Spatial integration of feeder cattle markets

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SPATIAL INTEGRATION OF FEEDER CATTLE MARKETS

by

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STATEMENT BY AUTHOR

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I hope the material in this thesis will help improve economists' understanding of markets and how they work. Any contributions towards this end will make the entire project worthwhile.

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ABSTRACT

Previous analyses of market integration often ignore the spatial aspect of economic activity. A model of imperfect competition with changed implications for pricing structures is used to analyze spatial pricing relationships between ten feeder cattle markets. The econometric model is applied to reveal price structures over a six year period, a two year period, and to identify changes in price structures corresponding with the change from physical delivery to cash settlement of feeder cattle futures contracts. The six year analysis indicates that all markets are integrated through a lagged adjustment process. The two year analysis reveals short-term patterns of price independence or nearly instantaneous price matching among some locations. The change to cash settlement corresponds with changes towards either independence or instantaneous price matching activity for the markets involved. Four high volume central plains locations act an an integrated central market which the other locations match.

CHAPTER 1

INTRODUCTION

Previous research on cattle market pricing has been directed towards fed cattle with less coverage of markets for feeder cattle, cull cows and bulls, and calves. Coverage of feeder cattle pricing has been largely limited to reports of differences in prices between markets (see Purcell, 1956, Stubblefield, 1966, Kearl, 1987), or to factors affecting feeder cattle pricing within a market (see Buccola, 1980, Faminow and Gum, 1986, Shroeder, Mintert, Brazle, and Grunewald, 1988, Lambert, McNulty, Grunewald, and Corah, 1989). James (1970) examined locational price differences in Texas markets, but recent work investigating the spatial relationships of feeder cattle pricing has been lacking, particularly in light of work examining spatial pricing relationships for slaughter cattle by Bailey and Brorsen (1985). Recently developed techniques could be used to provide some insights into the operation of these markets. Any information gained could be of particular interest to cattlemen, many of whom sell their calves as stockers or feeders.

Importance of the Problem

Cattle prices vary by area, which leads some producers to question whether the price they receive is fair, particularly during periods of low or falling prices or when local prices lie below those in major markets. Previous analyses have examined differences between grades or types of cattle to explain differences within a market, or to calculate price differences between markets and compare the differences to transport costs between the two points (see McPherson, 1956, James, 1970, Bailey and Brorsen, 1986). The results show some differences in prices which may be attributed to market inefficiencies, monopolistic practices, or factors affecting the value of animals at differing locations which are omitted from the models used. A spatial examination of feeder cattle prices could provide valuable information as to whether the variations in prices not attributable to the characteristics of the cattle being sold can be justified as part of an in integrated market or not.

Spatial integration of feeder cattle markets has not received much study in the past, partially due to problems of data availability. Statistics on the flow of feeder cattle within and between geographic areas are not readily available. The techniques used in this study are not dependent upon flow data, opening new opportunities for research.

This study of feeder cattle markets demonstrates an approach which has widespread applications to other commodities and industries and may improve economists' understanding of how markets work. Producers often worry about the fairness of the prices they receive and seek ways to improve their marketing decisions. The results of the analysis may provide better information on the operation and integration of the marketing system for users and reveal potential problem areas which can be targeted for further investigation.

If markets are competitive and integrated on a regional or national scale, changes in the supply and/or demand for feeder cattle in one location should result in adjustments in other areas. Because research towards identifying the integration or separation of feeder cattle markets is lacking, this study uses a spatial competition framework for analyzing interdependence among feeder cattle markets.

Objectives

The objectives of this thesis are:

1. Examine and describe important characteristics of the Arizona feeder cattle market.
2. Analyze the price differences for selected markets using descriptive statistics and graphics.
3. Test for evidence of feeder cattle market integration among locations using the Ravallion model (Ravallion, 1986) as presented by Faminow and Benson (1990).
4. Analyze test results from the Ravallion model for the price interactions (if any) occurring and discuss the implications they have for industry pricing practices and competitiveness
5 Test for significant changes in market relationships occurring with the change to cash settlement of feeder cattle futures contracts.

Procedure

The procedure to be followed in this study is as follows. The theory of spatial competition will be presented and its implications for the relationships between feeder cattle markets will be described. An empirical model to examine these relationships will be described to allow testing for market integration and between types of integration which may be found. The data used in the analysis is obtained from the Western Livestock Marketing Information Project (WLMIP) and local auction markets in Arizona, covering weekly observations over a six year period for the WLMIP data and a two year period for the Arizona auction data. Analysis of the data will be made using Ravallion's model as presented and interpreted in Faminow and Benson (1990), the results analyzed with regards to the hypotheses presented, and conclusions drawn. Implications of the spatial price patterns revealed will be discussed and the limitations of the evidence noted. Finally, the usefulness of the model employed will be evaluated and potential improvements and suggestions for further research will be presented.

Plan of Thesis

This thesis proceeds in the following order. The remainder of this chapter reviews the cattle feeding industry, the basis of spatial theory, and previous empirical studies and techniques measuring integration, establishing the direction for the following chapters. Chapter 2 examines the Arizona cattle market. Chapter 3 presents and discusses the relevant spatial competition theory and outlines the empirical model. Chapter 4 describes the data and methodology used in this thesis. The results of the analysis are presented in Chapter 5. The conclusions of the study and suggestions for further research are presented in Chapter 6.

The Cattle Feeding Industry

Feeder cattle are primarily associated with two sectors of the cattle industry, the cow/calf producer and the cattle feeder, both having geographic and firm size differences. Feeder cattle production is widely dispersed throughout the United States. The fourteen largest producing states in 1987, having a calf crop of one million or more head, produced 61% of the total calf crop (Agricultural Statistics 1988, 1988). Ten of these states form a band through the center of the United States, from Montana, Minnesota, and Wisconsin in the North, through the Plains and Western Corn Belt down to Texas. The other four states are California, Kentucky, Tennessee, and Florida. Excluding the New England states, Alaska and Hawaii, the remaining 28 states had an average calf crop of 541,000 head. Thus, while production is dominated by the center of the United States, large numbers of feeder cattle are produced throughout the country. Although the calf crop figures are not adjusted for replacement heifers and dairy calves, they are instructive in showing the geographic dispersion of calf, and thus feeder cattle, production.

In addition to the geographically widespread nature of cattle production, the average producer's herd size is small. In 1987, the average herd size per farm/ranch was 37 cows (Fitzgerald, 1989). Eighty-two percent of the cow herds were less than 50 head but comprised 34.0% of the 31.5 million total cows on the nation's 841,778 farms and ranches having cattle. The largest herds (over 200 head), comprising 31.1% of all cows, were located on 2.8% of the farms and ranches. Thus, while large operations hold significant numbers of cattle, small operations are the largest group overall. This contrasts with the size of the feeding industry. Out of 42,662 total feedlots in 1988 in the thirteen states covered by the Cattle on Feed (1989) report, 391 (0.9%) had a capacity of over 8000 head. These large feedlots produced 65.7% of the fed cattle sold in 1988.

Placements of steers and heifers in feedlots were heavily concentrated in the states of Colorado, Iowa, Kansas, Nebraska, and Texas in 1988. These five states accounted for 77.8% of the 24.3 million head of steers and heifers placed in feedlots in the thirteen feeding states surveyed in the USDA Cattle on Feed report. In fact, these five states placed 9.5 million more cattle on feed in 1988 than their total 1987 calf crop before accounting for replacement heifers and dairy cattle, indicating that large imports of feeder cattle from other parts of the United States must have occurred. Arizona placed about 75% more cattle on feed in 1988 than its 1987 calf crop while Idaho, Illinois, and Washington were about even. California feedlot placements in 1988 amounted to about 70% of the state's 1987 calf crop of 1.7 million head, while Minnesota, Oklahoma, and South Dakota had 1988 placements totaling less than half of their 1987 calf crops.

The geographic dispersion of calf production and relative concentration of cattle feeding suggests that considerable cattle movements and distances are involved in bringing cattle from the farm/ranch to the feedlot. In addition, the large numbers of cows in small herds contrasted with the dominance of large feedlots in producing fed cattle show that considerable amounts of consolidation must also occur between the calf producer and the feedlot gate. This evidence suggests that broad linkages of cattle prices exist throughout the nation in order to generate the aggregation and flows of cattle into the heavy volume cattle feeding states.

The Market and Spatial Price Integration

The study of integration begins with the definition of the concept of a market and its price. This results in a basis for analyzing market performance, or how markets work in relation to the goals and objectives of society. Cotterill (1987) lists some performance criteria, including profits, X-efficiency, and growth at the firm level. Allocative efficiency, full employment, and fairness/equity are among the additional criteria at the social level. While these criteria do not include integration of markets, integration is a component insofar as it reflects interdependence between product prices and firms, promoting competitive behavior, the results of which are measured by these criteria. Integration has been a popular topic recently, sometimes being used as a direct measure of pricing efficiency. However, the most important use of integration models may be in examining the extent (spatial or substitutable product range) of a market, and thus the competitive space over which it operates.

This section reviews previous research defining markets and the influence of space on their operation. This is followed by a discussion of the empirical methods which have been used to study integration in general and cattle markets in particular in order to form a background from which the theory and empirical model of this thesis are discussed.

Spatial Markets

Marshall (1959) defined a perfect market as "a district, small or large, in which there are many buyers and many sellers all so keenly on the alert and so acquainted with one another's affairs that the price of a commodity is always practically the same for the whole of the district". He also noted that in more perfect markets, a strong tendency existed for "the same price to be paid for the same things at the same time in all parts of the market," allowance being made for the cost of delivering goods to purchasers.

Studying the effects of distance as represented by transport costs became the basis for spatial economics theory. Applied work in spatial economics has been frequently used in market integration studies of agricultural commodities in developing countries and more recently in developed countries. The focus is on market integration, defined by Lele (1967) as the extent to which "price formation in one market is related to the prices in other markets." These studies (see Lele, 1967, Jones, 1968, Timmer, 1974, Hays and McCoy, 1978, Bailey and Brorsen, 1985, Stigler and Sherwin, 1985, Slade, 1986) concentrate on the analysis of prices determined by the interaction of a buyer(s) and seller(s) at individual market points.

Fetter (1970) explained the expected price relationship between two market points, stating: "If two selling markets, A and B, are geographically so situated that goods may be shipped from one to the other, obviously the same prices in the two markets cannot (except accidentally and temporarily) differ by more than the amount of the freight (and incidental expenses) between the two points. If the difference exceeded that sum, the one market would destroy the other... [B]oth markets can exist so long as the price difference of the two markets is less than the full freight difference."

Several points should be made about the statements of Marshall and Fetter by way of the following example. Assume a product manufactured at two markets, A and B, is delivered to buyers located at these market locations and in between, with the delivered price increasing by the transport rate (t) times the distance (u_{ij}) between the selling market and the buyer. The delivered price, P_D, will be

1.1 $$P_D=P_i+T \qquad i=A,B$$

where

1.2 $$T=tu_{ij} \qquad j=A,B,C,...$$

If

1.3 $$P_A+T_{AB}<P_B$$

(the delivered price from market A at location B is less than market B's price) market B will cease to exist since all buyers can get the product at less cost from market A. Thus, for both markets to exist,

1.4 $$P_A+T_{AB}\geq P_B.$$

The potential for arbitrage from A to B enforces this constraint. If equation 1.4 holds as an inequality, a market boundary will exist between A and B at the point where delivered prices are equal, or

1.5 $$P_A+tu_{Aj}=P_B+tu_{Bj}.$$

The boundary is a solution, not a fixed location, when the prices at A and B are allowed to change. As long as both markets exist, 1.4 will hold. Competition for sales volume (and thus market area) results in competition for the position of the market boundary. As a result of this competition, the prices of markets A and B will be interdependent. A price reaction function (discussed in Capozza and Van Order, 1978) will exist between the two markets' prices, thus assuring the interdependence of the markets. Since interdependence exists, the two markets may be seen as sub-markets or territories within an encompassing, linked market. These points are discussed in detail by Faminow and Benson (1990).

The use of the term "market" when referring to locations A or B or others may be misleading since it implies two separate and indentifiable markets. Locations A and B may be production and/or selling points, but are they actually two markets or one? If the locations are defined as two markets, then they do not compete with each other due to their separate nature, although competition may still occur internally in each market. If the locations are part of a single market, firms may act competitively or collusively internally at each location without necessarily behaving the same way between locations. Thus the term "location" rather than "market" might be a better description of these points.`

Empirical work on market integration has followed a general model of interdependence, written as $P_A=f(P_B)$. Buyers and sellers cannot be fully isolated, resulting in interdependent pricing. This general model may be examined as a system of differentials for quality characteristics (see Buccola, 1980, Faminow and Gum, 1986), or price reactions and adjustments between markets (see Bailey and Brorsen, 1985) Basing-point pricing systems ($P_A+T_{AB}=P_B$), in which price is set at one market or point and rises by the cost of transportation at points away from the central market (see Gee, 1985), reflect a perfectly interdependent form of the model.

A basing-point pricing system reflects a single market rather than the presence of multiple, interdependent sub-markets linked together within an encompassing market. It suggests that either demand and supply schedules are unified throughout the market or that local variations in supply or demand schedules are not being recognized. The presence of natural geographic differences, variations in population density, the availability and quality of natural resources, climate, and cultural and social patterns, to name a few, suggests that the latter alternative is the most probable. Thus, a basing-point pricing system reflects a relatively inefficient market because these local variations are not reflected in the operation of the market and its prices (Faminow and Benson, 1990).

Discriminatory pricing models (see Gee, 1985) allow buyers or sellers to be identified individually, resulting in pricing which is set from their individual demand or supply schedules. This result implies poor integration since buyers and sellers can now be isolated, and under constant marginal costs, market independence will result (Faminow and Benson, 1990).

A nearly uniform price relationship is taken to indicate a single or integrated market while non-uniformity or variations in prices greater than estimated transport costs are taken to indicate separate or inefficient markets (see Harriss, 1979). However, as discussed in Faminow and Benson (1990) and presented below, some of the points made in the theory need clarification since they change the conclusions which can be drawn from the evidence on price relationships. A uniform pricing relationship over space with high correlation coefficients may imply collusive activity. Furthermore, a highly uniform price relationship may ignore feedback relationships which would occur as a spatial market adjusts to a new spatial equilibrium in response to variations in localized supply or demand shifts.

While prices which vary by more than transport costs invite arbitrage, price movements may be highly divergent within the range over which arbitrage is not profitable. This may result in erroneous conclusions regarding market integration or segmentation when in fact the dynamics of supply and demand within or between localities are operating efficiently and competitively.

Empirical Techniques

The techniques used to analyze spatial prices have increased in sophistication over time. The most basic method of defining a market is by measuring cross-elasticities between products or locations (Shepherd, 1979). However, calculating cross-elasticities is difficult due to poor data availability and the lack of clear-cut market borders. To avoid this problem, other methods have been used to analyze prices for describing markets and spatial interrelationships. These methods include price correlations, hedonic estimation, variance components, and Granger causality.

Price Correlations

A number of studies using price correlations were conducted in the 1960's and 1970's in developing countries in South and Southeast Asia and West Africa. These studies are reviewed in Harriss (1979). A correlation coefficient of 1.0 has been taken to indicate perfect competition, however real world conditions are less than perfect so correlations of less than 1.0 would be expected (Lele, 1967). Although Lele expects correlations of less than 1.0, no objective criteria are established to identify "high" or "low" values. Some studies found high (defined as .9 or higher) correlations between prices (see Lele, 1967, Timmer, 1974); however correlations in other studies were often low (see Jones, 1968).

Using correlation coefficients to indicate market integration or perfect competition was criticized by Blyn (1973) and Harriss (1979). Blyn stated that using data containing trend or seasonal components could bias the correlations upward. The trend and seasonal factors could have a high correlation, raising the estimated coefficients of the underlying price movements. In addition, the coefficients can still be low if the markets being studied are both centers of supply and demand. This occurs because prices in one location may vary above or below those in a second location by an amount equal to transport costs before triggering an arbitrage induced price response. This relationship is called a "Gold Points" model by Jones (1968). Faminow and Benson (1990), discussed in detail in chapter 3, use techniques designed to examine these fluctuations under the "Gold Points" model.

Stigler and Sherwin (1985) define an integrated market as one in which price movements among market points will parallel each other. They deem a strong, parallel relationship as sufficient to conclude integration of market locations. They note, however, that statements about the competitiveness of the market defined cannot be made without additional investigation. Over time, movements to or departures from a parallel pricing pattern can be used to identify when changes in the integrated market area occur. This implies a pattern of full price matching over time, although not necessarily a high contemporaneous correlation.

Harriss (1979) adds to the criticism of drawing conclusions over the competitiveness of the market from correlations or price matching behavior by stating that monopoly procurement at fixed prices will give a perfect correlation. High correlations suggest stable margins between markets, which is equally indicative of monopoly as of competition.

Hedonic Index Estimation

Hedonic index estimation with dummy variables representing quality or location properties was used by Monke and Petzel (1984) to analyze cotton pricing in international markets. Their concern was whether different grades of cotton and different locations comprise separate markets, or whether an integrated market exists with price premiums or discounts for varying grades and locations. The result is an estimate of price premiums or discounts between grades and/or locations. This and price correlations imply integration between grades and/or locations. The hedonic index estimation method works well for data over longer periods since it measures long-run integration; however, the price correlations face the problems mentioned. In addition, causality information is not obtained and conclusions about the competitiveness of the market cannot be drawn.

Variance Components

The studies mentioned are all examinations of the behavior of margins between locations. Constant or near constant margins are given to imply integration. Delgado (1986) used a variance components approach to analyze margins. He calculated seasonal trends for individual market points, then tested these trends for equivalence. Equivalence was taken to indicate integration while divergence would be due to random or other factors, such as market failures. Findings of a lack of integration, however, do not identify the causes, whether random variation, market failure, market segregation, or other. In addition, no conclusions about competitiveness can be drawn.

Granger Causality

Studies of margins show statistical relations between prices at different locations, but do not necessarily show an interaction between these prices. Granger causality techniques have been introduced to capture the dynamic effects of interaction and show (statistical) causal relationships between time series price data at different market locations.

The technique proposed by Granger (1969) presents a method of analyzing causal and feedback relationships in data. This method suggests that a (statistical) causal relationship exists between two locations if the price at one location can be predicted more accurately by including current and past price data from the second location, as opposed to using an autoregressive model which does not include price data from the second location. A relationship of instantaneous causality is deemed to exist if prices at one location are more accurately predicted using contemporaneous prices at the second location than if these contemporaneous prices are omitted. A feedback relationship is deemed to exist if more accurate predictions of prices in each location can be obtained by using price data from the other location.

A number of studies of livestock market pricing have been conducted in recent years using the Granger causality approach, many of them dealing with hog markets but including some cattle markets. Most of the studies using this approach have used market independence, i.e. no causality, as the null hypothesis and market integration (or interdependence) as the alternative (Gupta and Mueller, 1982, Adamowicz, Baah, and Hawkins, 1984, Bailey and Brorsen, 1985). The type of causality occurring was then examined. Instantaneous causality was taken to indicate price efficient markets with a rapid flow of information. Feedback systems were considered less efficient, followed by one way causality and finally independence (Adamowicz, Baah, and Hawkins, 1984). Bailey and Brorsen (1985), in a study of regional U.S. fed cattle markets, did not classify the types of causality into orders of efficiency, but concluded that a high degree of instantaneous adjustment in all markets indicates high efficiency

Granger causality techniques, in the context in which they are used, result only in an indirect examination of efficiency. They test directly for statistical price relationships, from which statements regarding efficiency have been inferred but not thoroughly defined or examined. The efficiency conclusions inferred by these tests also do not clearly identify the type of efficiency being measured. Does it relate to the flow of information, allocation of the production and trade of the resources in question, or the operation of the trading system? The inferred conclusions of efficiency from Granger causality tests may be rather tenuous.

The statistical price relationships and the types of causality which have been defined reflect different forms of interdependence. Instantaneous causality is consistent with a basing-point pricing system (or the administration of a collusive pricing system), since prices at different locations adjust instantly and remain equal after allowing for transfer costs. Alternatively, Blank and Schmiesing (1990) note that the level of time aggregation may affect the results, particularly for Granger type tests. For example, daily pricing activity resulting in adjustments over the course of a few days may be lost if data are analyzed on the basis of weekly or monthly averages. The aggregation would result in findings of instantaneous causality which would not occur if the data were analyzed in less aggregated form. Thus, instantaneous causality may also indicate that the data should be examined in a less aggregated form so that the pricing adjustments can be identified. Finally, feedback relationships are consistent with an interdependent spatial market adjusting to variations in localized supply or demand shifts.

Multivariate Spatial Model

Ravallion (1986) developed an empirical formulation using time series price data for a set of locations which allowed testing market segmentation, a strong and weak form of short-run integration, and long-run integration as restricted forms of a more general model. Strong form short-run integration was defined as instantaneous causality with no lagged effects while the weak form only required that lagged effects vanish on average. Long-run integration was defined as an equilibrium in which market prices are constant over time, without disturbance by local stochastic effects.

Ravallion's interpretation of the restricted form tests follow the efficiency measures as discussed with the Granger causality model.[1] However, since efficiency isn't really being tested directly, the tests reveal the pricing system in effect assuming that the data aren't overly aggregated and masking any action-reaction processes. Thus, the short-run integration test is similar to the instantaneous causality test of Granger and is consistent with a collusive or basing-point pricing system. The long-run integration form reflects a feedback relationship and evidence for an interdependent spatial market searching for equilibrium. This changed interpretation of Ravallion's model is proposed in Faminow and Benson (1990) and discussed more fully in chapter 3.

Studies of Cattle Markets

Investigations of feeder cattle pricing have followed the methods used for studying market integration either spatially or across grades and quality differentials, sometimes investigating the effects of physical characteristics, then analyzing spatial

[1]The empirical equations of Ravallion's model, after removing the non-price factors, are essentially Granger causality equations but with parametric restrictions imposed and different implications as a result.

considerations in the residuals; however, the purpose of these studies was to investigate the factors affecting local cattle prices rather than the spatial integration of prices.

Some studies have analyzed cattle prices as a function of physical characteristics such as sex, weight, grade, yield, and type (slaughter, feeder, cows, bulls, calves) and external factors such as the lot size, uniformity, market volume, local supply and demand, and feed cost (see McPherson, 1956, Freund and Stout, 1958, Buccola, 1980, Faminow and Gum, 1986). These studies can provide economic information to producers concerning which selling methods or alternative locations can provide the best price for their type of cattle, which types of cattle to produce, and the relative premiums or discounts associated with different types, classes, weights, or cattle production systems.

The second approach analyzes spatial differences in prices within a region or between regions. Freund and Purcell (1959) examined residuals from a regression of grade and weight variables for different types of cattle to identify price differences among auctions within an area. They found some markets consistently priced over or under the average, while most fluctuated above or below the average over time. Stubblefield (1966) examined differences in prices between western markets for different grades of stocker-feeder cattle, comparing price averages and graphically showing changes over time. The discussion provided reasons why differences existed and relative prices changed over time, however the dynamics of price movements between different markets were not analyzed.

James (1970) examined differences in feeder steer prices in the Southwest using regressions to examine the effects of physical characteristics and location on price. The results provide values showing areas with above or below average prices, but do not indicate why these differences exist or what type of response occurs in one market from a price change in another market.

The techniques which have been discussed and applied to investigate livestock markets have provided valuable insights into the operation of these markets, however, holes remain. Recent work examining spatial interdependencies in feeder cattle markets is particularly lacking. Thus, a study of feeder cattle pricing relationships is appropriate. Applying the empirical model proposed by Ravallion (1986) and the interpretations of spatial economics and the implications of Ravallion's tests in Faminow and Benson (1990) should provide information about feeder cattle markets and the value of the model and its interpretation.

CHAPTER 2

THE ARIZONA FEEDER CATTLE INDUSTRY

This chapter briefly reviews and describes the Arizona feeder Cattle industry to illustrate some characteristics which may apply to much of the industry elsewhere and thus to the empirical analysis in later chapters. The purpose of this review is to demonstrate the large feeder cattle flows which occur across state lines, in part to show that political boundaries are unlikely to be an appropriate delineation of market boundaries. Additionally, other states are likely to have complex patterns of cattle flows, particularly those which have large feeding industries and which must import large numbers of cattle for this industry.

The cattle industry is the largest segment of Arizona's $1.781 billion agricultural sector, although the state ranked 34th out of the 50 states in cattle numbers in 1987. The $483 million in income generated from cattle amounted to 27.1% of the state's total agricultural income (1988 Arizona Agricultural Statistics, 1989). While the state has a relatively small calf crop, it does have a substantial cattle feeding industry which relies on imported feeder cattle from other states. This chapter reviews the cattle industry in Arizona, particularly as it relates to feeder cattle, demonstrating its interdependence with cattle markets in other states.

The January 1, 1987 Arizona cattle inventory shows that slightly over 54% of the cattle were located in three counties, Maricopa, Pinal, and Yuma (Table 2.1). This dominance is largely the result of a concentration of cattle feeding activity in these three counties and substantial dairy cattle numbers in Maricopa county. Range cattle (cattle and calves remaining) are distributed more evenly through the higher elevation areas in

Table 2.1 Arizona Cattle Inventory, January 1, 1988.

