Dakota, it was the State Department of Agriculture. In theory, this implies that price transparency in the cash market

is being provided by the reporting regime. The price revealed by MPR ( $P_t^M$ ) in South Dakota (SD) in period  $t$  equals the actual weighted average market price ( $P_t^{SD}$ ) for cash sales in period  $t$  for the reporting region plus a random error:

$$(1) \quad P_t^M(I_t^{SD}) = P_t^{SD} + \varepsilon_t.^2$$

The symbol  $I$  denotes that the information set contains all transaction data generated in South Dakota and collected by the price-reporting agency. The variable ( $\varepsilon$ ) denotes a random error occurring in the data collection and reporting process. If one assumes full industry compliance (complete information), then  $E(\varepsilon_t | I_t^{SD}) = 0$ ,  $\text{Var}(\varepsilon_t | I_t^{SD}) = \sigma^2 \varepsilon_t$ , and  $E(P_t^M | I_t^{SD}) = P_t^{SD}$ .<sup>3</sup> Assuming that the government's data collection procedures adhere to standardized collection and evaluation practices, then a unilateral, instantaneous, and complete integrated relationship between  $P_t^{SD}$  and  $P_t^M$  exists in the context of a price-reporting relationship. The integrated relationship exists if there is no systematic component associated with the error term.

#### *Voluntary Price-Reporting Regimes*

The information set ( $I_t^{NE}$ ) contains transaction price information for Nebraska (NE), voluntarily reported to the price-reporting agency. The information set determines the price revealed in the VPR system ( $P_t^V$ ) at time  $t$ , plus a random error:

$$(2) \quad P_t^V(I_t^{NE}) = P_t^{NE} + v_t.$$

$P_t^{NE}$  is the actual market-weighted average transaction price in NE, and  $v_t$  is the random error term resulting from random error in the data collection and reporting process. It is assumed that the VPR system draws a large enough sample when constructing  $I_t^{NE}$  to be representative of the market.<sup>4</sup> Hence, the VPR system is an efficient conduit for the transmission of market informa-

tion on slaughter cattle transactions in Nebraska. This implies that  $E(P_t^V | I_t^{NE}) = P_t^{NE}$ , given that  $E(v_t | I_t^{NE}) = 0$  and  $\text{Var}(v_t | I_t^{NE}) = \sigma^2 v_t$ . Assuming that the government's data collection procedures adhere to standardized collection and evaluation practices, then a unilateral, instantaneous, and complete integrated relationship between  $P_t^{NE}$  and  $P_t^V$  exists in the context of a price-reporting relationship.

The requirement for an integrated relationship between actual and reported market price is an error term that is stationary. Stationarity is imposed by the assumptions that  $E(v_t | I_t^{NE}) = 0$  and  $\text{Var}(v_t | I_t^{NE}) = \sigma^2 v_t$ . This implies that there is not a systematic component affecting the mean and variance of the error term.

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

Assume two spatially related regions (SD and NE) for the production of slaughter cattle. Assume that the NE market has a high level of production capacity for producing slaughter cattle, has processing facilities, and has a voluntary public price-reporting regime. In contrast, SD has a mandatory price-reporting regime, no processing facilities, and a lower level of slaughter cattle production capacity relative to NE. Assume that SD produces an excess supply of slaughter cattle because of a lack of processing facilities and that NE has excess demand for slaughter cattle due to processing facilities' having excess capacity. Producers in SD have a choice of selling their live cattle to a field representative of a processing firm located in NE or selling their cattle in SD to an intermediary (independent order buyer). The intermediary will assume the risk of delivering the cattle to a processing facility in NE and profit from arbitrage activity. Therefore, trade in live slaughter cattle between SD and NE is unilateral. This description is consistent with the production and marketing of slaughter cattle in South Dakota. There are no modern large-scale commercial beef packing plants in South Dakota, except for two plants processing cull cows. A majority of South Dakota slaughter cattle are shipped to Nebraska for processing.

Next, it is assumed that the market for slaughter cattle is competitive in South Dakota and Ne-

<sup>2</sup> This assumes full compliance with price-reporting regulations by all market participants. It is assumed that transaction costs associated with price reporting are zero. Accordingly, the intercept term is dropped.