County	All Cattle & Calves (x1000)	%	Dairy Cows (x1000)	%	Cattle on Feed (x1000)	%	Cattle & Calves Remaining (x1000)	%
Apache	54	5.6	--	--	--	--	54	10.5
Cochise	60	6.2	--	--	--	--	60	11.7
Coconino	47	4.9	--	--	--	--	47	9.2
Gila	34	3.5	--	--	--	--	34	6.6
Graham	39	4.1	--	--	--	--	39	7.6
Greenlee	10	1.0	--	--	--	--	10	1.9
La Paz	4	0.4	--	--	--	--	4	0.8
Maricopa	218	22.7	77	85.6	68	19.4	73	14.2
Mohave	23	2.4	--	--	--	--	23	4.5
Navajo	50	5.2	--	--	--	--	50	9.7
Pima	45	4.7	5	5.6	--	--	40	7.8
Pinal	189	19.7	5	5.6	169	48.1	15	2.9
Santa Cruz	20	2.1	--	--	--	--	20	3.9
Yavapai	53	5.5	--	--	--	--	53	10.3
Yuma	114	11.9	--	--	113	32.2	1	0.2
Other*	--	--	3	3.3	1	0.3	--	--
Arizona**	960	100	90	100	351	100	513	100

* Other refers to dairy cattle in counties other than Maricopa, Pima, and Pinal.
**Totals may not add due to rounding.
Source: 1987 Arizona Agricultural Statistics, 1988.

Table 2.2 Arizona Historic Cattle Numbers.

Year	All Cattle[1]	Cows/Heifers 2 Years & Over[1]	Calves Born[2]	Cattle on Feed Placements[2]	Fed Cattle Marketed for Slaughter[2]	Cattle on Feed[1]
1870	250	--	--	--	--	--
1875	320	--	--	--	--	--
1880	430	--	--	--	--	--
1885	690	--	--	--	--	--
1890	980	--	--	--	--	--
1900	850	--	--	--	--	--
1905	950	--	--	--	--	--
1910	995	--	--	--	--	--
1915	1300	--	--	--	--	--
1920	1620	--	--	--	--	--
1925	1300	751	338	--	--	--
1930	770	400	273	--	--	23
1935	958	496	312	--	--	28
1940	864	488	346	--	--	64
1945	930	504	328	--	--	42
1950	818	442	349	--	--	59
1955	983	477	363	--	--	169
1960	1019	396	297	--	--	265
1965	1140	444	342	--	650	348
1970	1302	416	341	874	860	510
1975	1170	436	316	976	729	319
1980	1050	330	300	647	554	420
1981	1075	360	280	541	519	401
1982	1000	355	285	634	496	330
1983	1000	360	275	645	533	385
1984	980	350	305	697	570	407
1985	1050	355	325	532	510	419
1986	1050	381	310	497	462	344
1987	1000	355	295	548	460	343
1988	960	350	300	444	428	351

[1] Number on January 1, in thousands.
[2] Total for the year, in thousands.
Source: Arizona Agricultural Statistics, various issues.

the northeast, the southeast, and in the central valleys where extensive farming occurs. Relatively few cattle outside of those in feedlots are found in the western counties following the Colorado River.

Cattle numbers in Arizona have gone through periods of expansion and contraction over the past 120 years. Numbers peaked at 1.75 million head in 1918, then declined to a low during the Depression in the early 1930's. Cattle numbers expanded during the late 1930's but remained below one million head until 1956. Numbers rose in the 1960's to peak at 1.4 million head in 1973, then began declining. Since 1980, the cattle inventory has fluctuated at around one million head while the breeding herd has fluctuated at around 355,000 head (Table 2.2).

Based on January Cattle on Feed surveys, very few cattle were fed in Arizona until after 1950 (Table 2.2), when feeding expanded until the January 1 inventory reached a peak in 1973 with 655,000 head. Fed cattle marketings also peaked in 1973 at 919,000 head, but have since declined to 428,000 head in 1988.

Many of the calves produced in Arizona are raised in the cooler, higher elevation areas away from the hot valleys where most of the feedlots are located. Additionally, many of these calves are shipped to other states, such as Colorado, New Mexico, or Texas. Archer (1976) reported that in the early 1970's over 50% of the calves produced in Arizona were shipped out of state for feeding. Although data on cattle outshipments are not currently available, a survey of several states receiving cattle from Arizona (see Table 2.5) indicates that Colorado, New Mexico, and Texas receive large numbers of Arizona cattle. Brundrett (1989) reports that during the late 1980's, many of the calves from the cooler areas of Arizona continue to move out of state for feeding in cooler locations. As a result of the calf outshipments, cattle feeding in Arizona is not highly dependent on the state's calf crop as a source of feeders. Placements of cattle on feed greatly exceed the total calf crop (Table 2.2), even before accounting for death loss and retention of replacements for the breeding herd. Thus large feeder cattle inshipments are required to keep the state's feedlots operating.

Archer (1976) reported that feedlot operators expressed a preference for cattle purchased out of state because of the greater availability of crossbreds which perform better than the more dominant straight bred cattle produced in Arizona. Additionally, feeder cattle grown in hot, more humid climates such as Texas and the Southeast were believed to adapt better to the feedlots in the hot valleys of central and western Arizona. The study reported by Archer (1976) also found that cattle from Texas and the Southeast gave better performance than Arizona produced cattle.

The pattern of importing cattle from Texas and the Southeast and exporting Arizona cattle for feeding in cooler climates continues in the 1980's (Brundrett, 1989). Feedlot placements in 1988 totaled 444,000 head (1988 Arizona Agricultural Statistics, 1989) while inshipments of steers, accounting for 98% of all cattle inshipments, totaled 410,542 head (Arizona State Veterinarian, 1989). Approximately one fourth to one third of the fed cattle produced in Arizona were exported to other states for slaughter, primarily to California and Texas (Brundrett, 1989).

Inshipments

The dependence of the Arizona cattle feeding industry on cattle from other states is evidenced by the large number of steers which are imported. Monthly inshipments of steers by state or country of origin for 1987 are shown in Table 2.3, while Table 2.4 and Figure 2.1 show the shares of total steer inshipments provided by each state and

Mexico. The previously noted preference for cattle from Texas and the Southeast is apparent, while Mexico also provided significant numbers of cattle.

Texas was the dominant source of steers, providing 43.0% of Arizona's imports. Over half the shipments occurred during July, August, and September. An additional peak occurred in November.

The second largest source of cattle was Mexico, providing 22.2% of total inshipments. Most shipments occurred during the winter and spring. December showed the largest volume with 30.3% of the Mexican total. Additionally, no cattle were imported during August, September, and October and only a few were imported during July and November. Mexican cattle inshipments are limited by annual export quotas imposed by Mexico. The export season begins in the late fall and continues until the quota is reached the following spring or summer. Mexican cattle are considered desirable since they show excellent performance when placed on feed (Fletcher, 1989, Adams, 1989). During the periods when Mexican cattle are unavailable, large imports from the Southeast and Texas occur.

Shipments from the Southeast composed 19.3% of Arizona's total imports. This regional area includes Alabama, Arkansas, Florida, Louisiana, and Mississippi. Shipments from the Southeast show a peak during the months of August, September, and October, providing over half the year's movement during these months. Of these five southeastern states, Florida is the largest source with 7.6%, followed by Arkansas with 6.3% of the total.

New Mexico ranked as the second largest single state in the number of steers sent to Arizona with 12.2% of the total. Shipments from New Mexico were highest during the late winter and spring months, following the pattern of Mexico.

Table 2.3 Sources of Arizona Steer Imports, by Month, 1987.

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Alabama	0	257	0	0	290	265	204	1513	2969	1667	418	275	7858
Arkansas	1832	1103	756	1150	2011	1696	2241	3788	5370	3410	2357	233	25947
California	3950	510	517	150	1121	1281	485	1061	790	311	486	501	11163
Colorado	9	0	0	22	18	0	0	100	2	3	0	1	155
Florida	2428	1543	2465	1834	1462	2646	348	0	7864	6212	2070	2174	31046
Idaho	0	0	0	0	0	0	0	0	4	10	0	0	14
Kansas	0	0	0	0	0	0	0	0	0	240	0	0	240
Louisiana	0	145	0	0	0	0	0	0	0	0	0	0	145
Mississippi	128	742	0	252	566	759	1639	3508	3269	2003	1175	220	14261
Missouri	0	0	0	0	0	0	0	0	0	0	3	0	3
Montana	0	0	0	1	0	0	0	0	0	0	0	0	1
Nebraska	0	0	0	0	0	0	0	3	0	0	0	0	3
New Mexico	5755	5157	9525	9677	4852	5643	703	967	1742	3700	626	1893	50240
Oklahoma	0	0	0	0	2	2	0	0	0	1	0	0	5
Oregon	0	30	12	5	0	70	29	0	117	0	142	0	405
South Dakota	0	0	0	3	0	0	0	0	0	0	0	0	3
Texas	7271	5552	7685	3224	16305	3317	31159	32308	29189	12650	23834	3949	176443
Utah	0	60	0	0	87	0	0	0	0	429	340	65	981
Washington	0	52	69	0	0	0	0	45	123	9	0	0	298
Wyoming	0	0	0	1	0	0	0	0	0	0	25	5	31
Mexico	9727	8794	12693	9821	6248	12552	3670	0	0	0	152	27643	91300
Total	31100	23945	33722	26140	32962	28231	40478	43293	51439	30645	31628	36959	410542
Southeast*	4388	3790	3221	3236	4329	5366	4432	8809	19472	13292	6020	2902	79257

*Southeast includes Alabama, Arkansas, Florida, Louisiana, and Mississippi.
Source: Arizona State Veterinarian

Table 2.4 Sources of Arizona Steer Imports, in Percentages, by Month, 1987.

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Alabama	0.0	3.3	0.0	0.0	3.7	3.4	2.6	19.3	37.8	21.2	5.3	3.5	1.9
Arkansas	7.1	4.3	2.9	4.4	7.8	6.5	8.6	14.6	20.7	13.1	9.1	0.9	6.3
California	35.4	4.6	4.6	1.3	10.0	11.5	4.3	9.5	7.1	2.8	4.4	4.5	2.7
Colorado	5.8	0.0	0.0	14.2	11.6	0.0	0.0	64.5	1.3	1.9	0.0	0.6	0.0
Florida	7.8	5.0	7.9	5.9	4.7	8.5	1.1	0.0	25.3	20.0	6.7	7.0	7.6
Idaho	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.6	71.4	0.0	0.0	0.0
Kansas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.1
Louisiana	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mississippi	0.9	5.2	0.0	1.8	4.0	5.3	11.5	24.6	22.9	14.0	8.2	1.5	3.5
Missouri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Montana	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nebraska	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
New Mexico	11.5	10.3	19.0	19.3	9.7	11.2	1.4	1.9	3.5	7.4	1.2	3.8	12.2
Oklahoma	0.0	0.0	0.0	0.0	40.0	40.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0
Oregon	0.0	7.4	3.0	1.2	0.0	17.3	7.2	0.0	28.9	0.0	35.1	0.0	0.1
South Dakota	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Texas	4.1	3.1	4.4	1.8	9.2	1.9	17.7	18.3	16.5	7.2	13.5	2.2	43.0
Utah	0.0	6.1	0.0	0.0	8.9	0.0	0.0	0.0	0.0	43.7	34.7	6.6	0.2
Washington	0.0	17.4	23.2	0.0	0.0	0.0	0.0	15.1	41.3	3.0	0.0	0.0	0.1
Wyoming	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	80.6	16.1	0.0
Mexico	10.7	9.6	13.9	10.8	6.8	13.7	4.0	0.0	0.0	0.0	0.2	30.3	22.2
Total**	7.6	5.8	8.2	6.4	8.0	6.9	9.9	10.5	12.5	7.5	7.7	9.0	100.0
Southeast*	5.5	4.8	4.1	4.1	5.5	6.8	5.6	11.1	24.6	16.8	7.6	3.7	19.3

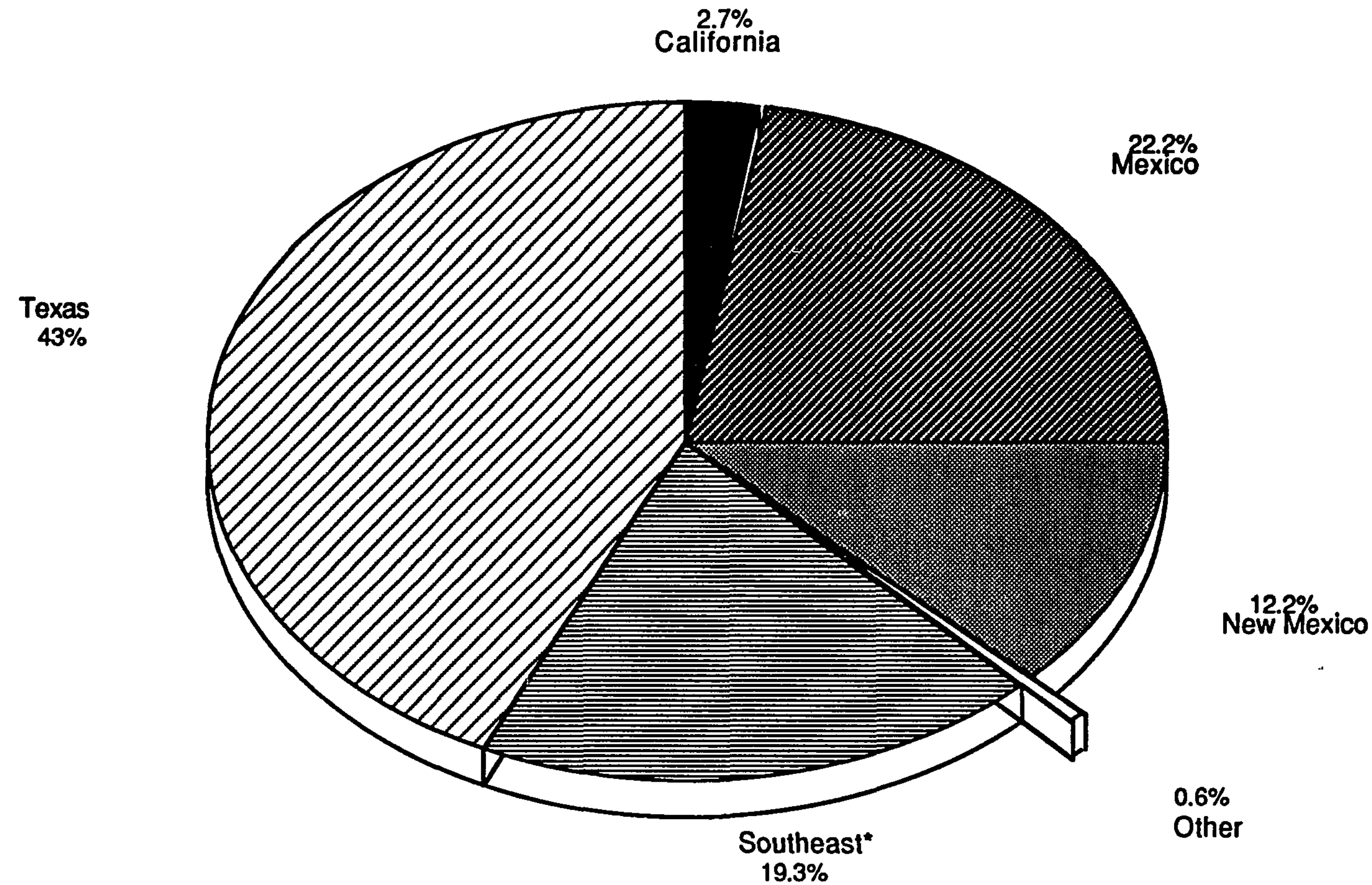
Values show the distribution of each state's total shipments to Arizona by month. Total values on the right indicate each state's percentage of total Arizona inshipments for the year. Totals at the bottom show the monthly distribution of inshipments during the year.

*Southeast includes Alabama, Arkansas, Florida, Louisiana, and Mississippi.

**Totals may not add due to rounding.

Source: Arizona State Veterinarian

Figure 2.1 Major Sources of Arizona Steer Imports in 1987, in Percentages.



*Southeast: Alabama, Arkansas, Florida, Louisiana, Mississippi

The seasonal variations in inshipments from different areas may largely reflect the availability of Mexican cattle, but may also be due to feed production, grazing seasons, or other production factors in other states. These seasonal patterns of movement suggest that pricing relationships should exist, and should also be most prominent during the periods when large cattle flows are occurring.

Outshipments

Menzie and Gum (1971) reported that for the period 1960-68, California received approximately 70% of the cattle shipped out of Arizona. It was both a major market for fat cattle out of Arizona feedlots and feeder cattle off farms and ranches. Other states receiving over 10,000 head of cattle from Arizona during this period included, in descending order, Texas, New Mexico, Colorado, Utah, and Kansas. Archer (1976) reported that about 52% of the Arizona calf crop available as stockers and feeders were shipped out of state during 1970-1975.

Since Arizona does not have any available statistics on cattle leaving the state, a brief survey of surrounding states and other states which have historically received large numbers of Arizona cattle for feeding was conducted. This provides some information on the destination of cattle shipments from the state in 1987. Data on monthly cattle shipments from Arizona were collected from six states which keep statistics on the origin of cattle inshipments. These states are Colorado, Idaho, Kansas, New Mexico, South Dakota, and Texas. Current statistics were not available from California and Utah. In the past, California has imported large numbers of cattle from Arizona; however California stopped reporting the data after 1985. In 1985, California received a total of 165,000 head of Arizona cattle, of which 59,000 head were classed as stockers and feeders, 18.2% of the 1985 calf crop before accounting for death loss, replacement heifers, or other disappearance. The remaining 106,000 head were for immediate slaughter (1985 California Livestock Statistics, 1986).

The monthly cattle import numbers provided by the six states are not necessarily separated into weights or classes. The Colorado numbers are for stocker and feeder cattle (Colorado Agricultural Statistics Service, 1989). The shipments of Arizona cattle to Idaho are primarily dairy cattle (Idaho State Veterinarian's Office, 1989). The statistics from Kansas are mostly feeder cattle (Kansas Animal Health Department, 1989). The shipments into New Mexico refer to all types of cattle with no breakdown by class (New Mexico Agricultural Statistics Service, 1989), while South Dakota reported the number of cattle shipped into the state for feeding purposes only (South Dakota Livestock Sanitary Board, 1989). The numbers of cattle shipped to Texas refer to all permits for cattle inshipments, with the exclusion of slaughter animals, and are not broken down into classes (Texas Agricultural Statistics Service, 1989). Due to the lack of uniformity in reporting methods, the data on Arizona outshipments do not present a clear picture of the number and destinations of cattle leaving Arizona for feeding elsewhere, although the data show that large shipments do occur and a general picture of the destinations of these cattle is obtained.

For the six states with data available (Table 2.5), those receiving over 10,000 head from Arizona in descending order are New Mexico, Colorado, and Texas. Shipments to Texas have fallen substantially while shipments to New Mexico have nearly doubled from their numbers in the 1960's. Shipments to Colorado grew substantially during the 1960-68 period, with the numbers for 1967 and 1968 being very similar to the 1987 numbers.

Table 2.5 Outshipments of Arizona Cattle to Selected States, 1987.

Month	Colorado	%	Idaho	%	Kansas	%	New Mexico	%	South Dakota	%	Texas	%	Total
January	282	1.0	176	4.2	1	0.0	9,909	22.1	0	0.0	4	0.0	10,372
February	166	0.6	524	12.6	84	3.2	10,522	23.5	0	0.0	1,362	13.4	12,658
March	514	1.9	519	12.5	0	0.0	1,046	2.3	0	0.0	518	5.1	2,597
April	8,668	31.6	364	8.8	337	12.7	1,271	2.8	0	0.0	706	6.9	11,346
May	7,474	27.2	515	12.4	1,459	54.9	824	1.8	661	21.6	0	0.0	10,933
June	1,947	7.1	177	4.3	0	0.0	532	1.2	2,288	74.9	452	4.4	5,396
July	1,456	5.3	314	7.6	0	0.0	241	0.5	107	3.5	120	1.2	2,238
August	1,836	6.7	646	15.5	40	1.5	436	1.0	0	0.0	19	0.2	2,977
September	1,232	4.5	363	8.7	0	0.0	5,846	13.0	0	0.0	313	3.1	7,754
October	2,639	9.6	68	1.6	550	20.7	9,359	20.9	0	0.0	3,735	36.6	7,497
November	759	2.8	415	10.0	187	7.0	2,401	5.4	0	0.0	3,735	36.6	7,497
December	463	1.7	75	1.8	0	0.0	2,412	5.4	0	0.0	2,032	19.9	4,982
Total	27,436	100	4,156	100	2,658	100	44,799	100	3,056	100	10,201	100	92,306

Sources: Colorado: Colorado Agricultural Statistics Service, 1989; Idaho: Idaho State Veterinarian's Office, 1989; Kansas: Kansas Animal Health Department, 1989; New Mexico: New Mexico Agricultural Statistics Service, 1989; South Dakota: South Dakota Livestock Sanitary Board, 1989; Texas: Texas Agricultural Statistics Service, 1989.

The three largest importers of Arizona cattle for which data are currently available show differing seasonal movement patterns. New Mexico received over 79% of its inshipments from Arizona during two-two month periods. January and February accounted for 45.6% of total movement to New Mexico in 1987 while an additional 33.9% of the total entered in September and October. Colorado received 58.8% of its total 1987 inshipments of stocker and feeder cattle from Arizona during the months of April and May. Texas received 56.5% of its cattle inshipments from Arizona in November and December of 1987. An additional peak occurred in Texas imports in February at 13.4%.

The shipments of feeder cattle from Arizona to other states follow seasonal patterns which may relate to prices or feed availability in other states or to production conditions within Arizona.

Summary

The shipments data show that large flows of cattle occur both into and out of Arizona. These flows demonstrate linkages between Arizona and other states. Arizona's large feedlot industry requires substantial feeder cattle imports to survive. The existence of the cattle flows would suggest that price relationships should exist between the states to provide an incentive for the movements. To the degree that pricing relationships increase or decrease on a seasonal basis, they will not be revealed by the model used in this study, however, movements do occur throughout the year, thus pricing relationships would be expected to exist on a year around basis, perhaps intensifying seasonally.

The analysis of market pricing structures allows for many linkages with other locations, thus it should be useful in revealing pricing patterns occurring between locations, along with patterns which would be expected to occur with Arizona as a result of the large interstate cattle flows. The following chapters will set up the theory and analyze pricing structures to determine whether price linkages exist between non-Arizona locations and/or with Arizona, along with implications about whether the feeder cattle industry is operating competitively.

CHAPTER 3

A THEORETICAL MODEL OF SPATIAL OLIGOPOLISTIC COMPETITION AND THE EMPIRICAL REFORMULATION

Economic analysis is generally carried out using the paradigm of perfect competition where market activity and firm behavior are compared to the perfectly competitive model in analyzing market efficiency. The issue of space/distance has often been treated as a consideration to be remembered but not included except perhaps peripherally in the primary analysis of the competitiveness, efficiency, and integration of markets. Other models of market structure such as monopolistic competition, oligopoly, or monopoly are used to illustrate and categorize deviations from the perfectly competitive ideal. Economists often have difficulty finding competitive, integrated markets at work in their analyses of behavior, even though a market may appear quite competitive on the surface (see Harriss, 1979, Delgado, 1986). In part as a result of this inconsistency, the role of space has received increasing attention in economic research. The perfect competition model provides insights into the way markets operate but does not adequately reflect the spatial dimension. The spatial nature of markets reduces the number of proximate buyers and sellers to levels which are more reflective of imperfectly competitive models.

Alternative market structures to the perfect competition ideal, such as monopolistic competition, oligopoly, or monopoly, all have one distinguishing characteristic in common: sellers in these markets have some market power (which may include non-price competition) which can influence price. Two conditions must exist to allow the exercise of this market power. First, there must be a basis upon which buyers can be assigned to separated markets, and second, the sellers must be able to exercise at least local monopoly power over one or more of these separated markets (Greenhut, Norman, and Hung 1987). These factors may allow, under certain demand conditions to be discussed later, price discrimination, under which prices to all buyers can be increased The manner in which buyers can be segregated into separate markets is usually some form of space, such as isolation through product differentiation, physical distance, or time, for example. Consequently, the evaluation of real world markets involves considering their spatial nature, including the ability to exercise market power through the segregation of buyers and sellers, resulting in markets which must be viewed as imperfectly competitive.

Faminow and Benson (1990) contend that oligopoly will tend to be the market structure seen, because even if there are many sellers in a geographic area, each will consider only the nearest rivals (and thus only a few firms) as its main competitors. This will be particularly likely if the product is nearly homogeneous in its characteristics except for location. Thus, spatial markets can be examined as oligopolies in which each firm sets its price based on product cost, buyer demand schedules, and the expected pricing responses, or conjectures, of proximate rivals. The firms no longer face perfectly elastic demand, characteristic of perfect competition, since the actions of the individual will have a noticeable affect on others and will result in changes in local prices and/or quantities. Although the market may include many firms, those located nearer a particular location will share more intense oligopolistic interactions while those farther away will be less responsive. Thus, distant firms will indirectly affect each other through intense competition with intermediately located firms although the intermediate firms also partially insulate the distant firms from each other.

Spatial market analysis often fails to completely capture the dampening effects of intermediate firms or locations. Spatial studies of markets involving the delineation of market boundaries (see Packers & Stockyards Administration (1982) as an example), generally utilize political divisions to demarcate markets. These markets may be further identified by a major city, a "pin point" to represent the entire market area. These boundaries may not capture the true market area. The delineated borders are generally held fixed, thus the idea of competition between market areas is assumed away at the start of the process. If boundaries are fixed,at least in the discrete form normally used, in which shifts tend to be all or nothing, market areas are independent since a price change in one area will not result in a shift of customers to the other. While the boundaries used are often intended to delineate regional or local characteristics or the general leadership of a particular market center, they are also misleading in the context of market integration. If other market areas exert influence on the delineated area, then the chosen boundaries are inappropriately held fixed when they actually may fluctuate due to the linked nature of the market areas and changing prices. Fixed boundaries impose a static system on one that is dynamic.

In addition to assuming fixed market boundaries, transport costs may be examined interregionally, between the central locations representing each market. However, their intraregional impact is assumed away. As a result, prices between central locations in each region may be expected to differ exactly by the transfer costs. This is similar to examining two distant firms while ignoring the importance of intermediate firms and their effects. While ignoring intermediate locations is often necessary due to data limitations, ignoring their importance results in different expectations for the pricing relationship displayed.

This system of discrete locations may provide a better understanding of the world as a set of islands on the sea compared to the perfect competition model in which all economic activity is treated as being located on the head of a single pin. However, changing to a model of linked oligopoly extends spatial analysis to include the importance of intermediate locations. As a result, economic activity can be viewed as occurring over a continuous, though possibly variable, space. The understanding of economic activity which follows from this may not be as neat as that of the perfect competition model, although it more accurately captures important economic relationships that occur in spatial markets.

F.O.B. Pricing

The use of the spatial oligopolistic competition model developed in Faminow and Benson (1990) provides a different understanding of market integration--or price interdependence--with implications for analyzing the performance of markets. The spatial oligopolistic competition model examined here is largely taken from Faminow and Benson (1990) with exceptions noted. In keeping with the form frequently used in the literature, the following model is presented in the context of an oligopoly (few sellers, many buyers) rather than as an oligopsony, which may be more appropriate for feeder cattle markets.[1] In addition, the model is presented in a simplified manner for purposes of clarity but can be generalized for more complex analysis. The model presented in this

[1] Referring to feeder cattle markets as oligopsonistic may generate some debate; however, in the context of space this characterization is plausible. Individual livestock sales (auctions) are often comprised of a number of producers selling to a limited number of buyers. Alternatively, when viewed interlocationally, producers often face a small number of alternative selling locations (methods). Thus, the alternative selling locations compete spatially for producer sales (and volume) with only a few rivals.

chapter begins with f.o.b. market pricing. It then expands to discuss discriminatory pricing and presents an empirical model from which data analysis can be conducted.

Three spatially separated firms (X, Y, and Z) are assumed to be located along a linear space containing evenly distributed buyers, as shown in Figure 3.1. Demand for the physical product by each buyer is represented by the general functional form

$$P = a - \frac{b}{v} q^{v} \tag{3.1}$$

where P represents the delivered price, q is the quantity demanded, a and b are positive constants, and v is a constant parameter which can be positive or negative but must be greater than negative one and not equal to zero. The delivered price, P, represents the price set by the firm plus the transport costs to deliver the product to the buyer, or

$$P=p+u \tag{3.2}$$

where p is the free on board (f.o.b.) mill price (price at the factory door) and u is the transport cost. The transport rate is assumed to be unitary (1) per unit of distance, thus u can be viewed interchangeably as the distance between the seller and buyer or as the cost of delivery from the seller to the buyer.[2] Combining (3.1) and (3.2) and rearranging gives

$$q = \left[\frac{v}{b}(a - p - u)\right]^{\frac{1}{v}} \tag{3.3}$$

This is the individual demand function faced by the firm for a buyer u units of distance away.

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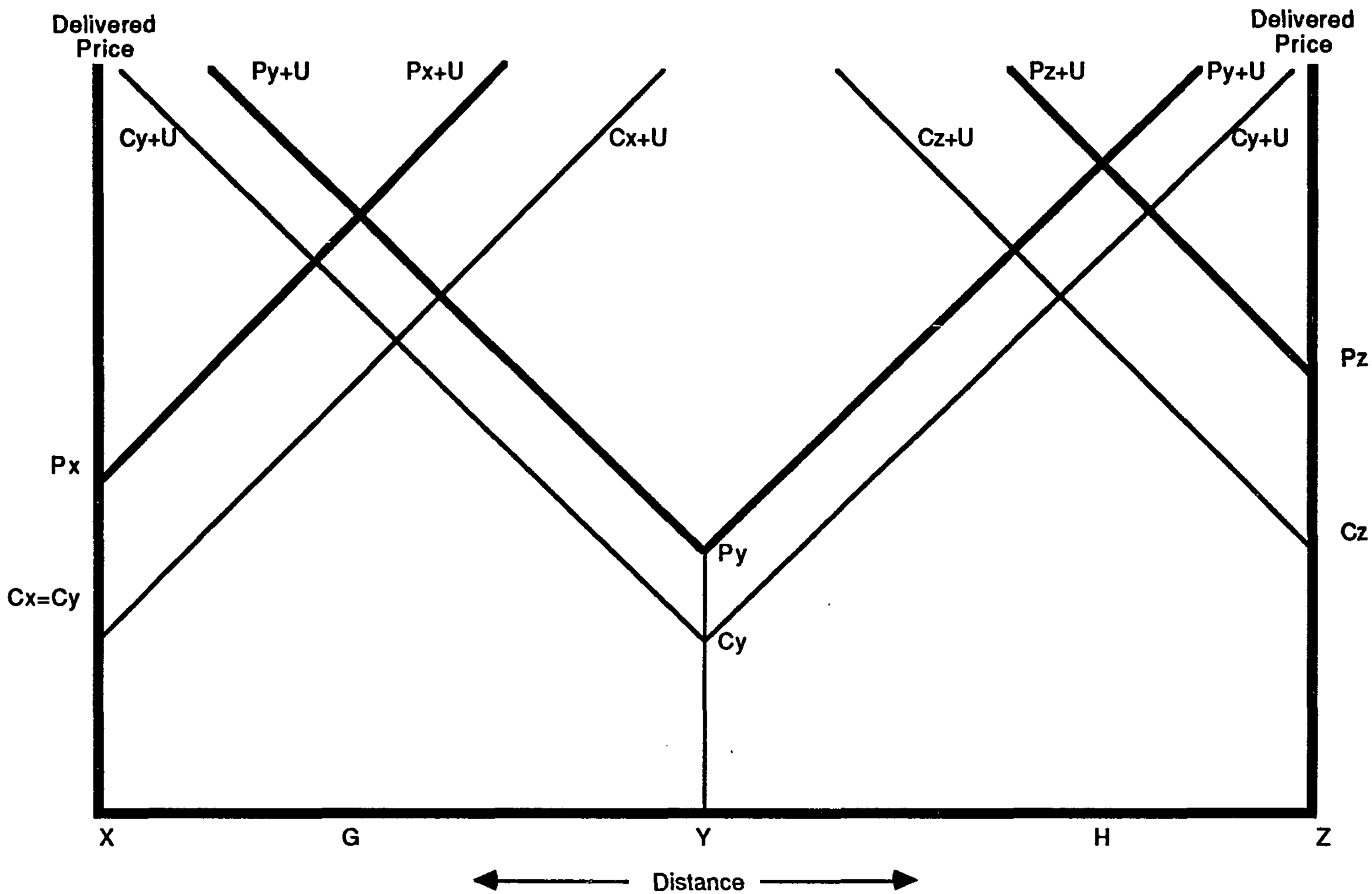
[2]A unitary transport rate simplifies the analysis. For non-unitary transport rates, the term u is rewritten as tu where t is the transport rate or transport cost equation and u is the distance. A form with tu merely changes the slope and possibly the intercept of the delivered price schedule.

Figure 3.1 F.O.B. Pricing.



Each firm is assumed to have a cost structure composed of a fixed component, F, and a constant marginal cost, c, giving a cost function of the form

(3.4) $$C_i = F_i + c_i Q_i \qquad i = X, Y, Z$$

where Q_i represents the output of firm i. The fixed and marginal cost values may differ for each firm, as is expected to be the case in practice, or the costs may be equal. Assuming that $c_X = c_Y < c_Z$, the presence of distance between the firms allows firm Z in Figure 3.1 to be the high cost producer, yet so long as his costs are not higher than the costs of his competitor(s) plus their transport costs, firm Z can still provide the commodity to some nearby buyers at a lower price than his competitors. Even with higher costs, firm Z can continue to exist and sell to a part of the market. Since each buyer is assumed to buy from the firm having the lowest delivered price, the market boundaries between firms X and Y occur at G where the delivered prices are equal, or

(3.5) $$p_x + u_x = p_y + u_y$$

Similarly, the market boundary between firms Y and Z occurs at point H, or

(3.6) $$p_y + u_y = p_z + u_z$$

as represented in Figure 3.1.

The individual demands of buyers up to each firm's market boundary are aggregated to determine the aggregate demand function faced by each firm. The profit maximizing f.o.b. mill price is determined from the aggregate demand function, resulting in an equation for each firm in which Q_i represents the aggregate quantity demanded from firm i. The equations are:

(3.7) $$Q_X = \int_0^G \left[\frac{v}{b}(a - p_X - u)\right]^{\frac{1}{v}} du = \frac{b}{v+1}\left[\frac{v}{b}(a - p_X)^{(v+1)/v} - \left(\frac{v}{b}(a - p_X - G)\right)^{(v+1)/v}\right]$$

(3.8) $$Q_Y = \int_0^{D_{XY}-G}\left[\frac{v}{b}(a - p_Y - u)\right]^{\frac{1}{v}} du + \int_0^{D_{YZ}-H}\left[\frac{v}{b}(a - p_Y - u)\right]^{\frac{1}{v}} du =$$
$$\frac{b}{v+1}\left[2\left(\frac{v}{b}(a - p_Y)\right)^{v+1/v} - \left(\frac{v}{b}(a - p_Y - D_{XY} + G)\right)^{v+1/v} - \left(\frac{v}{b}(a - p_Y - D_{YZ} + H)\right)^{v+1/v}\right]$$

(3.9) $$Q_Z = \int_0^{H}\left[\frac{v}{b}(a - p_Z - u)\right]^{\frac{1}{v}} du = \frac{b}{v+1}\left[\left(\frac{v}{b}(a - p_Z)\right)^{(v+1)/v} - \left(\frac{v}{b}(a - p_Z - H)\right)^{(v+1)/v}\right]$$

D_{XY} is the distance between X and Y, D_{YZ} is the distance between Y and Z, and G and H are the distances over which X and Z, respectively, sell.

Each firm seeks to maximize profit, defined as

(3.10) $$\pi_i = (p_i - c_i)Q_i - F_i$$

The profit maximizing point can be found by substituting (3.7), (3.8), or (3.9) into (3.10) and taking the derivative with respect to price. For X this gives

(3.11) $$\frac{d\pi_X}{dp_X} = \left[\frac{v}{b}(a - p_X)\right]^{(v+1)/v} - \left[\frac{v}{b}(a - p_X - G)\right]^{(v+1)/v}$$
$$+\frac{v+1}{b}(p_X - c_X)\left[\frac{v}{b}(a - p_X - G)^{1/v}\left(1 + \frac{dG}{dp_X}\right) - \frac{v}{b}(a - p_X)^{1/v}\right] = 0$$

The term dG/dp_X is called the boundary conjecture. It represents the change in the market boundary resulting from the change in p_X. This change has two components, the change in the boundary caused by the change in p_X and the change in the boundary caused by the price response of firm Y[3]. As a result, X must form an expectation of Y's response to a price change. For example, if X expected Y to match any price change, then the boundary would remain constant and $dG/dp_X=0$. It should be emphasized that the

[3]The boundary conjecture is the result of the conjectured price reaction of the rival firm as shown in equation 3.14. The conjectured price reaction and boundary conjecture are discussed more fully in Capozza and Van Order (1978).

conjecture is a price reaction expectation for Y, not a realization. The boundary conjecture is only one of the factors to be considered by the firm, as given below. As a result, the actual response of Y may differ from the expectation, leading X to respond to Y in an attempt to correct the mistaken expectation and maximize profits.

The boundary conjecture, (dG/dp_X), illustrates the oligopolistic nature of the market and the boundary linkages, the key factor linking the prices across the entire market, between firms. Since the boundary, (G), between firms X and Y occurs at the point where the delivered prices are equal, firm X must form some expectation of the response of Y to a change in p_X. Using (3.5), this can be seen by calculating the boundary G and taking the derivative of G with respect to the change in p_X.

(3.12) $$p_X + G = p_Y + (D_{XY} - G) \quad \text{or}$$

(3.13) $$G = \frac{1}{2}(p_Y - p_X + D_{XY})$$

(3.14) $$\frac{dG}{dp_X} = \frac{1}{2}\left(\frac{dp_Y}{dp_X} - 1\right)$$

Note that unitary transport costs are assumed, so that $G=u_X$ and $(D_{xy}-G)=u_y$ in (3.5).

In setting its price, firm X must consider the factors in its profit function, the size of the sales area (G), and the boundary conjecture of the expected response of its rivals to changes in p_X, or

(3.15) $$p_X = f\left(a, b, v, c_X, G, \frac{dG}{dp_X}\right)$$

Through G, X is linked to Y. Similarly for firms Y and Z, the boundary H is located at

(3.16) $$H = \frac{1}{2}(p_Y - p_Z + D_{YZ})$$

and the price functions for Y and Z can be written as

(3.17) $$p_Y = f\left(a, b, v, c_Y, G, H, \frac{dG}{dp_Y}, \frac{dH}{dp_Y}\right)$$

(3.18) $$p_Z = f\left(a, b, v, c_Z, H, \frac{dH}{dp_Z}\right)$$

Since three firms cover the entire market in this example, the assumption or estimation of the specific parameter values and conjectures allows solving equations (3.11), (3.13), and (3.14), and their counterparts for the other 2 firms as simultaneous equations problems for equilibrium prices, p_X, p_Y, and p_Z. Thus, as shown by equations (3.11), (3.13), (3.14), and (3.16) , the price at X is a function of the price set at Z through the transmitting linkages of G, Py, and H. Changes in price at X can be shown to be positively related to changes at Z by examining the comparative statics, as discussed in Faminow and Benson (1990), and Benson (1980).

Considering the impact of a price change at one location will show the positive relationship between changes in prices at X and Z. A price change initiated at Z, such as a decline, increases the size of H, shrinking the market and sales of firm Y. The decreased market size of Y results in an inward shift of its aggregate demand, calculated in (3.8). The lower sales volume may prompt Y to lower its price, resulting in a gain in market size as H decreases somewhat (Y regains some of the sales territory it lost to Z) and G decreases (Y captures sales territory that had been served by X). As a result, X now has a smaller market and a smaller resulting aggregate demand. The inward shift in demand may then lead X to produce a smaller quantity and lower its price. Thus the price change at Z has resulted in a price change at X even though the two firms don't directly compete with each other for their market boundary.

The price changes at X and Y do not have to equal the change initiated at Z. Firm Z has initially priced at a point where profits are maximized based on the parameters of costs, demand, and the conjecture of Y's response. Assuming an equilibrium was in existence, something must occur to generate the price change by Z. This change may be a change in conjecture or a change in cost or demand parameters. Additionally, this change may or may not directly impact firms X or Y. Thus, the price change does not have to be fully passed along by firms Y and X although Y and X will still make a response due to the price change at Z.

Price interdependence or market integration, as previously defined, combined with the discussion of spatial oligopoly given here, place all three firms (X, Y, and Z) in the same market, since the firms expect responses from the other firms to a price change and each determines its pricing in response to the others. Separate markets would exist and no integration would occur if price changes didn't move the market boundary and other firms also failed to make any response. One qualification must be added to this last statement. A market in disequilibrium may see a firm change its pricing to correct this condition without provoking a response or shift in the boundary. If the pricing move stops the change in the market boundary and restores equilibrium, other firms may not react and the boundary will be unchanged. This is the last step in reaching equilibrium, at which point, by definition, no further changes occur. This last move should not be construed as an indication of separated markets because it is the result of a movement to achieve equilibrium with the rest of the market. Finally, if price changes (responses) don't equal out over time, the distribution of shares of the overall market served by individual firms will change and over a longer period, the firm(s) losing market share will be forced to exit.[4]

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[4]The model is being discussed assuming that the market consists of three firms. This can be changed to consider a market consisting of a number of locations with several firms at each. Interlocational price integration does not necessarily imply interfirm competition, although some studies have taken evidence for interlocational integration (such as high correlation coefficients) as indicating interfirm competition. Since firm

The price response of other firms to a price change by one firm represents a simple static view of the actual process of price transmission and competition occurring. In reality, the process through which a new equilibrium occurs after one firm changes its price is likely to be a dynamic process under a competitive oligopoly. The initial price change leads to reactions and feedback as all firms (and the market) seek a new equilibrium.

Equilibrium prices need not be equal for all areas, and in fact may often differ for several reasons. In the example used, $c_X<c_Z$, however, $p_X+u_{XZ}>p_Z$. The higher costs at Z lead to the expectation that $p_X<p_Z$, yet the transport costs prevent firm X from selling within firm Z's market area. The rules of arbitrage do not guarantee net price uniformity, just that arbitrageurs will take advantage of price spreads greater than transport costs, forcing prices back in line in the two locations.

Occasional price differences greater than transport costs are not ruled out. Arbitrage will not occur until the arbitrageur expects to profit from the transfer. In a market in which the commodity cannot be priced until it is delivered and prices can change more frequently than the time needed for transport, excessive price differences must be great enough or frequent enough for the arbitrageur to expect to profit from the transfer before the commodity deteriorates and depreciates in value or storage costs exceed the expected profit.[5] Price uniformity across locations is not required for

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level data is often lacking but is required to examine interfirm competition, market level data should be analyzed differently, as this theoretical model attempts to do.

[5]This discussion assumes the arbitrageur will resell the commodity at the destination market price. Alternatively, an arbitrageur may intend to use the product in a manufacturing process, thus the contemporaneous price difference may be the relevant consideration. For an example in the cattle industry, a cattle feeder may engage in arbitrage based on contemporaneous prices since purchases are being made to fill feedlot needs at a particular time. Thus the expectation of profiting from the arbitrage activity depends on the contemporaneous price difference and the price expectation for the

equilibrium. The only requirement limiting price differences is that arbitrageurs must have no expectation of profit from arbitrage activities. In an interdependent market, prices net of transfer costs can differ for many reasons.[6]

Finally, the magnitude of a competing firm's price response may differ from that of the firm initiating the price change and/or the responses of other firms. For example, after Z initiates a price change (assume a decrease), Y may respond to recapture lost market area.[7] However, the change Y makes to regain a profit maximizing position must take into account the impact on the boundary with X and the expected response of X to such a change. As a result, the response of Y may differ from the action taken by Z, leading to a response from X which also differs. In a competitive market in which a dynamic process of action-reaction occurs as firms seek a new equilibrium, the magnitude of price responses can be expected to differ. The initial pricing responses of proximate firms will be more similar in magnitude than those of more distant firms. However, the differing price responses which occur will result in changes in firms' overall market share. The search for a new equilibrium will force an eventual equality in price changes upon the market or else exit from the industry will occur.

Spatial Price Discrimination

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finished manufactured product (slaughter cattle) at a future date rather than a short-term resale of the same feeder cattle at the destination.

[6]Note that while the commodity is assumed homogeneous except for its location, the costs of the firms are allowed to differ. Additionally, other factors may affect the firm, such as capacity, financial, or managerial constraints or advantages. Firms are not assumed to be homogeneous, just the commodity they sell.

[7]Firms may be more concerned with sales volume than sales area; however, under the assumptions of demand density, sales volume and market area are directly related and may be considered interchangeable for the purpose of conceptualizing the theory being presented.

Under the model of spatial markets with f.o.b. pricing presented, the firm faces competition only at the market boundary, although since pricing is f.o.b., the firm cannot segregate buyers by location. If the firm is able to segregate each location, it can set a profit maximizing price at each location unless restrained in some manner. Restraints could include legal/institutional restraints, the potential for arbitrage between locations, or the presence of a competitor in an area. The character of the demand function determines whether price discrimination is possible (assuming that none of the other constraints mentioned exist). In particular, the value of v in the demand equation (3.1) determines this possibility.

If buyers can be segregated by location, then f.o.b. pricing is no longer necessary. For example, the firm X sets its pricing by equating marginal revenue and marginal cost, deriving its marginal revenue curve from the demand curve it faces,

(3.19)
$$p_X\left(1+\left(\frac{1}{e}\right)\right)=c_X$$

where p_X is the price at X and e is the own price elasticity of demand. The formula for e is derived from equation (3.1), giving

(3.20)
$$e=\frac{p_X}{v(p_X - a)}$$

Substituting (3.20) into (3.19) provides the formula for equating marginal revenue and marginal cost. To this, transport costs (u) are included and the problem is solved for P, giving the discriminatory delivered pricing schedule for the firm.

(3.21)
$$P_x=\frac{(va+c_X)}{(1+v)}+\frac{1}{(1+v)}u$$

The first term on the right hand side is the price of the product at point X (the mill door). The second term reflects the delivery charge, with 1/(1+v) being the slope of the delivered price schedule.

Comparing this slope with the slope (u) which the transport rate generates in the nondiscriminatory model shows whether and what type of discrimination can occur. A slope that is less than u (v>0) indicates freight absorption is possible. Nearby buyers may be charged a higher transport rate than more distant buyers, assuming a fixed f.o.b. mill price to all buyers. Under freight absorption, arbitrage is not profitable. The firm will have a higher price at X and a flatter delivered price schedule compared to the f.o.b. pricing system. Thus, unless constraints exist to prevent it (legal constraints or buyers who provide their own transportation) a value of v greater than zero results in freight absorption. The same occurs for firms Y and Z as for X.

A slope that is steeper than than u (v<0) indicates that phantom freight, the opposite of freight absorption, may be occurring. Distant buyers can be discriminated against in favor of those nearby. Unless there are constraints present to prevent arbitrage, arbitrage will be profitable with phantom freight and the firm will be forced into f.o.b. pricing and the ability to segregate buyers by location does not allow the the firm to discriminate.

Under a price discrimination scheme, firms compete only at their market boundaries for sales with no need to adjust prices outside the market boundary. As a result, the price linkage between firms may be broken and the price interdependence seen under f.o.b. pricing may no longer exist, except at the market boundary where the firms are competing. A discriminatory scheme may also allow competitors to invade another's territory, generating considerable overlap (Greenhut and Greenhut, 1975). Such a departure from market integration requires constant marginal costs, since demand schedules are viewed separately at each location. Pricing is calculated to be profit maximizing for sales at each location, so an expansion or contraction of the boundary simply adds or subtracts demand schedules at the boundary, but has no effect on the schedules within the boundary.

Contrary to the constant marginal cost situation, if marginal costs are increasing with output, then the firm cannot price discriminate by equating marginal revenue to marginal cost plus transfer costs at each location. Rather, the firm must equate marginal revenue to the marginal cost of the last unit of total sales over the entire market area served by the firm (Greenhut, Norman, and Hung, 1987). Price discrimination and freight absorption can still occur, however, by using the total demand rather than the demand at each location as the basis for calculating the discriminatory schedule. Price interdependence is restored with upward sloping marginal costs because shifts in the boundary affect the firm's total quantity of sales, changing the marginal cost and resulting in a price adjustment at all locations served by the firm. The expectation of price actions, reactions, and a feedback process showing price interdependence is then expected to occur under f.o.b. pricing or under discriminatory pricing (freight absorption) with upsloping marginal costs.