<sup>3</sup> Note that the mathematical operators  $E$  and  $\text{Var}$  are conditional expectation and variance operators, respectively.

<sup>4</sup> The assumption is that the expected value of collected transaction prices is an unbiased estimate of equilibrium price and is consistent with Tomek (1980).

braska. This implies that opportunities for interregional arbitrage dissipate quickly, and that long-run competitive spatial equilibrium is consistent with zero marginal profit from arbitrage activity. This also implies that the cash markets for slaughter cattle in South Dakota and Nebraska are spatially integrated and that this relationship can be defined as

$$(3) \quad P_t^{SD} = \alpha + P_t^{NE} + \psi_t,$$

where  $\alpha$  is the intercept term capturing transaction costs,  $\psi_t$  is the random error term, and  $E(\psi_t) = 0$  and  $\text{Var}(\psi_t) = \sigma^2 \psi_t$ . Transaction costs include transportation, commission fees for dealers and order buyers, pencil shrinkage, etc.

Given the interregional spatial market relationship discussed above, it is reasonable to assume that an interregional spatial relationship exists between the South Dakota MPR price series and the Nebraska VPR price series:

$$(4) \quad P_t^M = a + P_t^V + e_t,$$

where “a” denotes the intercept term reflecting transaction cost, and “ $e_t$ ” is the random error term.

### Empirical Implications of the Thinning Market Hypothesis on Spatial Markets

The MPR literature discussing the thinning market effect contends that accuracy and timely transmission of cash market price information by the VPR system was degraded. We assert that a thinning market effect will distort the VPR system in two ways. First, as a cash market thins, a breakdown of the integrated relationship between a VPR system and the cash market it is reporting on will occur. Second, as a cash market thins, informed market participants are likely to have a competitive advantage over uninformed market participants, and this asymmetry may result in anti-competitive practices. In this case the VPR mechanism fails to provide transparency to market participants who rely on the VPR system for market information. Furthermore, the lack of transparency can provide an opportunity for informed market participants to take advantage of uninformed market participants. One example of

this type of anti-competitive behavior discussed in the literature is strategic price reporting (Koontz 1999, Fausti and Diersen 2004). The econometric implications of this type of market disruption are investigated next.

With respect to VPR in Nebraska, a thinning market effect will alter the information set and affect the first and second moments of the distribution of the error term [equation (2)]. This would result in a violation of our initial assumptions of  $E(v_t | I_t^{NE}) = 0$  and/or  $\text{Var}(v_t | I_t^{NE}) = \sigma^2 v_t$ . This implies that either  $E(v_t | I_t^{NE}) \neq 0$  or  $\text{Var}(v_t | I_t^{NE})$  changes as the content of the information set changes. If the amount of voluntarily reported transaction data declines over time in Nebraska (*ceteris paribus*), then voluntarily reported prices released to the public will exhibit increased variability. This assumption is consistent with the discussion of the consequences associated with a thinning market (Tomek 1980) for market efficiency, and the discussion found in the MPR literature (e.g., Azzam 2003). This implies that the variance term in the relationship defined in equation (2) will be inflated. As a consequence, the variance of the error term in equation (4) will also increase, rendering the error term in equation (4) nonstationary.<sup>5</sup>

This can be demonstrated by rearranging equation (4):  $P_t^M - P_t^V = a + e_t$ . Assume that “a” is a constant and allow a mean-preserving increase in dispersion. The implication of an increase in the variance of  $P_t^V$  can easily be shown by using the following definition:  $\text{Var}(P_t^M - P_t^V) = \text{Var}(P_t^M) + \text{Var}(P_t^V) - 2\text{Cov}(P_t^M, P_t^V) = \text{Var}(e_t)$ . If  $\text{Var}(P_t^V)$  increases, then  $\text{Var}(e_t)$  increases. In this case, linear cointegration estimation techniques could fail to find a cointegrated relationship between  $P_t^M$  and  $P_t^V$ . The failure to detect cointegration implies that the thinning market effect has disrupted the ability of the two price-reporting series to reflect the competitive spatial equilibrium relationship between the cash markets.<sup>6</sup>

Disequilibrium between the NE VPR series and the SD MPR series implies that the spatial re-

<sup>5</sup> The empirical implication of a thinning market effect is analogous to heteroscedasticity.

<sup>6</sup> The alternative explanation would be that the South Dakota and Nebraska cash markets are not linked by competitive spatial arbitrage. However, this alternative is not consistent with the structure of the interregional cash markets for live cattle.

relationship between the NE cash market and the NE VPR series is disrupted. In this case the NE VPR is not providing transparency to the participants in the NE and SD cash markets. However, if we verify empirically a cointegrated relationship between the NE VPR series and SD MPR series, then we have established that the NE and SD price-reporting series reflect the existence of a long-run spatial equilibrium relationship between the NE and SD cash markets. According to Barrett and Li (2002), this is the first condition necessary to establish that the NE VPR was providing transparency to the NE and SD cash markets.

#### *Thinning Market Hypothesis and Competitive Spatial Arbitrage*

Assume that the cash market can become less competitive as transparency declines (e.g., Koontz 1999). One would expect that within interregional spatial markets, the farther an area is from the market center the less competitive that area becomes as transparency deteriorates. Following this line of thought, we will relax our underlying assumption of competitive spatial arbitrage in the SD and NE cash markets. Assume that competitive spatial arbitrage breaks down in the cash markets between SD and NE. This implies that long-run marginal profit to arbitrage is positive. Accordingly, informed buyers of slaughter cattle can earn positive economic rent by purchasing cattle in SD from uninformed sellers and selling them in NE. As the NE cash market thins, non-competitive practices increase. This implies that positive profit to arbitrage increases in the long run.<sup>7</sup>

We assert that positive marginal profit from spatial arbitrage will be captured in the interregional cash market intercept term ( $\alpha$ ) defined in equation (3). In this case, the intercept term would then capture transaction cost and positive economic rent paid by SD producers who relied on

the NE VPR for price discovery. This can be easily demonstrated by rewriting equation (4) as

$$(5) \quad E[P_t^M] - E[P_t^V] = E[a] + E[e_t].$$

Assume that it is possible to measure profit from spatial arbitrage and let  $\beta_t$  denote increasing positive economic rent from arbitrage occurring in the cash market. Incorporating this assumption into the cash market equation [equation (3)], transaction cost is denoted by  $\alpha$  and economic rent is denoted by  $\beta_t$ :  $\partial\beta_t / \partial t > 0$ :

$$(6) \quad P_t^{SD} = \alpha + \beta_t + P_t^{NE} + \psi_t.$$

Next, equation (5) is modified first by substituting in equations (1) and (2) for  $P_t^M$  and  $P_t^V$ , and then by replacing  $P_t^{SD}$  with equation (6):

$$(7) \quad E[\alpha + \beta_t + P_t^{NE} + \psi_t + \varepsilon_t] - E[P_t^{NE} + v_t] = E[a] + E[e_t].$$

Taking the realization of the expected value components of equation (7), you have  $a = \alpha + \beta_t$ . Thus, the intercept term of the cointegrating equation [equation (4)] captures transaction cost and increasing economic rent.

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 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 equation (4) nonstationary (Gujarati 2003, p. 805).

### **Empirical Specification of the Spatial Relationships: MPR and VPR**

#### *Competitive Spatial Equilibrium*

The purpose of the MPR and VPR systems is to provide an accurate reflection of the transaction price information from their respective cash markets. Spatially linked cash markets are assumed to have a spatial relationship that is in equilibrium as a result of competitive spatial arbitrage. Therefore, if information on transaction price in NE is

<sup>7</sup> 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. Barrett and Li (2002) discuss a non-competitive outcome as spatial environments where markets are integrated but not competitive in equilibrium. This type of market environment is consistent with the TMH.



not distorted by a thinning market effect, then the information contained in the MPR from SD will mirror the information contained in the VPR from NE. This implies that in the absence of any market distortions,  $E(e_t) = 0$ , and  $\text{Var}(e_t) = \sigma^2 e_t$  is constant over time.