Basing-Point Pricing

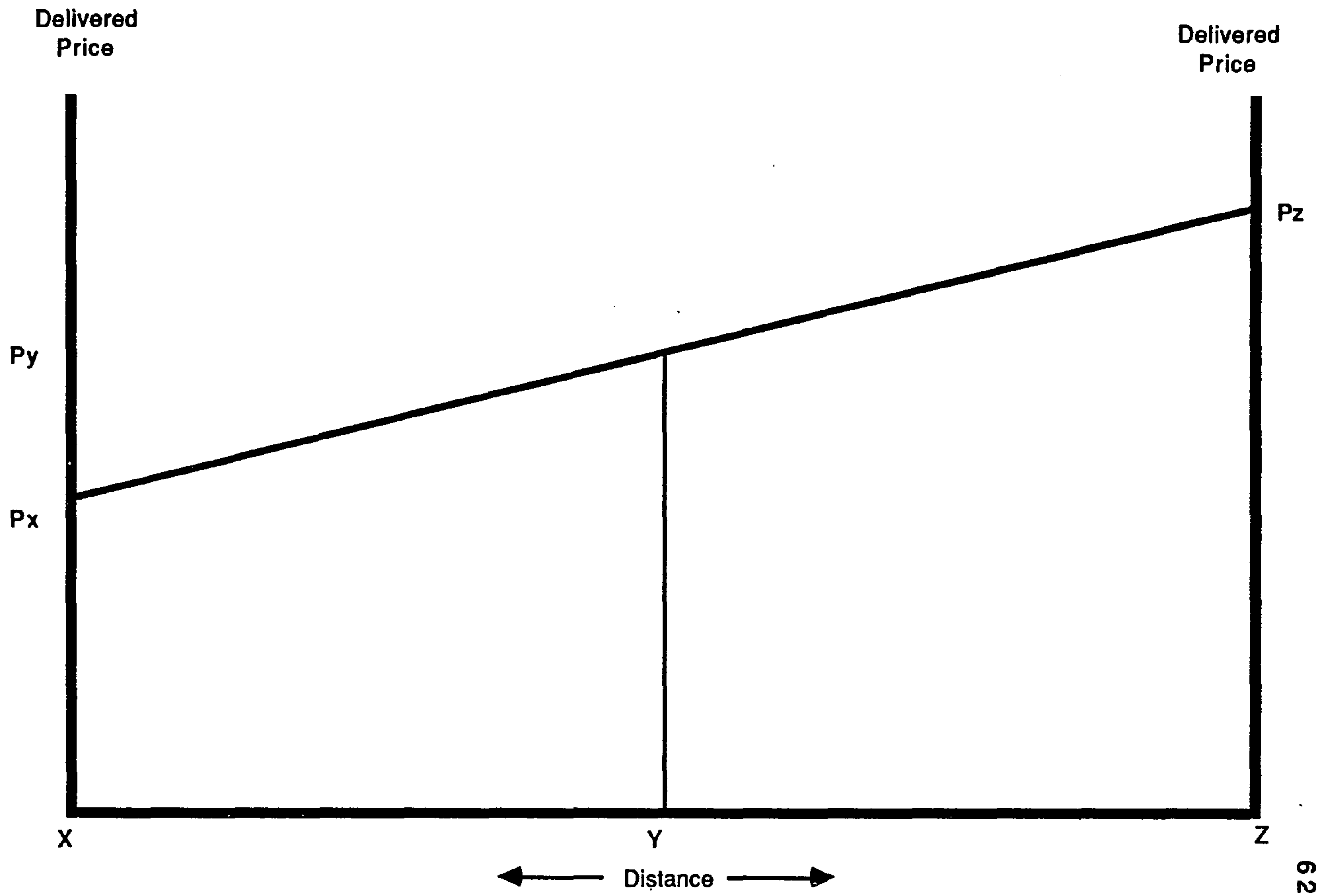
The model of spatial oligopolistic competition leads to the expectation that prices will vary over space and adjustments will be characterized by an action-reaction-feedback process. As previously mentioned, many market integration studies look for price differences equal to transport costs and instantaneous adjustments in prices, often called a basing-point system, in their pricing analysis as evidence of an efficient and competitive market. With a spatial oligopolistic competition model, basing-point pricing often appears as the result of a collusive system.

Figure 3.2 displays an example of a basing-point system with the base-point located at X. Price is set at X, then increased by transport costs at locations away from X as shown. Other firms, assumed to be located at Y and Z, follow the basing-point system rather than setting individual prices.

No indication is given that costs of production rise at exactly the same rate as transfer costs to cause firms Y and Z to select prices that imitate basing-point pricing when it is not occurring. With Y and Z located away from the base-point, any sales made towards the base-point (to the left) require heavy freight absorption while sales to the right merely recover the cost of freight. Thus if the costs of Y and Z force an f.o.b. price equal to the base-point price plus transfer costs, these firms lose money on any sales to the left of their location. The only customers they would want to serve would lie to the right, and they would still have to share their sales with the firm(s) located to the left. The site selection of Y and Z serves a smaller market to the right while sharing sales with every other firm. If Y and Z located at the same point as X, since they do not compete on price for market area, they would be able to share sales over the entire market rather than a segment of it.

If the costs of Y and Z do not force pricing up to the level of p_x+u, (where u is the distance from X to Y or Z), then the firms are setting collusive prices, absorbing freight on sales to the left and paying for the absorption with the profits from the excessive price charged at p_x+u. At the same time, all firms are sharing sales with each other. If Y or Z were to lower its price as in Figure 3.1, it could capture all of the market to its right and some of the market to the left. If unchecked, the cartel would fail, resulting in the competitive oligopoly result previously described.

Figure 3.2 Basing-point Pricing.



The simplicity of pricing in the basing-point system lends itself to easy monitoring by cartel members. Price changes can be expected to occur seemingly instantaneously throughout the market. Failure to adjust immediately would imply that some firms are taking the opportunity to reap windfall sales at the expense of other firms in the cartel, at least until they are forced back into line with the basing-point system or the cartel adjusts its pricing to the level of the cheating firm. Otherwise the cartel would break down.

In the basing-point example, the entire market is integrated since price changes are passed through to all areas. However, under this system, firms no longer compete in price, leaving buyers indifferent as to who they buy from, prompting firms to compete for sales in non-price ways and leading to the potential for significant amounts of cross hauling. Under a cartel-generated basing-point pricing system, markets are integrated, however price competition no longer exists, price changes occur instantaneously throughout the market, and prices differ exactly by transport costs to allow firms to share sales at all points in the market.

Empirical Reformulation and Testing

The theoretical model developed presents a view of spatial markets in which a competitive system is defined by price interlinkages or interdependencies rather than by integration as found with the basing-point system often used. The techniques of examining price correlations, price differences relative to transfer costs, and seasonal fluctuations as described in Chapter 1 all involve searching for basing-point pricing, which is taken to indicate a competitive market where arbitrage immediately forces price differences to no more than transfer costs. This result implies that extensive trade must exist between locations within the market and often calls for the determination of a central or base market.

The basing-point system implies that markets are divided into separate areas of production and consumption, or a system of discrete islands upon an ocean in which commodities produced on one island must be transported to another for sale. A mix of production and consumption between named locations may occur, however, for basing-point pricing to also occur, one area must produce a surplus which is then sent to other locations where production is insufficient to meet local demand and local firms have not expanded to serve the excess. The frequent failure to find strong indications of basing-point pricing, a highly attractive form of pricing under a cartel arrangement, would indicate that basing-point pricing fails to dominate markets. However, when basing-point pricing is not found (viewed as an efficient and competitive operation), the markets are classified as inefficient. Whether monopolistic arrangements exist is not verified by examining the efficiency of price transmission between locations. The model of spatial oligopoly attempts to provide a superior explanation for the pricing patterns observed when basing-point pricing is not found. In an interdependent market, net price equality need not occur under competition, although it remains a possibility.

The examination of the price adjustment process can be conducted empirically using the model of Ravallion (1986) as extended by Faminow and Benson (1990). This model uses the Ravallion analysis of integration within the framework of a primary central market interlinked with surrounding, smaller rural markets. The model is modified in such a way that a central price forming and rural price adopting structure (essentially basing-point pricing) is no longer implied. Instead, different spatial pricing systems are tested individually between all market locations in a pairwise fashion. No claims about the efficiency of the market are drawn directly from these tests. The empirical model developed here is characterized by many sellers and few buyers, which reflects the nature of the cattle markets studied in the empirical application of the model which follows this chapter.

The analysis involves a general model from which restrictions allow the testing of nested hypotheses regarding the type of price relationship existing between two market locations. The model

$$P_{y,t} = \sum_{j=1}^{n} a_j P_{y,t-j} + \sum_{k=0}^{m} b_k P_{x,t-k} + c_y I_{y,t} + e_t \tag{3.22}$$

uses $P_{x,t}$ as the independent variable (the price at X) and $P_{y,t}$ as the dependent variable (the price at Y) in time t. The $I_{y,t}$ term represents non-price influences such as volume, quality, or other factors. The a_j, b_k, and c_y are parameters to be estimated, while e_t is a white noise error term.

This model, as described in Ravallion, allows testing for different forms of integration as listed below.

(A) Independence: $b_k=0$, $k=0,\ldots,m$

(B) Long-run integration: $\sum_{j=1}^{n} a_j + \sum_{k=0}^{m} b_k = 1$

(C) Short-run integration (weak form): $b_0 = 1$, $\sum_{j=1}^{n} a_j + \sum_{k=1}^{m} b_k = 0$

(D) Short-run integration (strong form): $b_0=1$, $a_j=b_k=0$, $j=1\ldots n$, $k=1\ldots m$

The price interrelationships of the market locations can be examined by estimating the model for all bivariate combinations. To the degree that all market locations under study are interlinked, this model will leave out these linkages with the additional locations, leading to some specification bias. However, in the event that linkages do exist, the correlations in the data between the locations may result in multicolinearity among the parameters and problems with hypothesis testing. In the event of market independence, the model is correctly specified, while in the event that linkages do exist, the exogenous market in the bivariate pair serves as a proxy for the other omitted locations. Future efforts to expand the model could improve the results by directly measuring the simultaneous impacts (if any) of the other market locations which may be relevant. Additionally, retaining the bivariate structure of the model allows examining, to some degree, the relative strength of the price linkages as the distance between market locations differs by comparing the coefficients of determination from each pair.

Testing the independence hypothesis (A) involves examining whether all contemporaneous and lagged effects of the market location used as the independent variable in the equation are zero (b_k=0 for all k). If all b_k are zero, then the price formation process in market Y is termed independent of the market location X. Under a spatial distribution of buyers and sellers, this result is predicted only in a situation in which the market is characterized by price discrimination and constant marginal costs. Other explanations for such a result would involve truly separate markets created by legal or physical barriers difficult to evade or by prohibitively high transfer costs.

The second hypothesis is long-run integration, (B). It is not quite long-run in the sense usually used in economics, however it does cover a relatively long time period in a dynamic market. The long-run test requires that the effects of all contemporaneous and lagged variables ($\Sigma a_j + \Sigma b_k = 1$, j=1...n, k=0...m) add up to one. This says that price changes in one location add up to equal the price changes in another market reflecting a dynamic process over time. This is the result expected from a competitive spatial oligopoly in which prices in different locations adjust through an action-reaction-feedback process.

Under the weak form of short-run integration, (C), instantaneous adjustment is expected however some feedback is also allowed as long as the lagged effects cancel each other out ($b_0=1$, $\Sigma a_j+\Sigma b_k=0$, $j=1...n$, $k=1..m$). This would be consistent with an imperfect collusive arrangement in which some time is required to assure that all firms adopt the change in prices and the new price equilibrium is found. This result can occur for different reasons. Firms may tacitly collude, requiring a short interval for all to discover and adjust to the new price level. Alternatively, a collusive arrangement may only cover part of the entire market. Thus a price change by a firm within the collusive arrangement results in an immediate cartel adjustment while firms outside the cartel institute competitive price reactions, resulting in a feedback relationship until the cartel comes to an equilibrium with the non-collusive firms. This will result in some bivariate tests showing the weak form while others won't, pinpointing which market locations are most likely to be connected by collusive relationships and which aren't. Alternatively, this result may also occur if a feedback process of adjustment is nearly completed within the time period of each observation.

The strong form of short-run integration (D) identifies instantaneous price matching with no lagged effects ($b_0=1$, $a_j=b_k=0$ for $j=1...n$, $k=1...m$). With spatially distributed buyers and sellers, this result is consistent with basing-point pricing when prices differ by transport costs. Pricing is set for the base-point, resulting in prices to buyers at other locations which bear no reflection on localized demand or supply conditions. Alternatively, if data availability limits the test series to aggregated data, an interactive price adjustment process, consistent with a competitive oligopoly, may complete its adjustment within the aggregated time period. Modern communications can encourage such a result due to the fast, inexpensive dissemination of information. However, if this null hypothesis is not rejected, then the question of basing-point pricing versus a rapidly adjusting process can be partially determined through examining the transport differential. Price differences under a basing-point system are expected to differ by transport costs while they may not display this same difference under a process of rapid adjustment which is smoothed over by the aggregation process.

Can a system be non-collusive yet still be basing-point with price differences equal to transport costs? Consider an argument for a case having a strong one way local-to-central relationship. A small local market may be unable to efficiently price the commodity due to low volume[8] . This may be coupled with the potential for greater variability in quality such as may occur in a local market served by many sellers, each having only a small volume, with the result that pricing may become more efficiently determined if based on a larger central market. Additionally, it may be argued that under such low volume conditions, pricing in the small market location may become heavily influenced by arbitrageurs who seek to aggregate small lots for transport to the central area for final disposition.

This argument sounds plausible yet it does not fully include the spatial nature of the market. It is being argued that pricing at one location is being determined by arbitrage between locations; however, the arbitrageur is first a businessman and second an arbitrageur. The market being examined is spatial and continuous, rather than a

[8]Tomek (1980) investigated the effects of low or falling market volume on the efficiency of the price determination process. The study was conducted using data from the Denver terminal market during a period of declining cattle sales volume until it closed. His results found that as the volume declined, the variation in prices increased, suggesting that pricing became less precise as a result of the small volume.

discrete system of islands. The arbitrageur operates in the localized market, susceptible to the local conditions of supply and demand, as well as open to any opportunity which arises intraregionally and away from the central market location. The central market may provide a pricing base, interpreted as a starting point for price determination rather than a quoted price with transport cost adjustment. Thus a complete price matching relationship would still appear to be an unusual exception without the presence of a collusive basing-point system.

Empirical studies using different techniques, including price correlations, price differentials relative to transport costs, and Granger causality studies, generally seek the strong form of short-run integration, (D), as indicative of a competitive integrated market based on the efficient markets hypothesis of Fama (1970).

Fama proposed measuring the efficiency of stock prices by how well they anticipated and reflected market information proxied in different ways. The efficient market theory has been applied to studies of spatial markets under the interpretation that prices will instantaneously adjust if they are efficient. The relative levels of price efficiency proposed by Fama have been applied in Granger causality models as indicating the relative levels of market efficiency, as in Adamowicz, Baah, and Hawkins (1984) and Bailey and Brorsen (1985). The models of these studies, although different from the one used here, provide examples of cases in which basing point pricing has been sought as representing an efficient, competitive market.

The spatial nature of most markets introduces factors which may hinder the speed of adjustment. However, analyzing the speed and degree of price adjustment in a spatial market may reveal more about the pricing structure of the market than about the speed with which resources are efficiently reallocated.

Instantaneous price adjustment is more indicative of a basing-point pricing system than of a competitive and efficient market provided that factors affecting the potential speed of adjustment are considered in defining the length of time over which an observation occurs. This conclusion follows from the inclusion of spatial factors. Intraregional transport costs are real and intraregional trade exists. An efficient, competitive system will adjust rapidly, however the adjustment must occur throughout the market and regions within the market, not just between named sets of pins representing the market. Not only must firms within an area seek an equilibrium under constantly changing conditions, but they must also seek equilibrium with bordering firms. The dynamic process of price formation results in a lag while firms seek to discover an equilibrium both within a region and between regions. Instantaneous adjustment can only be explained if no dynamic feedback process is occurring, such as under a collusive system.

These two forms of short-run integration identify the pricing behavior occurring in the market if it is collusive. Instantaneous adjustment results from a collusive arrangement throughout the market while instantaneous adjustment with vanishing feedback results from an incomplete basing-point system. In both cases, determination of the collusive nature of the system requires the additional criterion of Takayama and Judge (1971) that prices are equal over time after adjusting for transport costs.

The short run tests are restricted forms of the long-run test. Failure to reject the short-run tests implies that a similar failure to reject will result for the long-run test (Ravallion, 1986) since the short run models are simply more restricted forms of the long-run test. Failure to reject the long-run test does not imply that the same will occur for the short-run tests. In the case that the long-run test is not rejected and the short ones are, the evidence would suggest that no collusive, basing-point system is in existence. This result would occur from a competitive f.o.b. oligopoly with price matching over the adjustment period and possibly for the increasing marginal cost model with price discrimination (Faminow and Benson, 1990).

It is possible to reject all four hypotheses presented in the model, however such a result should not be too disturbing, considering (3.22). Equation (3.22) includes a variable for the consideration of local influences such as quantity or quality variables or other influences which may change the structure of the market. The derivation of the long-run integration hypothesis in Ravallion (1986) involves differentiating (3.22) with respect to prices under long run equilibrium conditions. The effects of local influences ($c_y l_{y,t}$) drop out of the solution as a result. Thus, localized effects may be influencing local prices sufficiently to result in rejecting (B). The local influences may not be common to other parts of the market, so that while prices are not independent, they are influenced by the local forces sufficiently to result in rejecting the long-run integration hypothesis (long-run price matching), at least over the relatively short period of time defined as the long-run in the model. In addition, a rejection of all four hypotheses is unlikely if the market is in a long-run (in the economic sense) equilibrium. The result may be more common in a market in disequilibrium since partial price adjustment then results in economic incentives for the reallocation of resources over a period allowing for biological lags and the consumption (depreciation) of fixed resources or their conversion to other uses.

The model of competitive spatial oligopoly presented here provides a view of a dynamic market in which price changes are passed through the market by profit maximizing oligopolistic firms. This results in price adjustments as the firms jockey for market territory and react to incursions by their competitors. An important part of this model is the realization that markets cannot be broken into regions with a central location to designate each region. Intraregional transport costs are important, resulting in markets which do not have net price equality after allowing for transport costs.

Analysis of the model implies that, since net price equality is not necessary, prices will come to an equilibrium reflecting prices in other locations over time. This result falls contrary to the expectations expressed in some studies which implicitly seek a basing-point, collusive price structure as evidence of an integrated, competitive market. The tests derived from the model provide a means to examine the pricing reactions present between locations, providing a set of nested hypotheses to distinguish between the types of pricing behavior. In addition, while this model can identify types of pricing systems, a definitive statement about the conduct of the market still requires analysis of other factors impacting the character of the spatial market.

CHAPTER 4

DATA AND METHODOLOGY

This chapter outlines the sources and methods used to collect price data from eight locations around the United States and two local livestock auctions in Arizona. Following the descriptions of the data sources, the methods and issues surrounding the data adjustment process and estimation of the empirical model are reported.

Data Collection

Weekly average 600-700 lb. feeder steer prices were obtained from the Western Livestock Marketing Information Project (WLMIP) for eight locations in the United States. The data covered the period from January 2, 1983 to December 31, 1988. The locations used are Amarillo, Texas; Clovis, New Mexico; Colorado; Florida; Kansas City, Missouri; Oklahoma City, Oklahoma; Shasta, California; and Stockton, California. The prices represent weekly price averages from auction market and other quoted sales for the named location.

The annual feeder cattle volumes of all locations are reported in Table 4.1. The volume figures, except for Phoenix and Tucson are for all feeder cattle rather than just steers in the 600-700 lb. weight class. More specific data for the individual sex and weight classes were unavailable. The Phoenix and Tucson volume data are for 600-700 lb. steers only.

Amarillo has a large volume, ranking fourth over the 1983-1988 period. Volume declined substantially after 1985. Clovis is a smaller volume location near Amarillo, possibly representing a local-central market relationship.

Table 4.1 Annual Feeder Cattle Volumes Over the Period 1983-1988 by Location.

Location	1983	1984	1985	1986	1987	1988	Average
Amarillo	292,556	303,183	381,027	196,351	145,087	160,246	246,408
Clovis	19,599	29,869	37,844	46,280	42,559	51,970	38,020
Colorado	547,000	580,000	554,000	554,000	526,000	599,000	560,000
Florida	519,114	544,312	546,820	549,620	591,846	533,510	547,537
Kansas City	191,924	191,985	141,512	144,209	113,507	85,378	144,752
Oklahoma City	852,840	917,700	752,900	807,000	651,780	606,660	764,813
Shasta	103,080	113,514	122,878	105,012	113,654	104,791	110,488
Stockton	58,250	66,600	67,500	61,800	69,600	76,750	66,750
Phoenix	--	--	--	--	1,234	869	1,052
Tucson	--	--	--	--	880	737	808

Source: USDA Agricultural Marketing Service, 1990.

Clovis volume, the smallest of the eight WLMIP locations, showed a steady increase over the 1983-1988 period, nearly tripling over that time. The second highest volume occurred with Colorado, a high volume cattle feeding state. The Colorado data, however, are from a wide variety of sources since no single large auction is present in the state. Florida is similar to Colorado. The Florida volume is high, although it is generated through a number of smaller auctions and other quoted sources. Florida also ships large numbers of cattle to other states for feeding, ranking as the fourth largest source of feeder cattle imports into Arizona in 1987 (see chapter 2) and lies a considerable distance from most of the other locations. Kansas City was fifth in volume over the period, but showed a generally declining trend, with volume falling below Shasta in 1987 and 1988. Oklahoma City had the highest volume throughout the period and was a par delivery point until September, 1986 under the physical delivery system of settlement for feeder cattle futures contracts. The two California locations are closely located in the central California region but are distant from other locations. Volume at Shasta was fairly stable to somewhat higher during the 1983-1988 period. Stockton showed increasing volume, although it remained substantially below Shasta.

Amarillo, Kansas City, and Oklahoma City prices are widely reported by the news media, and together with Colorado (Greeley), served as delivery points under the physical delivery system of feeder cattle futures contract settlement until September, 1986. Plots of the data over the six year period, 1983-1988, are presented in Figures 4.1 to 4.8.

Figure 4.1 Weekly Average Steer Prices for Amarillo, 1983-1988.

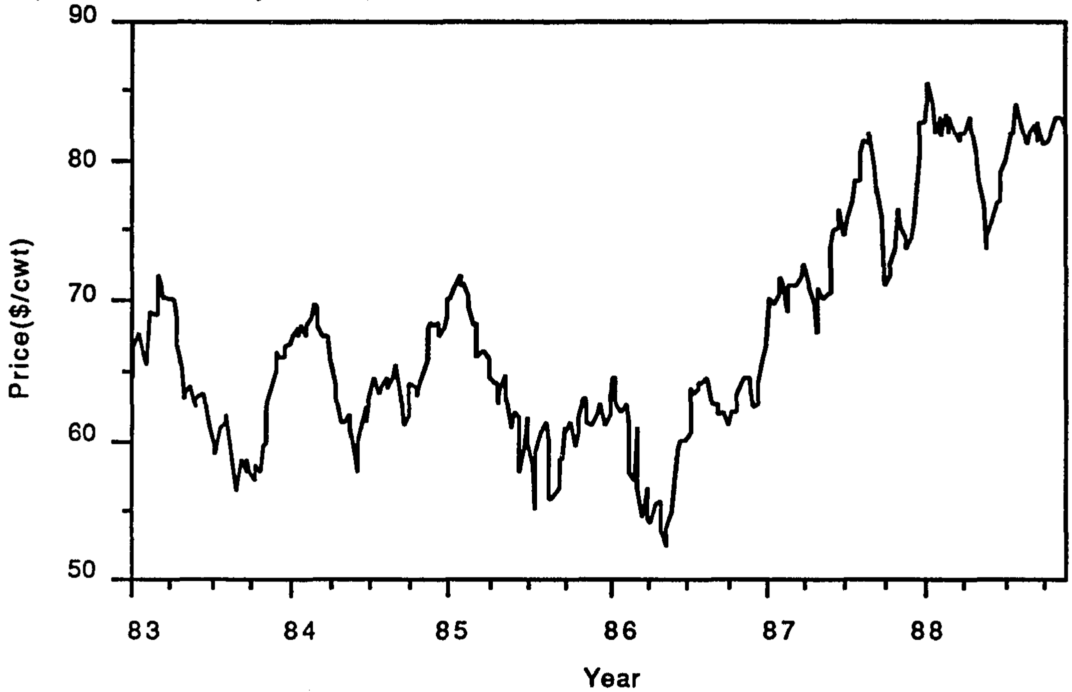


Figure 4.2 Weekly Average Steer Prices for Clovis, 1983-1988.

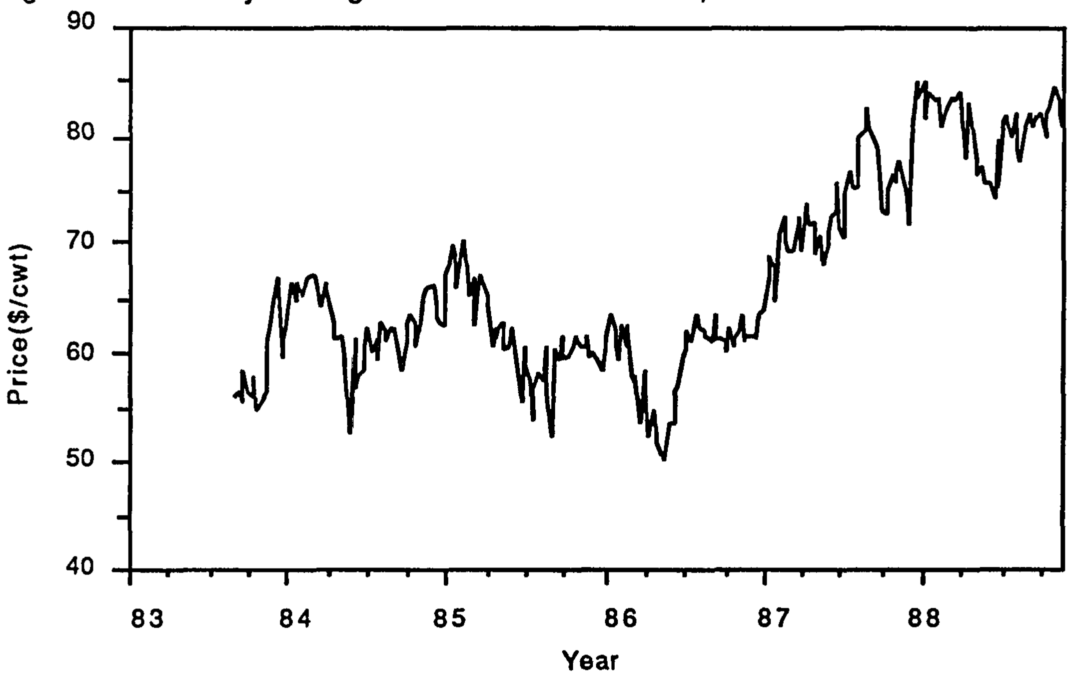


Figure 4.3 Weekly Average Steer Prices for Colorado, 1983-1988.

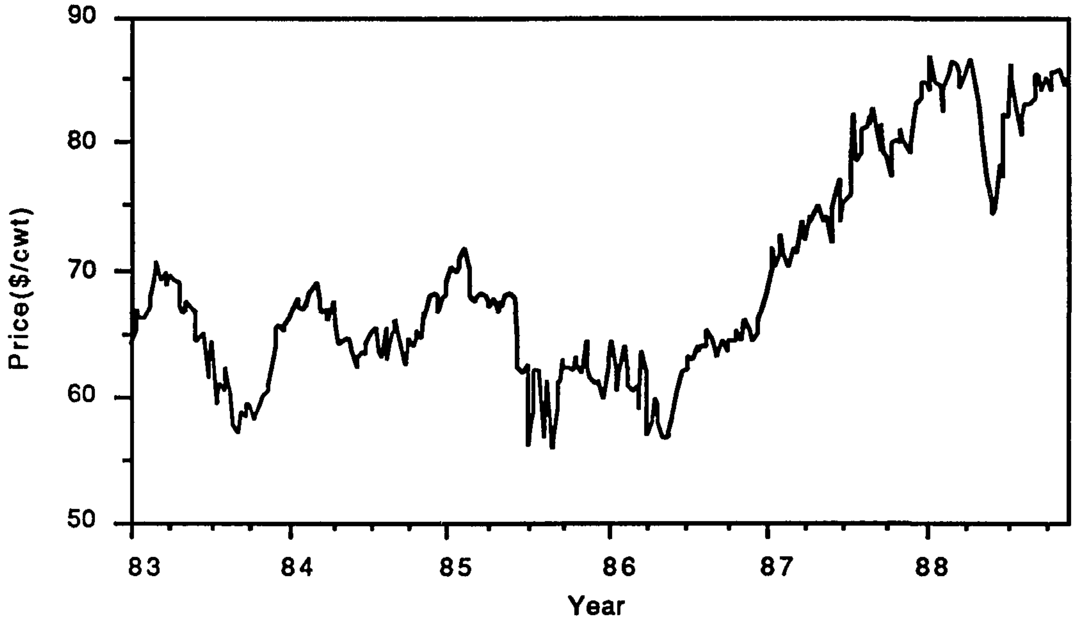


Figure 4.4 Weekly Average Steer Prices for Florida, 1983-1988.

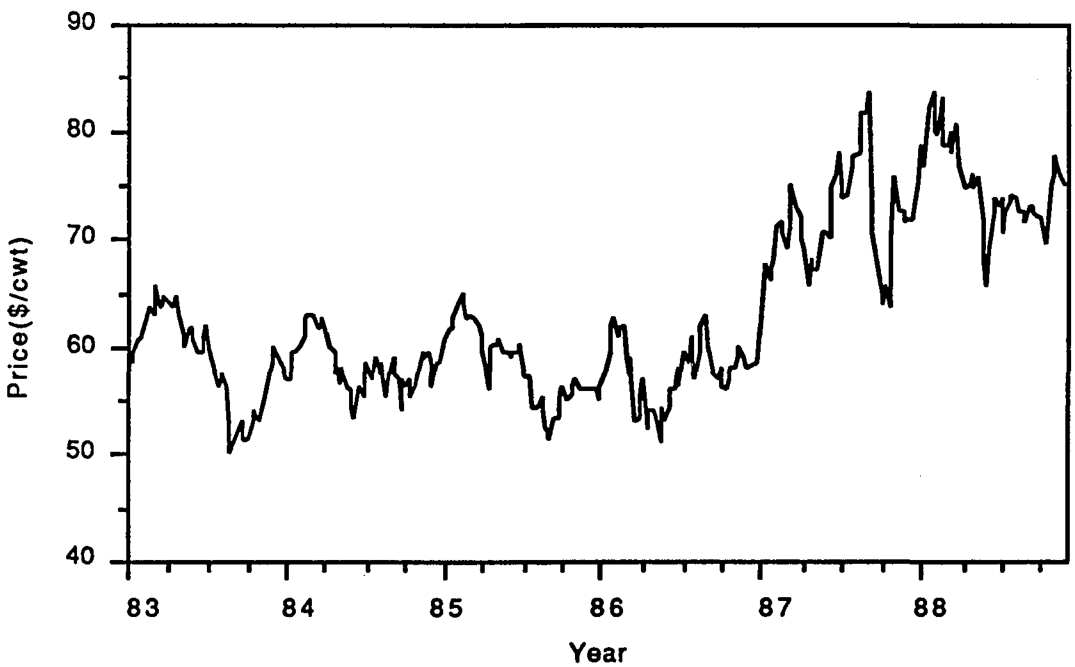


Figure 4.5 Weekly Average Steer Prices for Kansas City, 1983-1988.

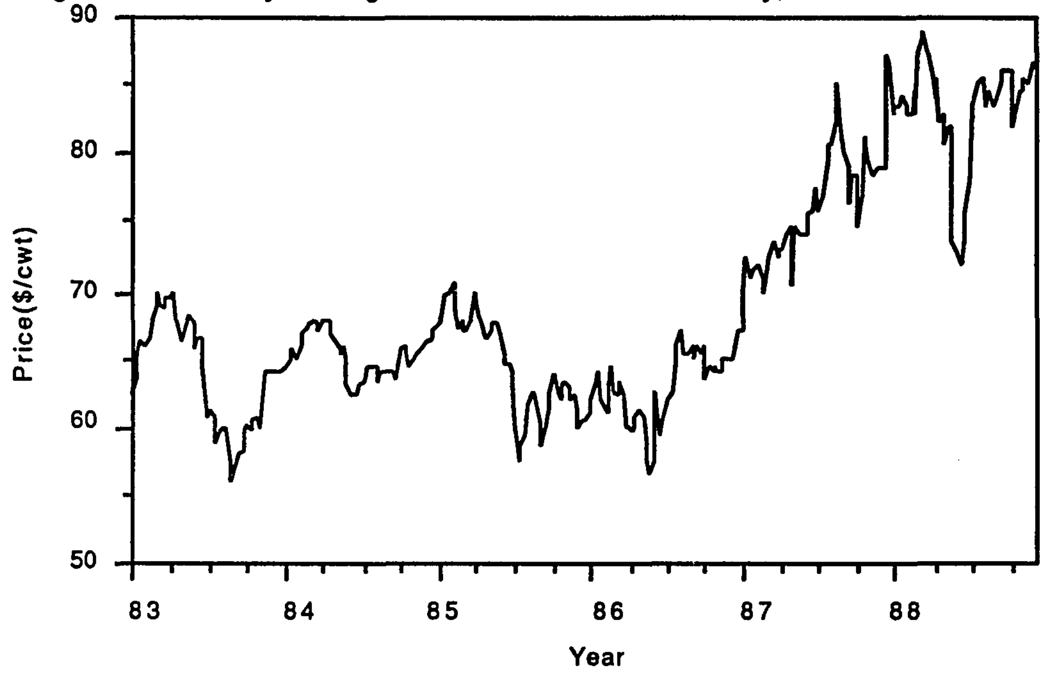


Figure 4.6 Weekly Average Steer Prices for Oklahoma City, 1983-1988.

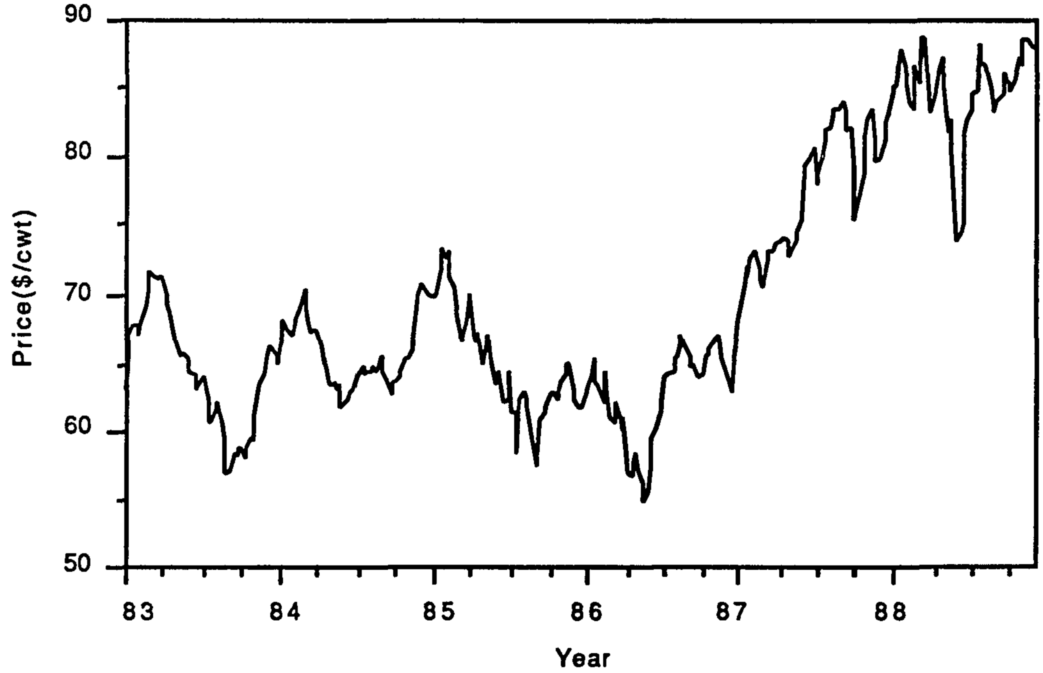


Figure 4.7 Weekly Average Steer Prices for Shasta, 1983-1988.

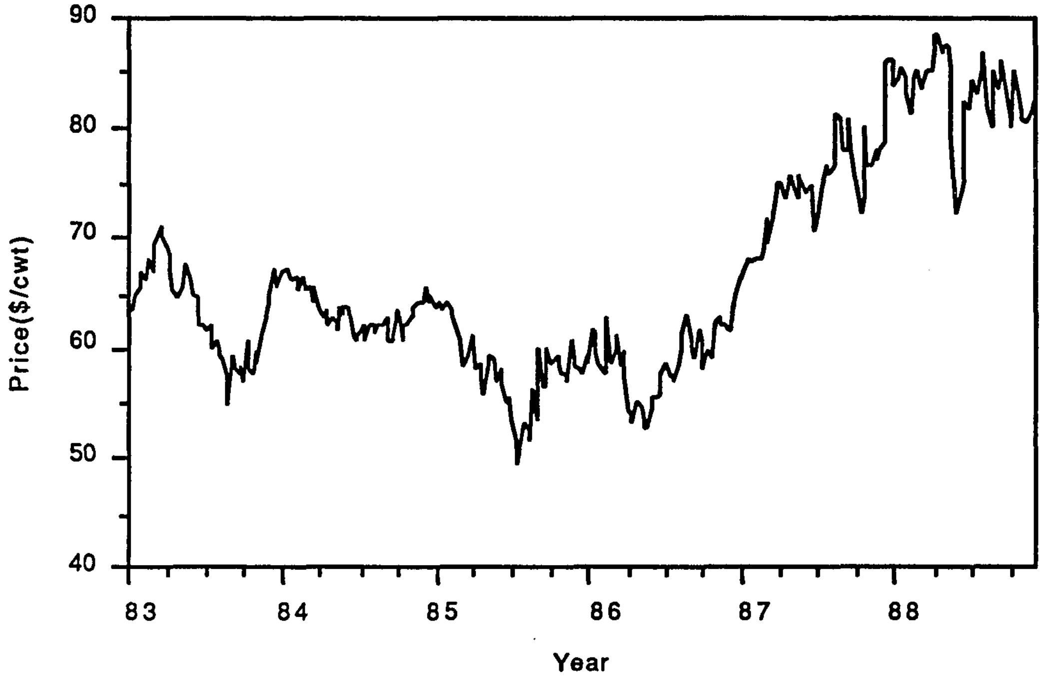
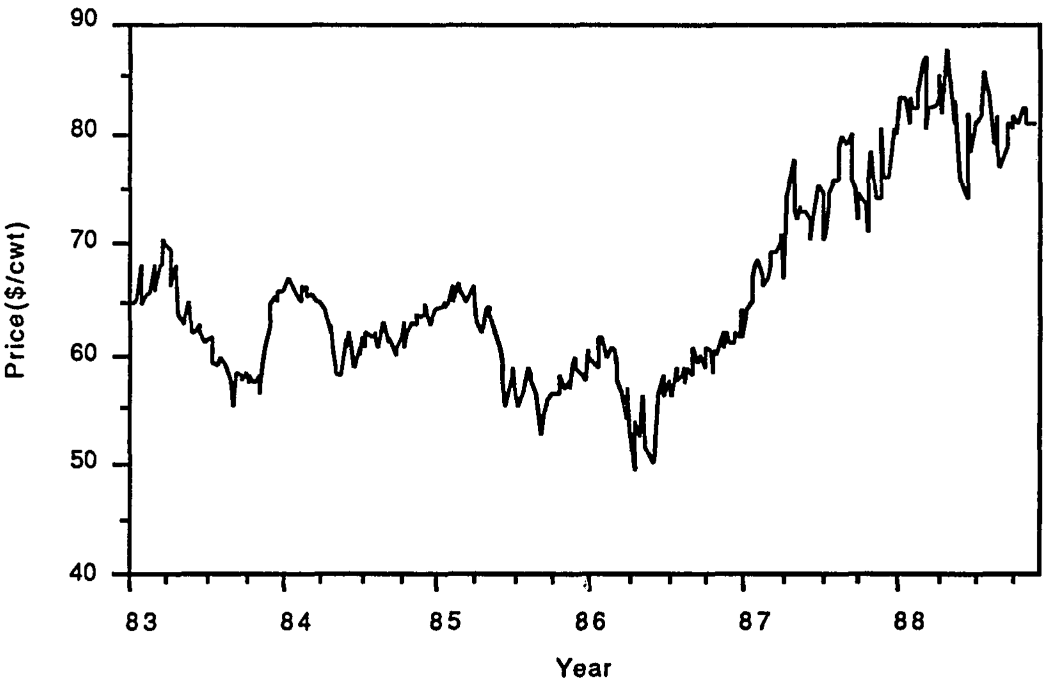


Figure 4.8 Weekly Average Steer Prices for Stockton, 1983-1988.



Some observations were missing at all locations during the six year time span covered. Most had some missing data at the start and end of the six year period. Otherwise, gaps in the data tended to be centered around major holidays. The Clovis series had a large gap during 1983 when prices were not reported. As a result, all analyses involving Clovis were conducted using the shortened period of September, 1983 to December, 1988. The Florida series had the most missing data, lacking 52 observations over the six year period.

The presence of gaps in the data may be due to several causes. A failure of reporting agencies to collect and publish the data may occur. Market reporters may feel that a price report is not accurate or representative of the week's sales, resulting in its being dropped. In either case, important information is missing. Another potential reason is a lack of any transactions during the week, a potentially important piece of information.

Breaking the model estimation up into short periods to avoid the gaps would not have avoided the problem for all markets. It also would have resulted in models using small data samples, seriously limiting the statistical value of the results due to limited degrees of freedom and in some cases precluding the use of the ordinary least squares technique since more variables than observations would have been present. In order to use as long and continuous a data series as possible and due to the generally singular occurrences of missing observations, missing values were replaced by linear interpolation using the last preceding and first following reported prices. Missing values at the start and end of the data series were dropped, resulting in a data series of 312 observations for all locations outside of Arizona except for Clovis, which had 278 observations. Other methods for handling the missing data problem exist, but they do not offer clear advantages.

Arizona Data

Auction market data were collected from two locations within Arizona. The locations of the two auctions are Tucson and Phoenix. The price data were collected for 600-700 lb. steers for the period January, 1987 to December, 1988 from sales receipt records at the Tucson auction, and from sales day summaries at the Phoenix auction. Animals with noted physical defects and dairy cattle which received large price discounts were omitted in calculating the weekly average prices. The Phoenix and Tucson auctions had the smallest volume of the ten locations (see Table 4.1). If all feeder cattle were included in the Arizona numbers to make them more comparable with the WLMIP locations, total volume would have remained below 10,000 head per year. Plots of the data from the auctions over the two year period, 1987-1988, are presented in Figures 4.9 and 4.10.

The data series from the Arizona auctions also suffered from missing observations. Where this occurred, it was due to either no sale being held that week or no animals in the weight/class involved were sold. The missing observations are treated as above for the other markets. Averages of the previous and following sales were used as a proxy.

The volume of animals sold in each sale tended to be low, averaging 17 head and 11 head in Tucson and Phoenix, respectively. The patterns of sales and lot sizes suggest that these markets tend to serve as secondary market outlets for many cattle producers. As such, many of the animals were

Figure 4.9 Weekly Average Steer Prices for Phoenix, 1987-1988.

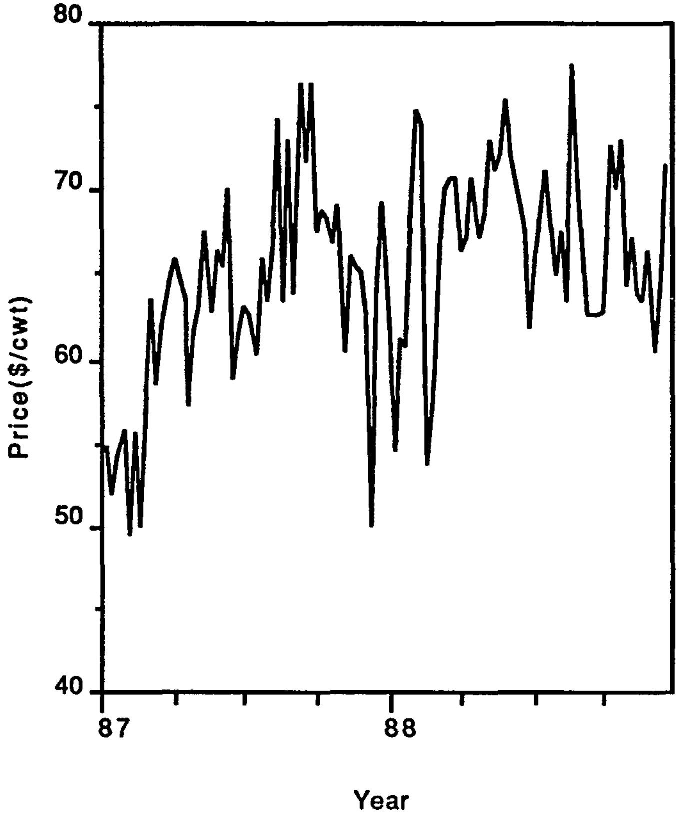
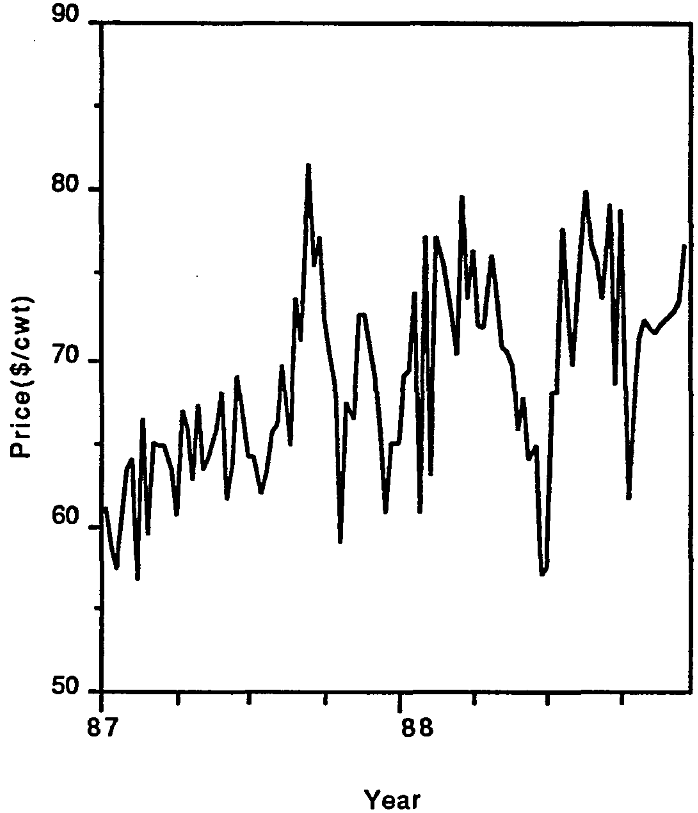


Figure 4.10 Weekly Average Steer Prices for Tucson, 1987-1988.



probably from small or part-time cattle producers or odd lots not sold as part of the year's main calf crop for larger producers.

Diagnostic Testing

The data were examined for obvious typographical errors or sudden, unusual price movements which might have indicated a reporting error. Unusual observations were compared with prices in the Livestock, Meat, and Wool Market News to check their accuracy. A few corrections for large differences in reported values were made to the Amarillo, Colorado, Kansas City, and Oklahoma City price series; however, these corrections involved less than 1% of the observations in these series.

The remainder of this chapter considers the issue of stationarity and reviews the lag selection process for the empirical model developed in chapter 3, which is then applied. It concludes with a review of the method used to test for significant changes in the pricing structure between markets following the introduction of cash settlement into the feeder cattle futures market.

Stationarity

In modeling time series data, economists often want to know if the stochastic process that generated the data varies with time. Stationary time series are "invariant with respect to time" (Pindyck and Rubinfeld, 1981). Most time series analysis involves the idea of weak stationarity in which the mean and variance of the data are finite and constant with respect to time (Chow, 1983). One of the reasons why stationarity is important is that time series over past and future periods can be represented by a fairly simple algebraic model. This model will have constant coefficients which allow testing hypotheses and making forecasts of future periods that lie within some confidence interval (Pindyck and Rubinfeld, 1981).

Data stationarity is examined through an Autoregressive Moving Average (ARMA) model explained in Box and Jenkins (1970). They describe a linear model for estimating and forecasting time series data in which observations are generated as a function of previous observations rather than as the result of exogenous economic variables. Thus, the time series Y_t is characterized by

(4.1) $$Y_t=f(Y_{t-i}) \quad i=1...m$$

where m is the maximum lag length, as opposed to being represented by

(4.2) $$Y_t=f(X_{k,t-i})$$

where $X_{k,t-i}$ is a set of k exogenous variables with lag lengths i=0...m. The form of an ARMA model is:

(4.3) $$(1-\phi_1B-\phi_2B^2-...-\phi_pB^p)Y_t=(1-\theta_1B-\theta_2B^2...-\theta_qB^q)e_t$$

(4.4) or $$\phi(B)Y_t=\theta(B)e_t$$

where B, the backshift operator, is defined to represent the number of lags in the model[1]. The number of autoregressive lags is p and the number of moving average lags is q. The terms $\phi(B)$ and $\theta(B)$ are polynomials in B, and e_t is a white noise process. The autoregressive polynomial, $\phi(B)$, represents a set of weights (ϕ) on past values of Y_t. By setting $\phi(B)=0$ and solving for the roots of B, the time series can be characterized as stationary or nonstationary. As an example, suppose we have a first order autoregressive process [AR(1)], where

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[1]For example, a one period lag where Y_t represents the data series would be written $BY_t=Y_{t-1}$.

the explicit form of $\phi(B)Y_t=\theta(B)e_t$ is $(1-\phi B)Y_t=e_t$ or $Y_t=\phi Y_{t-1}+e_t$. Solving for $1-\phi B=0$ we get $B=\frac{1}{\phi}$. Box and Jenkins (1970) define a stationary process as one in which $|B| > 1$ (lies outside the unit circle), or conversely, $|\phi|<1$. To understand the reason for this, think of ϕ as a weight indicating the portion of the previous observation present in the current one. The effect of an event p periods ago on the current value is ϕ^p. Thus, when $|\phi|<1$, events in the more distant past have less impact on the current value of Y_t than events in the more recent past. As events become more distant, ϕ^p becomes infinitesimally small. If $|\phi|=1$, then events in the distant past have equal importance as more recent events. If $|\phi|>1$, then events in the distant past have more importance than more recent events, the series is explosive, and quickly moves towards positive or negative infinity. Some additional conditions, described in Dickey, Bell, and Miller (1986), must also be met for a series to be stationary; however the primary concern is that $|\phi|<1$ ($|B|>1$).