Empirically, to support this proposition, statistical evidence of a cointegrated relationship between  $P_t^M$  and  $P_t^V$  is necessary to conclude that a long-run spatial equilibrium exists between the cash markets and the associated price-reporting systems. A cointegrated relationship between  $P_t^M$  and  $P_t^V$  is present only if  $e_t$  is stationary. Empirically demonstrating that a long-run competitive spatial equilibrium relationship between the SD MPR series and the NE VPR series exists is only the necessary condition for establishing that the NE VPR series provided transparency to the NE and SD cash markets. The sufficient condition is demonstrating that the SD MPR and NE VPR series are spatially integrated. The necessary and sufficient conditions must be tested to determine whether a thinning market effect had disrupted the ability of the NE VPR system to provide transparency to the NE and SD cash markets. If the necessary and sufficient conditions are confirmed, then we can conclude that the NE VPR was providing *spatial price transparency* to participants in the SD and NE cash markets for live slaughter cattle.

However, the literature (Barrett and Li 2002, McNew 1996, McNew and Fackler 1997, etc.) indicates that linear cointegration techniques are inadequate when (i) transaction costs are not stationary, (ii) trade is bilateral, or (iii) trade is discontinuous. For the interregional spatial relationship between SD and NE, only the issue of non-stationary transaction costs poses a potential problem. The other two potential caveats are not violated by the spatial relationship between the SD and NE markets. Empirical results discussed later indicate that transaction costs are stationary.

#### *Interregional Spatial Integration and Price Transparency*

According to the literature (e.g., Barrett and Li 2002), 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 as requiring the market mechanism to provide accurate and timely price information to market participants.

To test whether the VPR system provided full and accurate transmission of 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. This procedure will determine whether the MPR series in SD and the VPR series in NE are spatially integrated. By adopting the ECM framework to model the price transmission process across interregional markets, we can also test for the econometric anomalies alluded to by the TMH. According to Granger (1981, 1983), two cointegrated series [equation (4)] can be expressed as a simple error-correction model:

$$(8) \quad \Delta P_t^M = \gamma_0 + \gamma_1 \Delta P_t^V + \gamma_2 e_{t-1}.$$

The change in the equilibrium price of slaughter cattle from period  $t-1$  to  $t$  in SD is  $\Delta P_t^M$ . The change in the equilibrium price of slaughter cattle from period  $t-1$  to  $t$  in NE is  $\Delta P_t^V$ . The intercept term  $\gamma_0$  ( $\gamma_0 = \Delta a$ ) reflects changes in the long-run equilibrium relationship due to the effect of the price shock on transaction cost levels.<sup>8</sup> The slope parameter  $\gamma_1$  ( $0 \leq \gamma_1 \leq 1$ ) captures the transmission of the price shock occurring in NE, in time period  $t$ , to SD. If  $\gamma_1 = 1$ , then this would indicate “instantaneous perfect integration” as defined by Barrett and Li (2002). However, a weaker condition discussed by Barrett and Li is “perfect integration,” which requires only 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 NE to SD as a result of the price shock at time  $t$ . The deviation from parity adjustment parameter  $\gamma_2$  ( $0 \leq \gamma_2 \leq 1$ ) captures the transmission of the price shock residual to SD.

Empirical estimation of parameters  $\gamma_0$ ,  $\gamma_1$ , and  $\gamma_2$  in equation (8) will provide statistical evidence of whether the spatial relationship between  $P_t^M$

<sup>8</sup> We assume  $\gamma_0 = 0$ . Empirical evidence of  $\gamma_0 \neq 0$  indicates that either transaction cost or economic rent from arbitrage is nonstationary. In this case linear cointegration techniques would be inappropriate.

and  $P_t^V$  reflected interregional spatial integration of the SD and NE cash markets. If  $\gamma_0$  is insignificant, then the intercept term of the cointegrating regression is stationary. This implies that a thinning market effect was not destabilizing the price differential between SD and NE cash markets by creating opportunities for spatial arbitrage. If both  $\gamma_1$  and  $\gamma_2$  are statistically significant, we can conclude that the spatial relationships defined by equations (1) through (4) are integrated. The implication under this scenario is that the TMH is rejected for the Nebraska and South Dakota cash markets.

## Empirical Methodology and Results

### *Cointegration*

The time period selected for this study is the 19-month period just prior to federal MPR implementation. A test for the presence of cointegration will provide empirical evidence on the nature of the spatial relationships defined by equations (1) through (4). If a long-run equilibrium relationship is established, then an ECM modeling 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.