Since a series with roots inside the unit circle ($|B|<1$) is clearly explosive upon visual inspection, the question of stationarity revolves around whether the data are stationary ($|B|>1$) or nonstationary with one or more unit roots ($|B|=1$). An autoregressive process with one unit root is written

(4.5) $$\phi(B)(1-B)Y_t=e_t$$

(4.6) or $$\phi(B)\nabla Y_t=e_t$$

where

(4.7) $$\nabla Y_t=Y_t-Y_{t-1},$$

the first difference of Y_t. Differencing data to remove unit roots is a popular method of transforming a nonstationary series to a stationary one.

Differencing is also used to remove seasonal or cyclical patterns in which the lag in the difference operator is the length of one complete cycle.

The use of differencing to obtain stationarity in time series data is discussed by Plosser and Schwert (1978). They explain that the difference transformation removes a linear time trend and/or a stochastic trend (such as a random walk) from the time series. Plosser and Schwert show that if nonstationary data is underdifferenced (remains nonstationary), the residuals of regressions on the data are likely to be nonstationary, with the result that parameter estimates may be statistically inconsistent with potentially misleading results. In the event that nonstationary data are overdifferenced (differenced after stationarity is achieved), the resulting regression residuals contain a first order moving average process [MA(1)]; however the estimated parameters are unbiased and consistent but inefficient. Additionally, they show that the first order autocorrelation coefficient will have a value of approximately -0.5 while the partial autocorrelation coefficients will slowly approach zero, indicating that a first order moving average structure has been introduced into the data.

Nelson and Plosser (1982) note that many macroeconomic variables are considered to be composed of a deterministic secular or growth component and a stationary, stochastic cyclical component. Thus, the growth component can be represented by a time trend which, if removed, will result in a stationary series with constant mean. Alternatively, they note that the secular movement may be stochastic rather than deterministic, with the result that models based on fitting time trends rather than differencing will be mispecified. Nelson and Plosser seek to dispel several arguments against differencing data and note some advantages over simple detrending. In examining a number of macroeconomic time series, they find differencing to be preferable to detrending the series to achieve stationarity. Differencing removes time trends and Plosser and Schwert (1978) find that the effects of overdifferencing are less onerous than the effects of underdifferencing (although just differencing is preferable overall). Perhaps an appropriate rule-of-thumb, to modify an old surgical adage, would be "when in doubt, difference it out".

The need for stationarity when time series data are analyzed using Granger causality tests has received some debate in recent years. Findings by Sheehan and Grieves (1982) that U.S. GNP showed a causal relationship towards sunspots helped to spur further investigation into the issue of stationarity. The appearance of such an apparently spurious causal connection threatens the credibility of Granger causality techniques in drawing economically useful conclusions from findings of temporal relationships. Although this study does not use Granger Causality, the Ravallion technique is quite similar in many respects.

Granger (1969) describes causality testing under the assumption of stationary data. Sims (1972), in his presentation of a variation of Granger's model, states that the regression residuals of the causality test must be white noise to allow hypothesis testing. He also assumes stationarity before applying a filter to remove serial correlation in the original data so that the regression residuals are also serially uncorrelated.

Pierce and Haugh (1977) present another version of Granger causality testing, calling for the reduction of time series data to white noise prior to searching for causal relationships, thus assuring that stationarity in the data is achieved.

In contrast to the calls for obtaining stationarity before testing for causality, Nerlove, Grether, and Carvalho (1979) propose that transforming data to stationarity before analysis is not always necessary. They suggest that transformations applied to achieve stationarity in different time series cancel each other out, thus the nonstationarity in one time series from a particular time period should be allowed to explain the nonstationarity in another. However, nonstationarity not common between series should still be removed before analyzing the data. In addition, Granger (1981) cautions against using a stationary variable to explain a nonstationary one.

The empirical evidence does not suggest that transforming nonstationary data to stationarity will bias the results against finding causal relationships where they are expected on *a priori* grounds. Several studies have found, however, that regressions considered spurious on *a priori* grounds are more likely to result when data is not rendered stationary prior to testing for causality. Plosser and Schwert (1978) found spurious results using nonstationary data which disappeared when the data were transformed to stationarity. Bessler and Kling (1984) sought to refute Sheehan and Grieves (1982) results relating U.S. GNP and sunspots by transforming the GNP data to stationarity before conducting the tests, generating results showing that no statistical causal relationship existed. Using microeconomic price data rather than macroeconomic data, Ziemer and Collins (1984) found a substantial number of spurious results when investigating causal relationships between eight series of agricultural data and three series of unrelated data. They did not transform the data to stationarity and retest, although the regression residuals appeared to be white noise based on their Q statistics. Bailey and Brorsen (1985) report that the results from causality tests of cattle prices using nonstationary data and the same data transformed to stationarity were similar.

The dangers of obtaining spurious results appear to be reduced by transforming the data to stationarity prior to performing the causality tests. The use of nonstationary data appears to result in more risk of spurious regression results and makes it more difficult to get serially uncorrelated error terms to provide accurate hypothesis testing. Additionally, the use of nonstationary data does not appear to offer significant advantages while overdifferencing, as reported by Plosser and Schwert (1978), creates a moving average problem in the data. The data used here are transformed to stationarity through differencing prior to testing for causality. In addition, the theory explained in Chapter 3 discusses price movements in terms of changes in prices (first differences), the level of prices having less importance.

Determining Stationarity in Practice

In practice, determining stationarity in time series data involves simple and easily applied techniques. Perhaps the most obvious and subjective technique is to look at a time plot of the data. Under the definition of time invariant mean and variance previously noted, a visual inspection can quickly suggest the presence of trends or nonconstant variance. Examination of plots of the price data in Figures 4.1 to 4.10 suggests that the mean prices are not constant over time. Price variability differs with the market, however no marked changes in the size of the variance within markets appear to occur except possibly in several locations in 1987-88 as seen by examining the plots of first differences in Figures 4.11 to 4.20. The variation in the Tucson auction appears to differ substantially in late 1987 and 1988 compared to early 1987. With the exception of the Arizona data, the plots also suggest a seasonal pattern of behavior. Plots of the first differences of the data in Figures 4.11 to 4.20 appear to show fluctuations around zero with little apparent change in the magnitude of the variation except for the Stockton data in which variation may increase. Although less pronounced, some seasonal patterns may still exist in the differenced data. Visual inspection of plots of the residuals of the empirical model did not suggest any problems with heteroskedasticity.

The next technique for examining the stationarity of the data involves inspection of the autocorrelation (AC) function. The following discussion is based on the more complete discussion found in Box and Jenkins (1970). If the data have any roots which lie on or very close to the unit circle, the AC function will die out very slowly. Conversely, if the data are stationary, the AC function will quickly die out and approach zero. The key item is whether the AC function follows a smooth, slow path of decline or rapidly approaches zero as the number of lags increase. Schwert (1987) shows that the AC function doesn't necessarily have to start out near 1.0 and may be much smaller;

Figure 4.11 First Differences of Amarillo Price Data, 1983-1988.

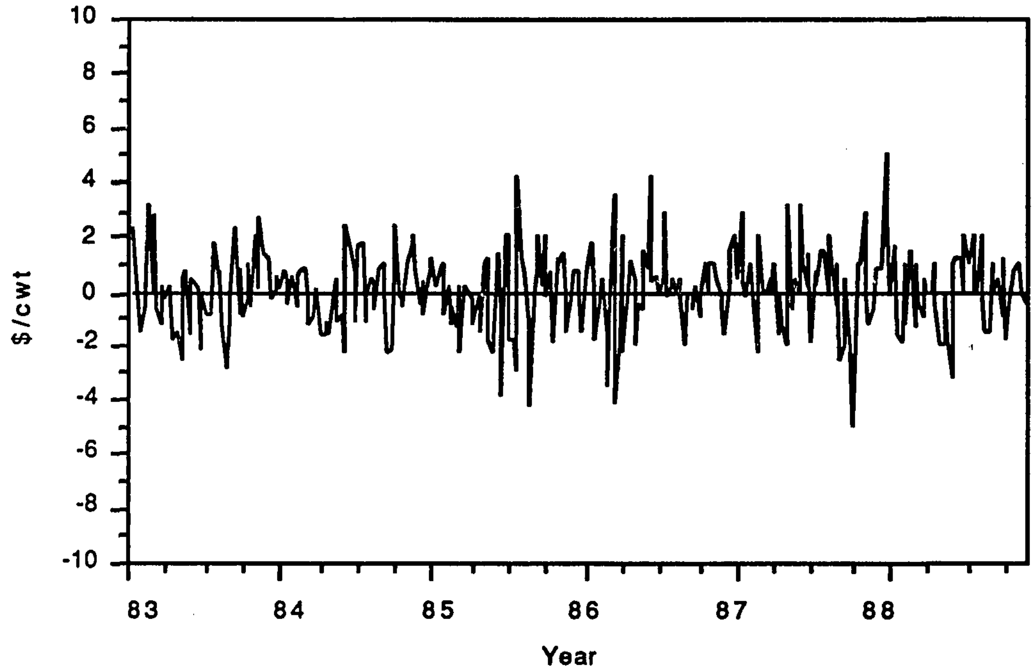


Figure 4.12 First Differences of Clovis Price Data, 1983-1988.

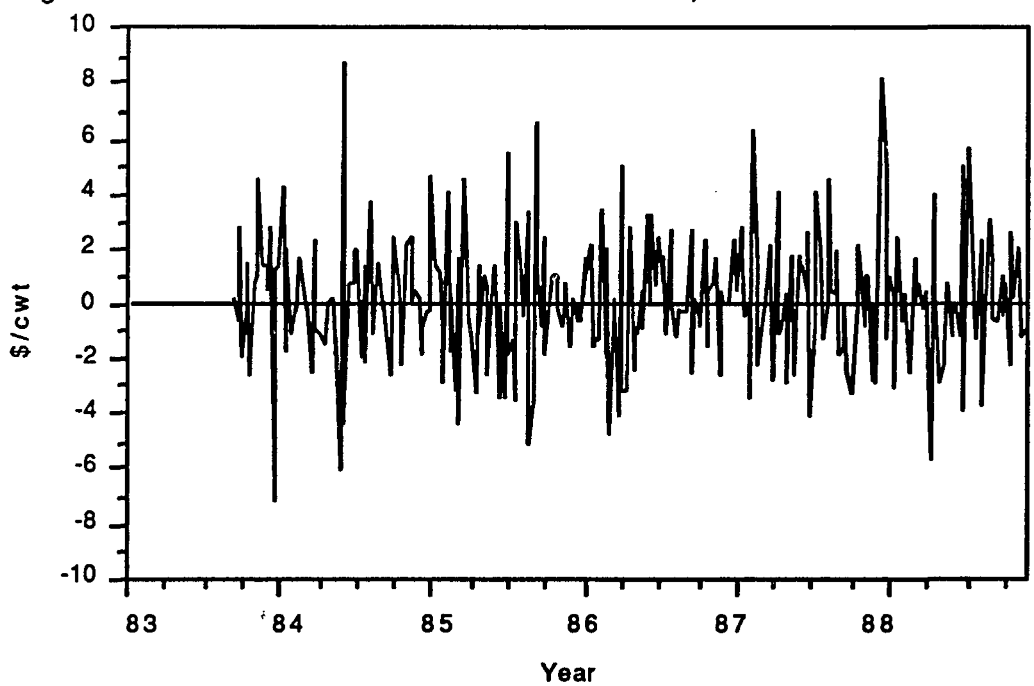


Figure 4.13 First Differences of Colorado Price Data, 1983-1988.

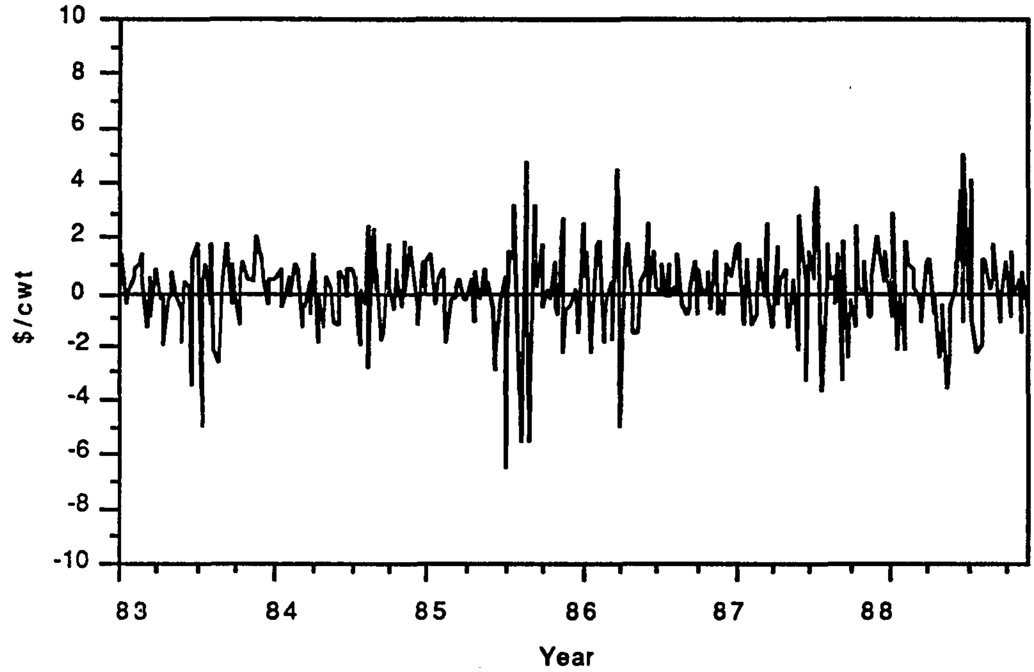


Figure 4.14 First Differences of Florida Price Data, 1983-1988.

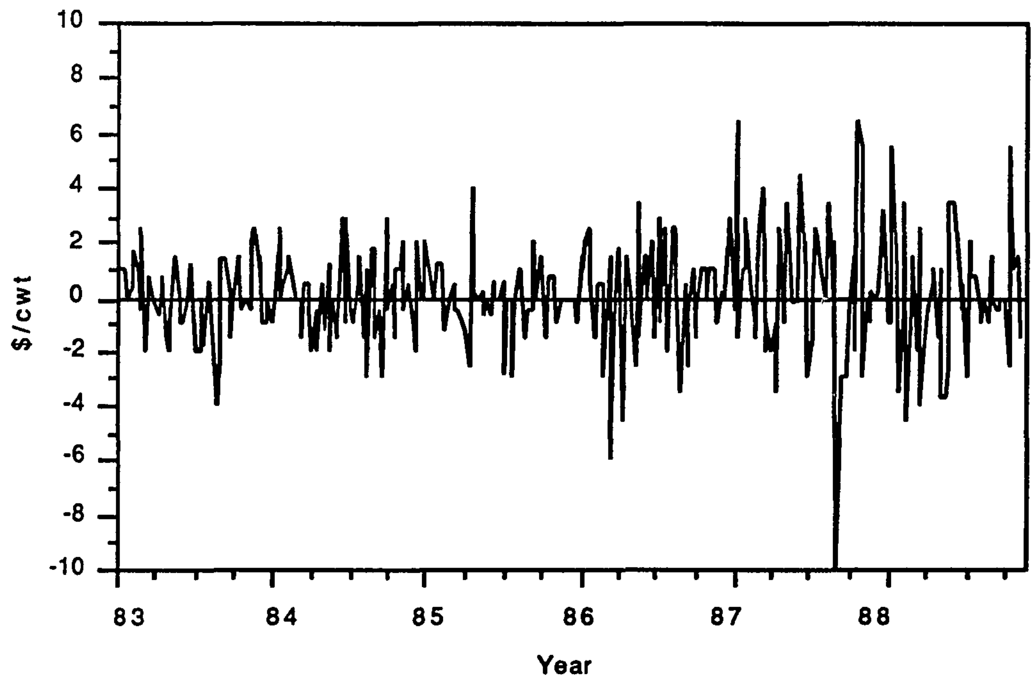


Figure 4.15 First Differences of Kansas City Price Data, 1983-1988.

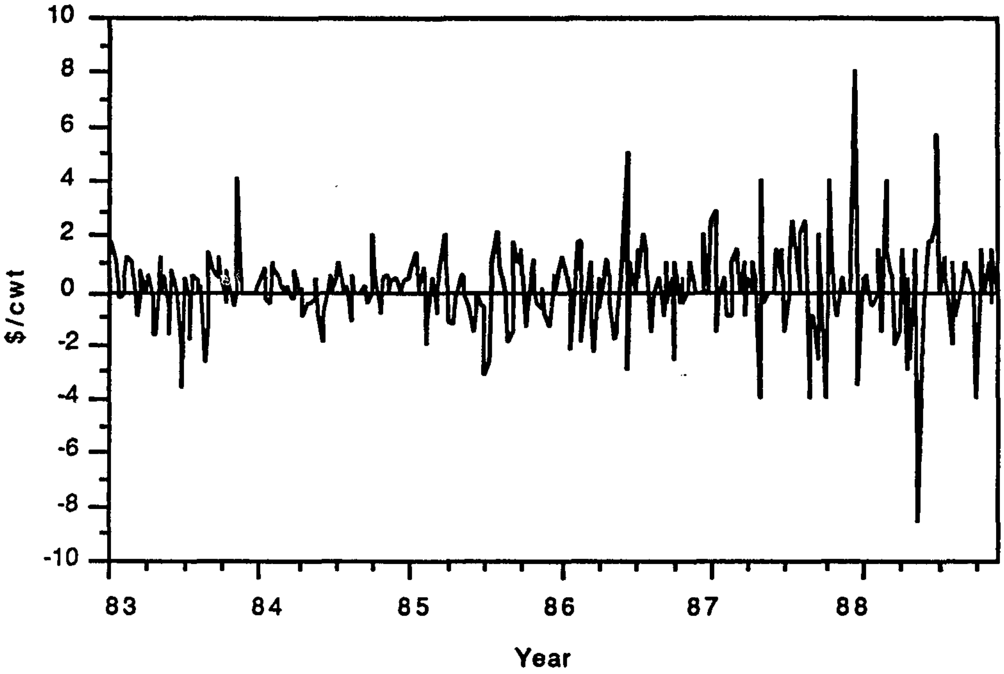


Figure 4.16 First Differences of Oklahoma City Price Data, 1983-1988.

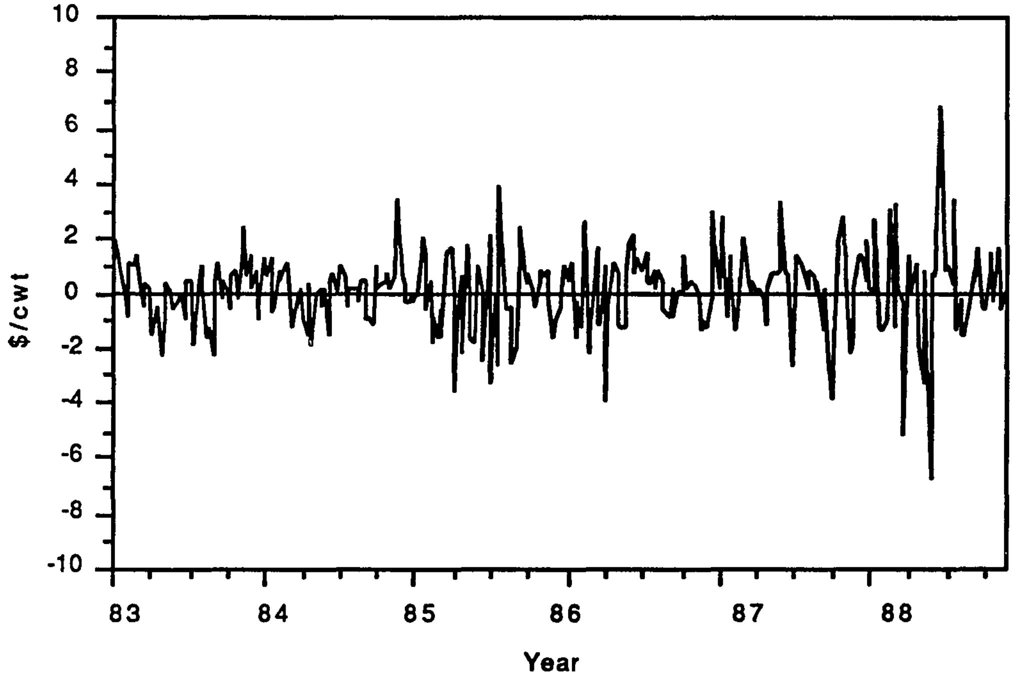


Figure 4.17 First Differences of Shasta Price Data, 1983-1988.

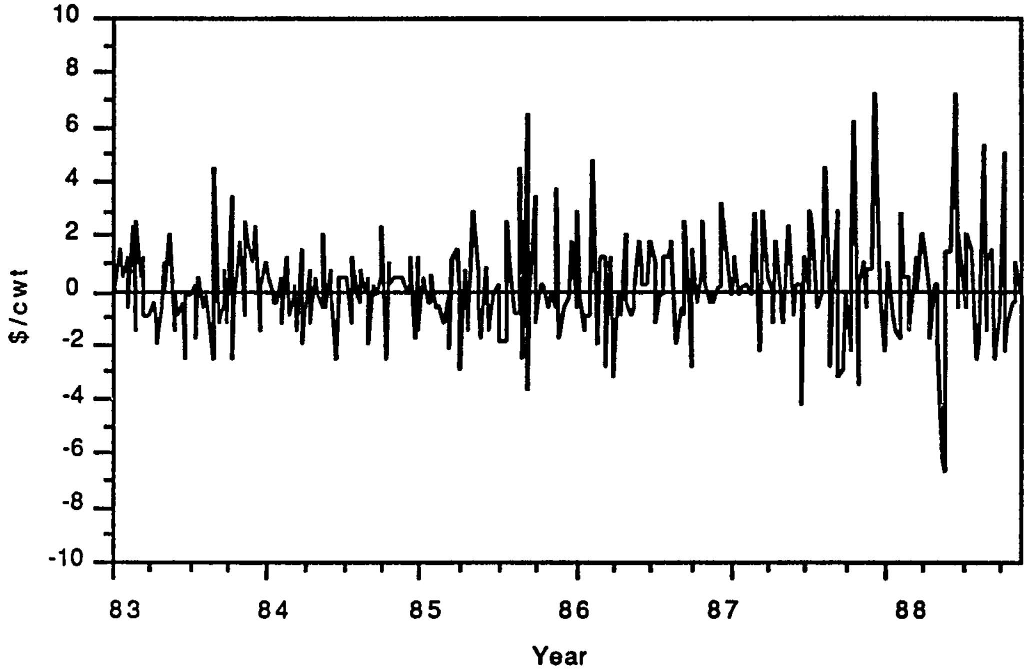


Figure 4.18 First Differences of Stockton Price Data, 1983-1988.

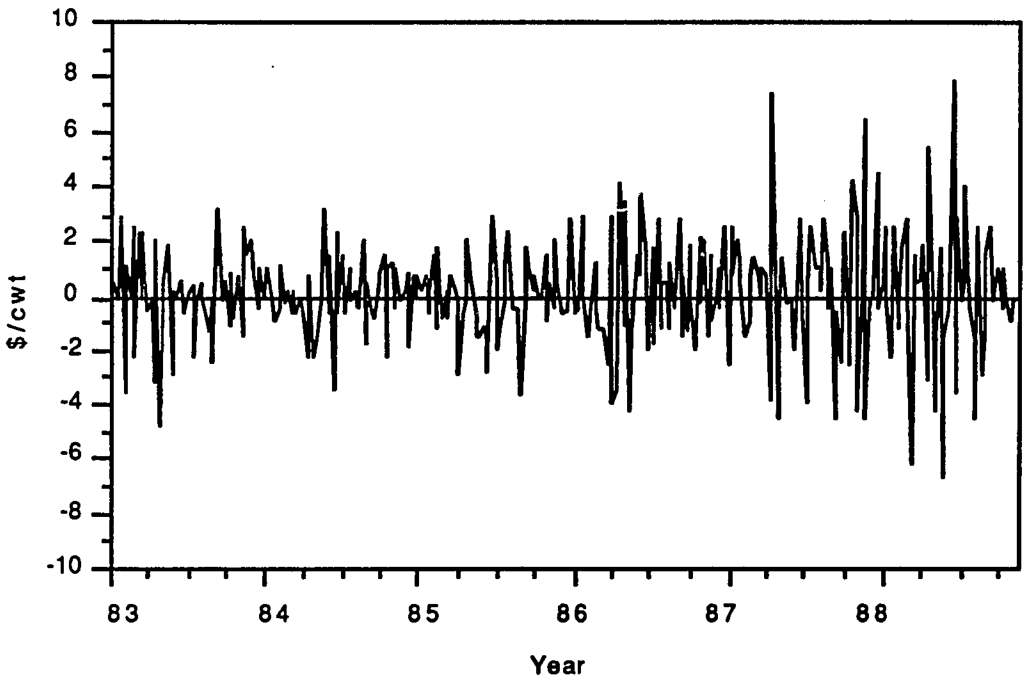


Figure 4.19 First Differences of Phoenix Price Data, 1987-1988.