The empirical analysis will begin with unit root tests to determine if the selected price series are nonstationary. 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 [equation (4)] is tested for the existence of a unit root to determine if the two price series are cointegrated. If the MPR and VPR series are determined to be cointegrated, then the relationship between them can be expressed as an ECM (Granger 1981, 1983, Engle and Granger 1987).

### *Data*

In July of 1999, South Dakota Codified Law, Chapter 40-15B (SDCL 2000), required that mandatory livestock price reporting in South Da-

kota begin on September 1, 1999. All private livestock transactions of slaughter animals were to be reported to the South Dakota Department of Agriculture. Only auction markets were excluded from the regulations. Civil and criminal (felony-level) penalties were incorporated into the regulations to discourage non-compliance. 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.<sup>9</sup> 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.

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 raised in South Dakota. The data set contains 59,614 head and 300 recorded transactions.<sup>10</sup> The VPR series selected is the AMS Nebraska Daily Direct Weighted Average report. The two price series were matched with respect to transaction dates.

### *Empirical Results: Testing for Unit Roots*

In Table 1, the Dickey-Fuller (DF) and Augmented Dickey-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 whether 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 struc-

<sup>9</sup> 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 (2004).

<sup>10</sup> The mandatory price-reporting data set supplied to the authors 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, and heifer and Holstein transactions were excluded from the sample. Voluntarily reported price data were collected from various issues of the AMS Livestock, Meat and Wool Weekly Summary and Statistics report (Agricultural Marketing Service, various issues).

**Table 1. Unit Root Test Results<sup>a</sup>**

Price Series	No. of Obs.	Tau Statistics	P-Value
Nebraska Daily Direct Weighted-Average Report <sup>b</sup>	142	-0.80	0.81
South Dakota Mandatory Price-Reporting Data <sup>c</sup>	142	-1.34	0.61

<sup>a</sup> Statistical analysis was conducted using SAS (1993).

<sup>b</sup> The order of the autoregressive model selected for the ADF test is AR(0). Durbin-Watson  $d$  test stat = 1.68.

<sup>c</sup> The order of the autoregressive model selected for the ADF test is AR(1). Durbin's  $t = -1.27$ .

ture 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 nonstationary versus the alternative that the series does not have a unit root and is stationary. The unit root hypothesis test indicates that both price series are non-stationary (Table 1).

#### *Empirical Results: Testing for Cointegration*

Table 2 contains the cointegration results for equation (4). The empirical evidence suggests that the spatial relationship between the South Dakota mandatory price report series and the Nebraska direct series reflects a long-run competitive spatial equilibrium relationship existing between the South Dakota and Nebraska cash markets. The cointegration results establish the necessary condition for the existence of spatial price transparency and the rejection of the TMH.

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 suspected flaws in the VPR system. The spatial equilibrium literature clearly indicates that inter-regional integration occurs only if price shocks are completely transmitted from one region to another. An error-correction mechanism is employed to investigate the effect of short-run anomalies on the long-run relationship just established.

#### *Empirical Results: ECM Analysis of Spatial Relationship Between MPR and VPR*

In the last section we established that there is statistical evidence of a long-run spatial equilibrium relationship linking the South Dakota and Ne-

braska 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 VPR system to act as an efficient mechanism 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 that the trends in transaction and transport costs were relatively flat during the time period covered by this study.<sup>11</sup> 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. 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. It is during this period of disequilibrium that price transparency can be affected. The

<sup>11</sup> During the period covered by this study, the average Midwest retail weekly #2 diesel price per gallon was \$1.41 and the standard deviation was \$0.12 (U.S. Department of Energy 2006).

**Table 2. South Dakota Mandatory Price Report Cointegration Test Results**

Price-Series Cointegration Regression	Cointegration Regression				
	No. of Obs.	Intercept Estimate	Parameter Estimate	Tau Statistics	P-Value
SDMPR and NEVPR <sup>a</sup>	142	5.14	0.917	-9.27	0.001

<sup>a</sup> The order of the autoregressive model selected for the ADF test is AR(0). Durbin-Watson *d* test stat = 2.025.