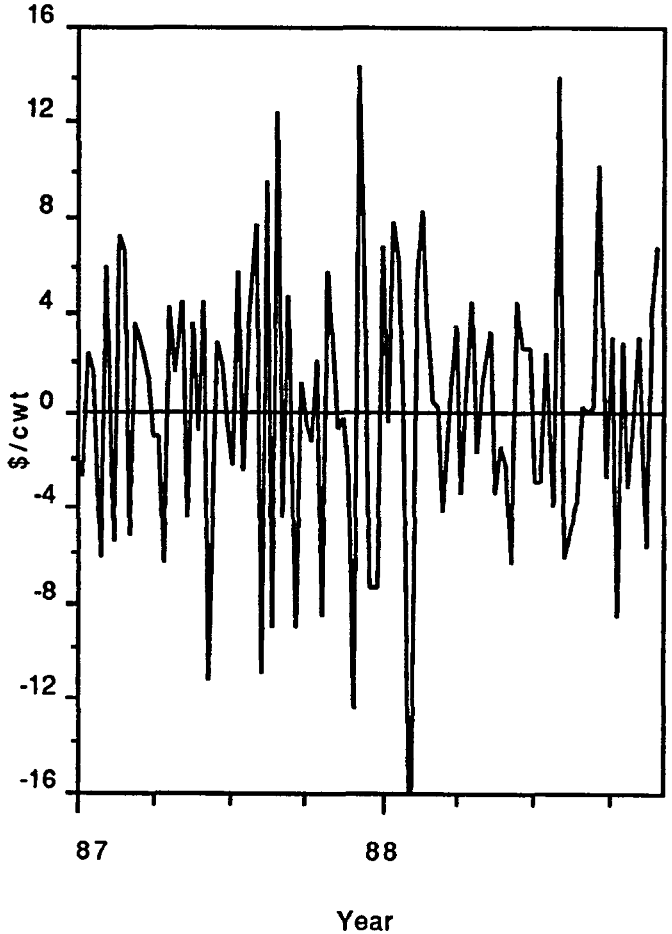
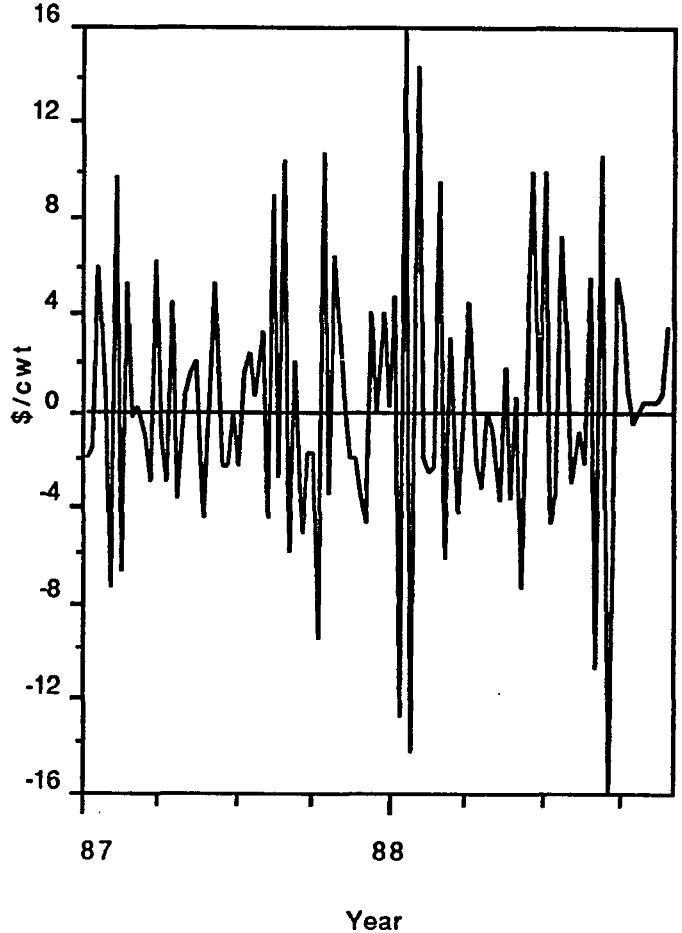


Figure 4.20 First Differences of Tucson Price Data, 1987-1988.



however, if the data are nonstationary, the rate of decay will remain very slow.

To test if any of the individual AC values (r_k) are nonzero, Box and Jenkins (1970) recommend the use of Bartlett's test. Under this test, the standard error of the estimate is

(4.8) $$\hat{\sigma}_{r_k} \cong \frac{1}{\sqrt{n}} \sqrt{1 + 2\sum_{i=1}^{p} r_i^2} \qquad k>p$$

where p is some specific number of lags over which r is not necessarily zero. Thus, to examine each AC value, the above formula would reduce to

(4.9) $$2\hat{\sigma} \cong \frac{2}{\sqrt{n}}$$

at the 5% level of confidence. If all the r_k are zero, the series would be white noise. If some are not zero, then the series would show an ARIMA (p,d,q) structure.

The AC function can also be used to detect seasonality in the data, which also results in nonstationarity. If seasonality is present to the degree that it leaves the data nonstationary, differencing the data using a lag of one full seasonal cycle will remove the seasonal nonstationarity. For example, if the data show an annual cycle, the AC function will show a high correlation at lag multiples of one year, the values tapering off slowly. Differencing the data by subtracting the value one year previous from the current value will remove the seasonal variation.

Autocorrelation functions were calculated for all the time series. The individual AC values for lags one to thirty and fifty-one to sixty are printed in Tables 4.2 to 4.11 for the original data, first and second differences. The AC

Table 4.2 Estimated Autocorrelations and Partial Autocorrelations of Amarillo Price Data.

Weekly Average Feeder Cattle Prices.

Undifferenced Data
312 Observations

	Lags	1	2	3	4	5	6	7	8	9	10
AC	1-10	a**.9786**	**.9540**	**.9309**	**.9074**	**.8836**	**8603**	**.8384**	**.8128**	**.7885**	**.7664**
	11-20	**.7432**	**.7220**	**.7036**	**.6851**	**.6667**	**.6514**	**.6390**	**.6267**	**.6166**	**.6070**
	21-30	**.5993**	**.5927**	**.5889**	**.5836**	**.5776**	**.5738**	**.5711**	**.5664**	**.5603**	**.5542**
	51-60	**.2989**	**.2878**	**.2749**	**.2610**	**.2439**	**.2247**	**.2049**	**.1862**	**.1673**	**.1490**
PAC	1-10	**.9786**	-.0907	.0326	-.0309	-.0140	-.0007	.0184	-.1028	.0312	.0257
	11-20	-.0392	.0401	.0445	-.0240	.0054	.0582	.0394	.0004	.0471	-.0193
	21-30	.0569	.0181	.0519	-.0481	.0072	.0368	.0303	-.0469	-.0176	-.0094
	51-60	-.0198	-.0417	-.0697	-.0393	-.0834	-.0678	-.0345	.0276	-.0076	-.0003

First Differenced Data
311 Observations

	Lags	1	2	3	4	5	6	7	8	9	10
AC	1-10	.1066	-.0484	.0070	.0270	.0004	-.0284	.1199	-.0638	-.0473	.0012
	11-20	-.0479	-.0941	.0235	-.0442	-.1452	-.1024	.0293	-.0721	-.0110	-.0275
	21-30	-.0105	-.0402	.0452	.0382	-.0419	-.0211	-.0118	-.0039	.0094	.1151
	51-60	.1059	.0787	.0168	.0840	.0382	.0164	.0298	.0299	.0035	.0037
PAC	1-10	.1066	-.0605	.0193	.0214	-.0036	-.0258	.1274	-.0989	-.0140	-.0008
	11-20	-.0583	-.0822	.0538	-.0895	-.1103	-.0753	.0275	-.0916	.0403	-.0729
	21-30	.0065	-.0327	.0565	-.0259	-.0114	-.0617	-.0235	-.0295	.0179	.0531
	51-60	.0513	.0991	-.0097	.0739	.0416	.0296	-.0315	.0542	.0334	.0378

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.2 continued Estimated Autocorrelations and Partial Autocorrelations of Amarillo Price Data.

Weekly Average Feeder Cattle Prices.

Second Differenced Data
310 Observations

	Lags	1	2	3	4	5	6	7	8	9	10
AC											
Lags	1-10	a **-.4124**	**-.1136**	.0186	.0245	-.0048	-.0930	**.1800**	-.1043	-.0181	.0530
	11-20	-.0009	-.0927	.1063	.0191	-.0805	-.0470	**.1244**	-.0917	.0490	-.0232
	21-30	.0269	-.0651	.0570	.0370	-.0555	.0043	.0008	-.0063	-.0504	**.1223**
	51-60	.0128	.0173	-.0721	.0652	-.0151	-.0159	.0041	.0147	-.0152	-.0022
PAC											
Lags	1-10	**-.4124**	**-.3418**	**-.2527**	**-.1785**	**-.1396**	**-.2483**	-.0151	-.0911	-.0938	-.0308
	11-20	-.0101	**-.1356**	.0140	.0313	-.0153	-.1039	.0130	-.1133	.0082	-.0719
	21-30	-.0315	-.1084	-.0141	-.0214	.0255	-.0167	-.0131	-.0569	-.0825	.0069
	51-60	-.0587	.0499	-.0324	.0068	.0199	.0775	-.0094	.0119	.0115	.0543

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.3 Estimated Autocorrelations and Partial Autocorrelations of Clovis Price Data.

Weekly Average Feeder Cattle Prices.

	Lags	1	2	3	4	5	6	7	8	9	10
Undifferenced Data, 277 Observations											
AC	1-10	**.9594**[a]	**.9376**	**.9136**	**.8936**	**.8744**	**.8526**	**.8331**	**.8092**	**.7868**	**.7658**
	11-20	**.7466**	**.7290**	**.7154**	**.7029**	**.6960**	**.6804**	**.6735**	**.6651**	**.6567**	**.6421**
	21-30	**.6371**	**.6360**	**.6263**	**.6192**	**.6171**	**.6152**	**.6135**	**.6105**	**.6040**	**.5984**
	51-60	**.2876**	**.2815**	**.2674**	**.2513**	**.2321**	**.2102**	**.1996**	**.1834**	**.1717**	**.1488**
PAC	1-10	**.9594**	**.2159**	.0148	.0405	.0233	-.0343	.0078	-.0555	-.0189	.0093
	11-20	.0183	.0206	.0613	.0364	.0886	-.0752	.0676	.0202	-.0102	-.0924
	21-30	.0942	.0905	-.0720	-.0051	.1010	.0337	.0229	-.0082	-.0482	-.0120
	51-60	-.0320	.0907	-.0856	-.0518	**-.1249**	-.0538	.0672	-.0555	.0331	-.1025
First Differenced Data, 276 Observations											
AC	1-10	**-.2910**	.0146	-.0540	-.0079	.0384	-.0019	.0222	-.0128	-.0194	.0130
	11-20	-.0218	-.0571	.0021	-.0363	.0667	**-.1576**	.0522	.0162	.0746	**-.1234**
	21-30	-.0132	.0897	.0071	-.0769	.0000	-.0079	.0076	.0395	-.0140	.0427
	51-60	-.0413	.0881	.0286	.0109	.0292	**-.1433**	.0912	-.0502	**.1831**	**-.1618**
PAC	1-10	**-.2910**	-.0766	-.0788	-.0516	.0182	.0117	.0284	.0073	-.0186	.0030
	11-20	-.0212	-.0821	-.0474	-.0643	.0291	**-.1501**	-.0431	.0144	.0875	-.0924
	21-30	-.0703	.0744	.0524	-.0943	-.0625	-.0251	-.0161	-.0005	-.0168	.0478
	51-60	-.0247	.0842	.0755	.0865	.0577	-.0789	.0206	-.0723	**.1596**	-.0386

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.3 cont Estimated Autocorrelations and Partial Autocorrelations of Clovis Price Data.

Weekly Average Feeder Cattle Prices.

Second Differenced Data
275 Observations

AC		1	2	3	4	5	6	7	8	9	10
Lags	1-10	**a-.6186**	**.1448**	-.0432	-.0007	.0342	-.0262	.0237	-.0114	-.0149	.0257
	11-20	.0001	-.0359	.0381	-.0556	**.1257**	**-.1665**	.0940	-.0359	.0994	-.1178
	21-30	.0000	.0744	-.0012	-.0619	.0328	-.0094	-.0056	.0322	-.0427	.0100
	51-60	-.0909	.0739	-.0169	-.0127	.0737	**-.1582**	**.1464**	**-.1449**	**.2234**	**-.2275**
PAC											
Lags	1-10	**-.6186**	**-.3852**	**-.2995**	**-.2824**	**-.2128**	**-.1886**	**-.1398**	-.0991	-.1092	-.0768
	11-20	-.0177	-.0549	-.0365	**-.1218**	.0528	-.0638	-.1133	**-.1679**	.0183	-.0061
	21-30	**-.1432**	-.1035	.0451	.0059	-.0329	-.0421	-.0556	-.0373	-.0970	**-.1920**
	51-60	-.0823	-.0640	-.0700	-.0354	.0985	-.0078	.0814	**-.1449**	.0612	-.0112

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.4 Estimated Autocorrelations and Partial Autocorrelations of Colorado Price Data.

Weekly Average Feeder Cattle Prices.

	1	2	3	4	5	6	7	8	9	10
Undifferenced Data, 313 Observations										
AC										
Lags 1-10	a.9767	.9585	.9435	.9265	.9094	.8918	.8762	.8596	.8450	.8308
11-20	.8144	.7984	.7819	.7661	.7534	.7433	.7323	.7192	.7031	.6881
21-30	.6755	.6649	.6559	.6489	.6452	.6404	.6353	.6302	.6207	.6080
51-60	.3000	.2849	.2699	.2552	.2402	.2234	.2100	.1949	.1789	.1634
PAC										
Lags 1-10	.9767	.0964	.0739	-.0335	-.0154	-.0256	.0334	-.0229	.0382	.0051
11-20	-.0466	-.0128	-.0242	.0059	.0638	.0702	-.0030	-.0497	-.0990	-.0094
21-30	.0442	.0690	.0609	.0586	.0676	-.0192	-.0199	-.0084	-.0832	-.0828
51-60	-.0628	-.0060	-.0423	-.0222	-.0269	-.0558	.0548	-.0039	-.0291	-.0312
First Differenced Data, 312 Observations										
AC										
Lags 1-10	-.1499	-.0718	.0199	.0140	.0147	-.0260	.0156	-.0264	-.0169	.0323
11-20	-.0094	.0423	-.0076	-.0895	-.0565	.0345	.0172	.0380	-.0514	.0160
21-30	-.0719	.0406	-.0803	-.0163	.0077	.0045	-.0353	.0178	.0842	-.0664
51-60	-.0302	.0394	.0079	-.0095	.0390	-.0845	.0447	.0328	.0330	-.0387
PAC										
Lags 1-10	-.1499	-.0965	-.0065	.0096	.0207	-.0188	.0114	-.0272	-.0242	.0221
11-20	-.0030	.0468	.0073	-.0869	-.0913	-.0046	.0106	.0571	-.0295	.0082
21-30	-.0831	.0105	-.0958	-.0337	-.0096	.0177	-.0335	-.0022	.0632	-.0503
51-60	-.0287	.0522	.0132	.0174	.0436	-.0725	.0027	.0420	.0755	-.0186

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.4 cont. Estimated Autocorrelations and Partial Autocorrelations of Colorado Price Data.

Weekly Average Feeder Cattle Prices.

Second Differenced Data
311 Observations

	Lags	1	2	3	4	5	6	7	8	9	10
AC	1-10	[a] **-.5341**	-.0056	.0429	-.0033	.0184	-.0369	.0370	-.0223	-.0165	.0387
	11-20	-.0390	.0425	.0145	-.0497	-.0240	.0449	-.0169	.0479	-.0658	.0664
	21-30	-.0846	.0980	-.0787	.0184	.0085	.0150	-.0366	-.0081	.0936	-.0791
	51-60	-.0789	.0435	-.0067	-.0289	.0765	-.1107	.0610	-.0039	.0292	-.0596
PAC	1-10	**-.5341**	**-.4070**	**-.2997**	**-.2387**	**-.1592**	**-.1639**	-.1074	-.1002	**-.1307**	-.0923
	11-20	**-.1253**	-.0745	.0204	.0172	-.0669	-.0752	-.1121	-.0216	-.0544	.0364
	21-30	-.0516	.0524	-.0129	-.0314	-.0560	-.0079	-.0369	-.0957	.0188	-.0054
	51-60	-.0459	-.0048	-.0092	-.0330	.0835	.0035	-.0319	-.0567	.0354	-.0121

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.5 Estimated Autocorrelations and Partial Autocorrelations of Florida Price Data.

Weekly Average Feeder Cattle Prices.

Undifferenced Data
311 Observations

		1	2	3	4	5	6	7	8	9	10
AC											
Lags	1-10	a.9662	.9340	.9021	.8738	.8456	.8241	.8016	.7797	.7642	.7451
	11-20	.7281	.7084	.6911	.6725	.6617	.6521	.6454	.6455	.6457	.6481
	21-30	.6416	.6352	.6304	.6275	.6206	.6177	.6127	.6021	.5928	.5832
	51-60	.3487	.3411	.3268	.3092	.2869	.2638	.2444	.2298	.2124	.1982
PAC											
Lags	1-10	.9662	.0043	-.0104	.0382	-.0111	.0852	-.0187	-.0030	.0948	-.0600
	11-20	.0316	-.0425	.0213	-.0049	.0927	.0262	.0440	.1131	.0152	.0571
	21-30	-.1111	.0033	.0697	.0086	-.0321	.0487	-.0236	-.0762	.0043	.0017
	51-60	-.0704	-.0701	-.1099	-.0346	-.0656	-.0324	.0225	.0122	-.0304	-.0189

First Differenced Data
310 Observations

		1	2	3	4	5	6	7	8	9	10
AC											
Lags	1-10	-.0315	-.0190	-.0465	.0094	-.0482	-.0077	-.0114	-.0982	.0460	-.0398
	11-20	.0486	-.0261	.0069	-.1314	-.0263	-.0633	-.1150	.0009	-.0105	.1188
	21-30	-.0010	-.0360	-.0237	.1085	-.0248	.0010	.0460	-.0617	.0065	-.0095
	51-60	.0609	.1122	.0438	.0898	-.0199	-.0018	-.0121	.0339	-.0361	-.0180
PAC											
Lags	1-10	-.0315	-.0201	-.0478	.0059	-.0498	-.0128	-.0137	-.1050	.0388	-.0464
	11-20	.0378	-.0222	-.0080	-.1286	-.0448	-.0820	-.1358	-.0290	-.0358	.0891
	21-30	-.0048	-.0822	-.0259	.0727	-.0323	-.0011	.0428	-.0620	-.0132	-.0397
	51-60	.0369	.1189	.0266	.0844	.0004	.0155	.0201	-.0013	.0365	-.0213

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.5 cont. Estimated Autocorrelations and Partial Autocorrelations of Florida Price Data.

Weekly Average Feeder Cattle Prices.

Second Differenced Data
309 Observations

		1	2	3	4	5	6	7	8	9	10
AC											
Lags	1-10	[a] **-.5066**	.0211	-.0408	.0566	-.0510	.0232	.0390	-.1105	.1107	-.0845
	11-20	.0803	-.0532	.0832	**-.1187**	.0700	.0079	-.0817	.0614	-.0700	**.1229**
	21-30	-.0416	-.0226	-.0575	.1289	-.0786	-.0098	.0733	-.0826	.0389	-.0147
	51-60	-.0106	.0571	-.0560	.0752	-.0584	.0140	-.0313	.0583	-.0434	.0222
PAC											
Lags	1-10	**-.5066**	**-.3170**	**-.2803**	**-.1714**	**-.1802**	**-.1511**	-.0543	**-.1828**	-.0802	**-.1501**
	11-20	-.0747	-.0817	.0336	-.0590	-.0246	.0206	-.0911	-.0752	**-.1829**	-.0693
	21-30	.0084	-.0509	**-.1350**	-.0193	-.0469	-.0850	.0180	-.0308	-.0061	.0043
	51-60	**-.1143**	-.0128	-.0649	.0214	.0107	.0093	.0267	-.0101	.0475	.0668

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.6 Estimated Autocorrelations and Partial Autocorrelations of Kansas City Price Data.

Weekly Average Feeder Cattle Prices.

Undifferenced Data
312 Observations

		1	2	3	4	5	6	7	8	9	10
AC											
Lags	1-10	[a].9759	.9510	.9306	.9095	.8904	.8726	.8593	.8470	.8289	.8084
	11-20	.7892	.7735	.7586	.7445	.7330	.7230	.7150	.7043	.6921	.6817
	21-30	.6681	.6516	.6419	.6362	.6333	.6322	.6323	.6340	.6241	.6120
	51-60	.3154	.3014	.2871	.2711	.2563	.2443	.2292	.2129	.1942	.1790
PAC											
Lags	1-10	.9759	-.0300	.0817	-.0275	.0388	.0142	.0927	.0131	-.1105	-.0551
	11-20	.0083	.0657	.0105	.0170	.0239	.0227	.0612	-.0309	-.0235	.0164
	21-30	-.0746	-.0601	.1312	.0607	.0658	.0495	.0504	.0449	-.2156	-.0032
	51-60	-.1086	.0590	-.0659	-.0725	-.0213	.0029	-.0212	-.0216	-.0289	.0628

First Differenced Data
311 Observations

		1	2	3	4	5	6	7	8	9	10
AC											
Lags	1-10	.0375	-.0941	.0022	-.0358	-.0394	-.0909	.0013	.0830	.0658	-.0469
	11-20	-.0836	-.0058	-.0013	-.0809	-.0871	-.0479	.0363	.0470	-.0426	.1227
	21-30	.0751	-.0624	-.0588	-.0635	-.0404	-.0546	-.0707	.1254	.0691	.0511
	51-60	.0416	.0070	.0574	-.0366	-.0745	.0645	.0179	.0656	-.0053	-.0346
PAC											
Lags	1-10	.0375	-.0957	.0098	-.0458	-.0353	-.0971	.0017	.0642	.0601	-.0478
	11-20	-.0783	-.0128	-.0035	-.0694	-.0860	-.0812	.0015	.0320	-.0400	.1196
	21-30	.0398	-.0465	-.0304	-.0520	-.0584	-.0788	-.0973	.0937	.0105	.0527
	51-60	.0827	.0197	.0905	-.0160	-.0370	.0508	-.0009	.0354	-.0264	-.0172

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.6 cont. Estimated Autocorrelations and Partial Autocorrelations of Kansas City Price Data.

Weekly Average Feeder Cattle Prices.

Second Differenced Data
310 Observations

		1	2	3	4	5	6	7	8	9	10
AC											
Lags	1-10	a**-.4315**	**-.1172**	.0697	-.0187	.0241	-.0745	.0052	.0541	.0489	-.0408
	11-20	-.0586	.0373	.0448	-.0367	-.0234	-.0270	.0399	.0515	**-.1311**	.1119
	21-30	.0442	-.0727	.0069	-.0127	.0143	.0018	-.1090	**.1289**	-.0194	.0362
	51-60	.0208	-.0447	.0749	-.0278	-.0919	.0948	-.0488	.0623	-.0213	-.0413
PAC											
Lags	1-10	**-.4315**	**-.3729**	**-.2292**	**-.1958**	**-.1158**	**-.1926**	**-.2143**	**-.1713**	-.0489	-.0216
	11-20	-.0858	-.0870	-.0168	-.0016	-.0101	-.0946	-.1109	-.0323	**-.1733**	-.0718
	21-30	.0160	-.0040	.0185	.0286	.0416	.0507	**-.1338**	-.0397	-.0730	.0086
	51-60	-.0025	-.0697	.0398	.0539	-.0345	.0190	-.0141	.0453	.0288	-.0345

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.7 Estimated Autocorrelations and Partial Autocorrelations of Oklahoma City Price Data.

Weekly Average Feeder Cattle Prices.