Note: "SDMPR" is South Dakota Mandatory Price Report. "NEVPR" is Nebraska's voluntary price reporting.

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.<sup>12</sup>

Based on the work by Granger (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 OLS version of the ECM defined in equation (8) is

$$(9) \quad \Delta P_t^M = \gamma_0 + \gamma_1 \Delta P_t^V + \gamma_2 e_{t-1} + z_t,$$

where  $z_t$  is the random error term. The empirical estimates for equation (9) are provided in Table 3.

The intercept estimate in Table 3 is statistically zero. This result answers the caveat raised that a thinning market effect could degrade the competitive market environment. This empirical evidence also indicates that transaction costs were stationary during the period investigated in this study. This suggests that a normal profit from spatial arbitrage was being earned in the SD and NE cash markets. Therefore we conclude that there is no empirical support for the presence of anti-competitive practices, such as strategic price reporting, affecting the NE and SD cash markets during the time period covered by this study.

Empirical evidence presented in Table 3 indicates that 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 SD MPR series in

period *t* + 1. The empirical evidence suggests that price shocks occurring in the NE cash market were being transmitted to the SD cash market and that these price shocks were accurately reflected in the NE VPR price series.

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 (2000) definition of "perfect integration" are satisfied. According to Fausti and Diersen (2004), when interregional spatial markets exhibit perfect integration, then spatial price transparency also exists within these interregional spatial markets. Table 4 provides empirical estimates for the speed of adjustment process.

The ECM estimates indicate that 94 percent 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 percent by day two. Empirical evidence provided in Table 4 suggests that market integration did exist. Thus the sufficient condition for transparency is met.

The evidence from Tables 2 and 4 supports 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 perfect integration and that the VPR system did provide spatial price transparency to participants in these markets.

## Conclusions and Summary

It was demonstrated in the theoretical development of the empirical model that a significant presence of a thinning market effect will distort the transmission of the spatial price relationship

<sup>12</sup> The possibility of excess profit potential arising in this type of situation has been alluded to by Goodwin and Schroeder (1991) and Tomek (1980).

**Table 3. Error-Correction Model OLS Estimates**

Price-Series ECM Regressions	No. of Obs.	ECM Regression Estimates <sup>a</sup>		
		Intercept Estimate	Slope Estimate	Speed of Adjustment Estimate
$\Delta$ SDMPR and NEVPR <sup>b</sup>	142	0.03 (0.29)	0.752 (6.62)	-0.755 (-9.16)

<sup>a</sup> Student t test statistics are given in parentheses below the respective parameter estimate.

<sup>b</sup> 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.

Note: "SDMPR" is South Dakota Mandatory Price Report. "NEVPR" is Nebraska's voluntary price reporting.

**Table 4. South Dakota Mandatory Price-Reporting Series: "Speed of Adjustment" Over Time to a Price Shock at Time  $t$** 

Cointegrating Regressions	Time Period		
	$t$	$t + 1$	$t + 2$
SDMPR and NEVPR	75.20%	93.98%	98.52%

Note: "SDMPR" is South Dakota Mandatory Price Report. "NEVPR" is Nebraska's voluntary price reporting.

between South Dakota and Nebraska cash markets being reported by the VPR system for Nebraska. The consequence of this distortion is the loss of spatial price transparency, as asserted in MPR literature.

We found no empirical evidence of a thinning market effect distorting the voluntary price-reporting mechanism for the Nebraska cash market. We found no evidence of a noncompetitive market environment distorting the South Dakota and Nebraska cash markets for live slaughter cattle prior to the implementation of federal MPR.

For the period when South Dakota required mandatory livestock reporting, we did find empirical support for the existence of a spatial relationship between South Dakota and Nebraska cash markets and their respective price-reporting regimes for live slaughter cattle that is consistent with Barrett and Li's (2002) concept of "perfect integration."

While the analysis covers a small corner of the livestock sector, this case study supports the previously published results of Fausti and Diersen (2004) and extends the literature by providing a theoretical and empirical framework for modeling and testing for the presence of market distortions. Our contribution establishes the conditions necessary for a VPR system to provide price transpar-

ency and foster price discovery in cash markets, but within a linear cointegration framework.

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