Undifferenced Data
312 Observations

		1	2	3	4	5	6	7	8	9	10
AC Lags	1-10	a.9802	.9575	.9346	.9140	.8963	.8799	.8650	.8485	.8324	.8162
	11-20	.7992	.7828	.7693	.7552	.7410	.7261	.7124	.6985	.6832	.6704
	21-30	.6579	.6459	.6349	.6258	.6222	.6197	.6187	.6119	.6018	.5919
	51-60	.3133	.2996	.2858	.2699	.2523	.2332	.2152	.1973	.1806	.1654
PAC Lags	1-10	.9802	-.0853	-.0132	.0489	.0570	.0115	.0271	-.0457	.0152	-.0055
	11-20	-.0316	.0109	.0653	-.0415	-.0047	-.0175	.0327	-.0174	-.0445	.0599
	21-30	-.0010	-.0044	.0218	.0452	.1410	.0108	.0351	-.1375	-.0391	.0170
	51-60	-.0891	-.0345	-.0406	-.0820	-.0344	-.0405	-.0311	-.0205	.0118	-.0220

First Differenced Data
311 Observations

		1	2	3	4	5	6	7	8	9	10
AC Lags	1-10	.1360	-.0029	-.0910	-.0784	-.0546	-.0060	.0952	-.0256	-.0118	.0182
	11-20	.0214	-.1042	.0402	-.0204	-.0247	-.1170	-.0072	.0166	-.0038	-.0088
	21-30	.0039	-.0202	-.0517	-.0325	-.0229	-.0386	.0150	.0503	.0194	-.0745
	51-60	.0230	.0561	.0963	.0209	-.0110	-.0296	.0380	.0323	-.0003	-.0117
PAC Lags	1-10	.1360	-.0218	-.0893	-.0552	-.0391	-.0023	.0872	-.0635	-.0063	.0342
	11-20	.0182	-.1130	.0739	-.0423	-.0225	-.1184	.0147	.0065	-.0060	-.0502
	21-30	.0132	-.0190	-.0298	-.0562	-.0051	-.0495	.0256	.0000	.0165	-.0909
	51-60	.0089	.0377	.0969	-.0137	.0055	.0419	.0263	.0354	.0119	.0074

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.7 cont. Estimated Autocorrelations and Partial Autocorrelations of Oklahoma City Price Data.

Weekly Average Feeder Cattle Prices.

Second Differenced Data
310 Observations

		1	2	3	4	5	6	7	8	9	10
AC Lags	1-10	[a] **-.4189**	-.0280	-.0571	-.0097	-.0142	-.0312	**.1292**	-.0758	-.0086	.0140
	11-20	.0752	**-.1539**	**.1176**	-.0329	.0541	**-.1194**	.0473	.0261	-.0076	-.0104
	21-30	.0210	.0037	-.0280	.0033	.0145	-.0358	.0103	.0346	.0355	-.0751
	51-60	-.0590	-.0028	.0659	-.0216	-.0084	-.0525	.0434	.0150	-.0129	.0229
PAC Lags	1-10	**-.4189**	**-.2469**	**-.2263**	**-.2013**	**-.1978**	**-.2395**	-.0664	**-.1134**	**-.1351**	-.1047
	11-20	.0282	-.1486	-.0212	-.0388	.0585	-.0785	-.0621	-.0434	.0034	-.0580
	21-30	-.0220	-.0142	.0123	-.0410	.0014	-.0655	-.0283	-.0437	.0587	-.0261
	51-60	-.0250	-.0756	.0411	.0222	-.0113	.0018	-.0005	.0228	.0205	.0907

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.8 Estimated Autocorrelations and Partial Autocorrelations of Shasta Price Data.

Weekly Average Feeder Cattle Prices.

	Lags	1	2	3	4	5	6	7	8	9	10
Undifferenced Data, 312 Observations											
AC											
Lags	1-10	[a] **.9780**	**.9600**	**.9445**	**.9302**	**.9174**	**.9011**	**.8860**	**.8727**	**.8609**	**.8509**
	11-20	**.8392**	**.8261**	**.8129**	**.7986**	**.7892**	**.7817**	**.7708**	**.7537**	**.7364**	**.7221**
	21-30	**.7095**	**.6946**	**.6812**	**.6665**	**.6576**	**.6533**	**.6506**	**.6423**	**.6310**	**.6168**
	51-60	**.3384**	**.3240**	**.3084**	**.2929**	**.2782**	**.2633**	**.2489**	**.2317**	**.2179**	**.2052**
PAC											
Lags	1-10	**.9780**	.0812	.0570	.0304	.0389	-.0783	.0124	.0297	.0363	.0448
	11-20	-.0212	-.0387	-.0174	-.0406	.0924	.0653	-.0540	**-.1543**	-.0461	.0208
	21-30	.0282	-.0376	.0535	-.0306	.1025	.1034	.0774	-.1103	-.0677	-.1026
	51-60	-.0173	.0190	-.0548	-.0683	-.0355	.0458	.0608	-.0842	.0109	-.0398
First Differenced Data, 311 Observations											
AC											
Lags	1-10	-.1121	-.0513	-.0386	-.0474	.0788	-.0612	.0179	-.0502	-.0859	.0147
	11-20	.0582	.0111	.0065	-.0637	-.0903	.0552	**.1363**	.0293	-.0499	-.0654
	21-30	.0672	-.0193	.0248	-.0647	**-.1145**	-.0228	.0565	-.0098	.0530	-.0870
	51-60	.0228	.0525	-.0050	-.0272	.0153	-.0114	.0309	-.0136	-.0071	-.0128
PAC											
Lags	1-10	-.1121	-.0647	-.0529	-.0630	.0612	-.0546	.0084	-.0521	-.0976	-.0241
	11-20	.0505	.0052	.0151	-.0521	-.1118	.0166	**.1319**	.0477	-.0177	-.0454
	21-30	.0519	-.0271	.0135	-.0737	-.1076	-.0393	.0521	-.0507	.0302	-.0831
	51-60	.0184	.0645	.0716	.0000	-.0340	-.0606	.0603	.0363	.0833	-.0224

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.8 cont. Estimated Autocorrelations and Partial Autocorrelations of Shasta Price Data.

Weekly Average Feeder Cattle Prices.

Second Differenced Data
310 Observations

		1	2	3	4	5	6	7	8	9	10
AC											
Lags	1-10	[a] **-.5274**	.0216	.0095	-.0606	**.1195**	-.0981	.0657	-.0145	-.0613	.0260
	11-20	.0406	-.0191	.0297	-.0197	-.0775	.0288	.0846	-.0125	-.0284	-.0667
	21-30	.0987	-.0589	.0605	-.0181	-.0636	.0052	.0657	-.0581	.0914	-.0680
	51-60	-.0224	.0393	-.0159	-.0290	.0311	-.0313	.0395	-.0233	.0056	-.0321
PAC											
Lags	1-10	**-.5274**	**-.3553**	**-.2573**	**-.3004**	**-.1398**	**-.1771**	-.0991	-.0534	**-.1231**	**-.1749**
	11-20	-.1105	-.1085	-.0359	.0179	-.1104	**-.2056**	-.1061	-.0361	-.0084	-.1024
	21-30	-.0193	-.0583	.0292	.0568	-.0162	-.1041	.0011	-.0785	.0347	.0314
	51-60	-.0775	-.0820	-.0088	.0246	.0504	-.0704	-.0444	-.0898	.0170	.0054

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.9 Estimated Autocorrelations and Partial Autocorrelations of Stockton Price Data.

Weekly Average Feeder Cattle Prices.

Undifferenced Data
312 Observations

	Lags	1	2	3	4	5	6	7	8	9	10
AC	1-10	a**.9708**	**.9535**	**.9384**	**.9266**	**.9067**	**.8909**	**.8796**	**.8646**	**.8530**	**.8392**
	11-20	**.8260**	**.8117**	**.8011**	**.7863**	**.7682**	**.7534**	**.7371**	**.7227**	**.7033**	**.6896**
	21-30	**.6779**	**.6666**	**.6548**	**.6416**	**.6382**	**.6331**	**.6232**	**.6131**	**.6023**	**.5905**
	51-60	**.2925**	**.2774**	**.2605**	**.2383**	**.2239**	**.2104**	**.1964**	**.1805**	**.1678**	**.1562**
PAC	1-10	**.9708**	**.1909**	.0720	.0788	**-.1180**	.0183	.0826	-.0485	.0666	-.0278
	11-20	-.0264	-.0038	.0397	-.0563	-.0781	.0118	-.0428	.0287	-.0683	.0344
	21-30	.0669	.0134	.0163	-.0335	.1501	.0533	-.0830	.0066	-.0770	-.0365
	51-60	-.0113	-.0516	-.0394	**-.1259**	.0577	.0692	-.0029	-.0153	-.0223	.0314

First Differenced Data
311 Observations

	Lags	1	2	3	4	5	6	7	8	9	10
AC	1-10	**-.2409**	-.0443	-.0658	**.1469**	-.0828	-.0794	.0735	-.0623	.0430	-.0151
	11-20	.0574	-.0600	.0673	.0242	-.0323	-.0340	-.0579	.0952	-.0673	-.0367
	21-30	-.0123	.0466	-.0177	-.1026	.0263	.0785	-.0811	.0344	-.0052	-.0012
	51-60	.0088	.0359	.0524	-.0775	-.0206	-.0427	.0734	-.0101	-.0559	.0232
PAC	1-10	**-.2409**	-.1087	-.1116	.1039	-.0333	-.1014	.0387	-.0793	.0220	.0174
	11-20	.0329	-.0194	.0523	.0487	-.0079	-.0250	-.0893	.0453	-.0233	-.0666
	21-30	-.0249	-.0096	-.0115	-.1053	-.0511	.0645	-.0739	.0416	-.0059	-.0238
	51-60	.0622	.0690	.1109	-.0263	-.0400	-.0274	-.0002	.0440	-.0533	.0037

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.9 cont. Estimated Autocorrelations and Partial Autocorrelations of Stockton Price Data.

Weekly Average Feeder Cattle Prices.

Second Differenced Data
310 Observations

		1	2	3	4	5	6	7	8	9	10
AC											
Lags	1-10	a **-.5791**	.0874	-.0934	**.1776**	-.0938	-.0606	**.1170**	-.0978	.0662	-.0530
	11-20	.0769	-.0987	.0690	.0047	-.0212	.0084	.0715	**.1271**	-.0771	.0019
	21-30	-.0137	.0494	.0086	-.0863	.0307	.0852	**-.1103**	.0622	-.0177	.0146
	51-60	-.0196	.0040	.0593	-.0753	.0318	-.0556	.0802	-.0151	-.0503	.0364
PAC											
Lags	1-10	**-.5791**	**-.3732**	**-.4197**	**-.1964**	-.1098	**-.2222**	-.0824	**-.1686**	**-.1407**	**-.1381**
	11-20	-.0747	**-.1353**	**-.1169**	-.0536	-.0328	.0292	-.1042	-.0310	.0112	-.0320
	21-30	-.0453	-.0416	.0488	-.0112	**-.1221**	.0181	-.0952	-.0427	-.0244	-.0401
	51-60	-.0774	**-.1157**	.0236	.0358	.0224	-.0042	-.0466	.0511	-.0074	-.0149

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.10 Estimated Autocorrelations and Partial Autocorrelations of Phoenix Price Data.

Weekly Average Feeder Cattle Prices.

Undifferenced Data
102 Observations

	Lags	1	2	3	4	5	6	7	8	9	10
AC	1-10	[a] **.5274**	**.3787**	**.2482**	**.2946**	**.2958**	**.2997**	.1938	.0461	.1277	.1045
	11-20	.0949	.0077	.0214	-.0035	-.0149	-.0172	-.0263	-.0176	.0362	.0000
	21-30	-.0149	-.0172	-.0263	-.0176	-.0021	-.0933	-.0912	.0173	.0105	-.0897
	51-60	.0575	.0125	-.0269	-.0219	-.0861	-.0618	-.0778	-.0345	-.1122	-.0956
PAC	1-10	**.5274**	.1392	.0039	.1808	.1003	.0790	-.0597	-.1657	.1450	-.0342
	11-20	-.0436	-.0605	.0399	.0058	-.0705	-.0150	.0395	.0157	.0790	-.0751
	21-30	-.0027	.1390	.0033	-.0516	-.0565	-.1280	.0121	-.765	-.0641	-.0999
	51-60	.0610	-.0182	-.1340	.0934	-.0533	-.0210	-.0728	.0193	-.0233	-.0830

First Differenced Data
101 Observations

	Lags	1	2	3	4	5	6	7	8	9	10
AC	1-10	**-.3555**	-.0053	**-.2023**	.0353	.0149	.0965	.0739	**-.2497**	.1040	-.0088
	11-20	.1102	-.1071	.0391	-.0187	-.0381	.0115	-.0268	-.0098	.0772	.0089
	21-30	-.1252	.0663	.0152	.0449	.0602	-.1173	-.1308	.1427	.0878	-.0685
	51-60	.1014	-.0213	-.0007	.0511	-.0777	.0635	-.0693	.0780	-.1045	.0825
PAC	1-10	**-.3555**	-.1508	**-.3024**	**-.2136**	-.1515	-.0384	.1017	**-.2043**	-.0416	.0026
	11-20	.0511	-.0550	-.0116	.0572	-.0238	-.0945	-.0971	-.1157	.0328	-.0209
	21-30	-.1692	-.0153	.0190	.0204	.1239	-.0240	-.1398	.0653	.0706	-.0753
	51-60	.0062	.1092	-.0554	.0676	.0349	.0827	.0135	-.0088	-.0197	-.0612

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.10 cont. Estimated Autocorrelations and Partial Autocorrelations of Phoenix Price Data.

Weekly Average Feeder Cattle Prices.

Second Differenced Data
100 Observations

		1	2	3	4	5	6	7	8	9	10
AC Lags	1-10	a **-.6292**	**.2102**	-.1705	.1025	-.0397	.0384	.1203	**-.2641**	.1805	-.0970
	11-20	.1336	-.1365	.0756	-.0131	-.0212	.0329	-.0346	-.0153	.0556	.0269
	21-30	-.1189	.0803	-.0251	.0034	.0788	-.0644	-.1043	.1204	.0347	-.0726
	51-60	.1421	-.0555	.0059	.0627	-.1026	.0997	-.1159	.1419	-.1441	.1166
PAC Lags	1-10	**-.6292**	**-.3073**	**-.3491**	**-.3138**	**-.2981**	**-.2849**	.0944	-.0860	-.0768	-.0706
	11-20	.0387	-.0201	-.0802	.0116	.0701	.0451	.0151	-.1247	-.0170	.1033
	21-30	-.0734	-.0754	-.0277	-.0678	.0958	.1243	-.1033	-.0308	.1121	.0296
	51-60	-.0813	.0786	-.0401	.0252	.0056	.0667	.0294	.0141	.0336	.0037

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.11 Estimated Autocorrelations and Partial Autocorrelations of Tucson Price Data.

Weekly Average Feeder Cattle Prices.

Undifferenced Data
102 Observations

	Lags	1	2	3	4	5	6	7	8	9	10
AC	1-10	[a]**.5241**	**.5850**	**.3506**	**.3155**	**.2237**	.1839	.0850	.0634	.0413	.0620
	11-20	.0144	.0046	.0039	.0542	.0760	.1049	.1219	.0303	.1279	.1298
	21-30	.1848	.1562	.1446	.1248	.1736	.1676	.1768	.1263	.0699	.0308
	51-60	-.0130	-.0530	-.0578	-.1034	-.0633	-.1580	-.1406	-.1792	-.1316	-.1297
PAC	1-10	**.5241**	**.4279**	-.0827	-.0399	.0262	.0063	-.0949	-.0188	.0567	.0651
	11-20	-.0616	-.0531	.0477	.1093	.0429	.0107	.0499	-.1487	.0934	.1515
	21-30	.0599	-.0392	-.0372	.0168	.0992	.0460	.0192	-.0119	-.1258	-.1000
	51-60	-.1161	-.0669	-.0318	.0299	.0388	-.1190	.0238	.0290	-.0056	.0183

First Differenced Data
101 Observations

	Lags	1	2	3	4	5	6	7	8	9	10
AC	1-10	**-.5835**	**.3200**	**-.2027**	.0636	-.0748	.0878	-.1032	.0160	.0369	.0894
	11-20	-.0897	.0095	-.0692	.0422	-.0217	.0209	.1005	-.1979	.1272	-.0627
	21-30	.0631	.0118	.0220	-.0548	.0560	-.0367	.0608	.0004	-.0089	-.0127
	51-60	-.0686	-.0175	.0323	-.0943	.1099	-.0876	.0254	-.0425	.0425	-.0240
PAC	1-10	**-.5835**	-.0311	-.0430	-.0995	-.1137	.0179	-.0593	-.1387	-.1133	.0540
	11-20	-.0348	-.1575	-.1826	-.0915	-.0772	-.1217	.0977	-.1585	**-.2118**	-.1193
	21-30	-.0420	-.0050	-.0189	-.0868	-.0733	-.1078	-.0464	.1290	.0887	-.0225
	51-60	.0182	.0161	-.0127	-.0500	.0309	-.1127	-.1566	-.0149	.0109	-.0471

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

Table 4.11 cont. Estimated Autocorrelations and Partial Autocorrelations of Tucson Price Data.

Weekly Average Feeder Cattle Prices.

Second Differenced Data
100 Observations

		1	2	3	4	5	6	7	8	9	10
AC											
Lags	1-10	[a] **-.7855**	**.4527**	**-.2506**	.1263	-.0914	.1085	-.0961	.0522	-.0571	.1038
	11-20	-.0974	.0651	-.0670	.0575	-.0324	-.0127	.1184	-.1983	.1665	-.1012
	21-30	.0529	-.0155	.0226	-.0563	.0675	-.0633	.0521	-.0177	-.0002	.0024
	51-60	-.0976	.0024	.0554	-.1069	.1322	-.1053	.0611	-.0493	.0446	-.0298
PAC											
Lags	1-10	**-.7855**	**-.4291**	**-.2546**	**-.2012**	**-.2682**	-.1372	-.0532	-.0936	**-.2354**	-.0869
	11-20	.0367	.0265	-.0789	-.0808	-.0284	**-.2037**	.0766	.0703	-.0625	-.1146
	21-30	-.1107	-.0653	.0059	-.0218	.0137	-.0398	-.1500	-.0147	.1182	.1744
	51-60	-.0334	.0175	.0486	-.0460	.0870	.0867	-.0756	-.0684	-.0046	-.0404

a Boldface values are significantly different from zero using Bartlett's test at the 5% level.

values for the undifferenced data for all locations outside of Arizona start out high and decrease very slowly. The Arizona AC values appear to decay more rapidly. Looking at the tables of the first differences, the AC values start out much smaller and decrease rapidly towards zero and fluctuate. Finally, in examining the tables for the second differenced data, the AC values all start out fairly large and negative declining to insignificant levels rapidly. The PAC values for the second differenced data tend to trail off more slowly. This pattern would tend to indicate that a moving average structure has been introduced into the data, indicative of overdifferencing as mentioned in Plosser and Schwert, (1978). For the Arizona data, the AC values for the original data do not strongly indicate nonstationarity; however the first differences do not show the evidence of an introduced moving average term as appears in the second differences of the other locations. The second differences of the Arizona data suggest that a moving average term has been introduced. Based on the evidence, it would appear that differencing the data at least once is necessary while differencing it twice is unnecessary.

Other, more involved methods of examining the data for stationarity have been proposed, such as those of Dickey-Fuller as explained in Schwert (1987) and more recently a graphic method has been suggested by Cressie (1988). The use of the stationary first differenced data also fits in with the model presented in chapter 3, which examines <u>changes</u> in prices rather than levels or changes in changes.

<u>Lag Selection</u>

The empirical model discussed in the last part of chapter 3 requires a set of lags to model the price adjustment structure between locations within the market, or to identify price independence between locations. Ideally, the number of lags used in the model will be the "true" number which apply, although this is seldom known with certainty in applied work. It is generally preferred to base the lag specification on *a priori* grounds, which will presumably reflect the "true" lag order, rather than an *a posteriori* specification, which enhances the likelihood that the model design will confirm or reject hypotheses rather than test hypotheses. Additionally, an *a posteriori* selection is more likely to produce data specific results which will not hold up in out of sample use.

When the lag structure is not specified on *a priori* grounds, it must be selected through either *ad hoc* or statistically objective procedures, however even the more objective procedures are based on a subjective trade-off between the costs of using too few lags and using too many. *Ad hoc* methods may be based on the experience and intuition of market observers and participants, thus generating a lag structure on partially *a priori* grounds. The more objective methods may allow a greater set of lags to be tested in order to try to find the best statistical fit and identify the lag relationships existing when *a priori* information is not sufficient. Regardless of the procedure used to select the lags, the resulting lag structure must generate uncorrelated residuals in order to allow statistically valid hypothesis testing.

Studies have shown that Granger causality models, somewhat similar to the model used here, are sensitive to the lag structure selected. Nakhaeizadeh

(1987) conducted Granger tests on West German economic data using a series of lag structures. The F-statistics showed contradictory causality results depending on the number of lags used. Jones (1989) examined several *ad hoc* lag selections and three statistical search methods for lag length determination, reviewing an earlier study by Thornton and Batten (1985) of these lag specification procedures.[2] The results of Jones' analysis contradicted some of the conclusions of Thornton and Batten regarding the value of *ad hoc* lag specifications; however, both found the Final Prediction Error (FPE) method of lag determination to perform better than the other statistical methods examined when assessed for finding causality which was determined to exist following a global lag search. While the FPE method performed better than the other statistical methods, Jones (1989).found that one of the *ad hoc* methods was even more accurate.

As a result of the studies finding Akaike's FPE method to perform the best of the statistical methods studied and its usage in recent causality testing studies (see Bailey and Brorsen, 1985, Chowdhury, 1987), the Akaike FPE method as developed in Hsiao (1979) was used to estimate the initial lag specifications used in the model.

Akaike FPE Method

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[2]The *ad hoc* lag structures investigated were of equal length and a "rule-of-thumb" structure which were suggested in Thornton and Batten (1985). The statistical lag structures were the FPE (Final Prediction Error) of Akaike as proposed in Hsiao (1981), the Baysian Economic Criterion (BEC) found in Geweke, Meese, and Dent (1983), and the Pagano-Hartley (P-G) method found in Pagano and Hartley (1981).

The following explanation of the FPE method is based on Hsiao (1979). Distributed lag models face a trade-off between unbiasedness and efficiency in the lag length selected. If a lag structure of a lower order than the "true" order is selected, the coefficient estimates will be efficient but biased by the effects of the missing lags and the residuals will be serially correlated. If a higher order lag structure is chosen the coefficient estimates will be unbiased but inefficient. Thus, the FPE method provides a weighting scheme to balance this trade-off, putting more emphasis on achieving unbiased estimates than efficient ones.

Hsiao defined the FPE as the (asymptotic) mean square prediction error, or

$$\text{FPE of } Y_t = E(Y_t - \hat{Y}_t)^2 \tag{4.10}$$

where $\hat{Y}_t$ is the least squares estimate of Y_t from the equation

$$Y_t = \psi_{11}^m(L)Y_t + \psi_{12}^n(L)X_t + a + e_t \tag{4.11}$$

The values m and n represent the order of the lags in $\psi_{11}(L)$ and $\psi_{12}(L)$. The estimate of the FPE is then defined as

$$\text{FPE}_Y(m,n) = \frac{T+m+n+1}{T-m-n-1} \cdot \sum_{t=1}^{T}\left(Y_t - \hat{Y}_t\right)^2 \tag{4.12}$$

where T is the total number of observations used in the estimation process. The lag specification selected has the lowest FPE from the calculated set of FPE's for lags up to the highest *a priori* specified order M. Hsiao also suggested a method to determine this order without calculating every FPE up to m,n=M in order to reduce the size of the search to approximately 2M equations.

The lags initially selected using the shortcut suggested by Hsiao (1979) failed to select the lags with the minimum FPE in several cases when tests to confirm the results, suggested by Hsiao, were performed. As a result, a global search was undertaken using a maximum of 30 lags to identify the lag structures for the WLMIP locations using the six year data period. The lags resulting from the global search are presented in Table 4.12. While varying considerably in length, one or two week lags were the most frequently selected.

The FPE minimizing lags were then used to specify the empirical model. The model was estimated, but when the Q statistics were examined, the null hypothesis of no autocorrelation was rejected in 17 out of the 56 cases at the 5% level. Due to the importance of having no significant autocorrelation in the residuals, the FPE lags were no longer used and an *ad hoc* search was conducted using equal lags until all significant autocorrelation, based on the Q statistics, was removed.

Ad hoc Lag Selection

The failure of the FPE method to remove autocorrelation in the residuals resulted in the use of *ad hoc* methods to select the final lag lengths for the model. A sequential process was used, beginning with two lags on both the lagged dependent and independent variables of equation 3.22. The resulting Q statistics were examined for the absence of autocorrelation in the residuals at the 5% level of confidence.

The lag lengths were increased and the model re-estimated until sixteen lags were reached. At this point, all Q statistics were no longer rejected at the 5% level of confidence. Many of the location pairs failed to reject the hypothesis of no autocorrelation at lower numbers of lags; however, in order

Table 4.12 Selected Number of Lags Using the FPE Criterion for 1983-1988.

	Amarillo	Clovis	Colorado	Florida	Kansas City	Oklahoma City	Shasta	Stockton
Amarillo	1*	2,2	2,14	2,18	1,1	2,18	8,1	1,1
Clovis	4,3	1	4,3	4,18	4,3	3,3	3,3	3,1
Colorado	2,1	2,1	2	2,1	2,2	2,1	3,3	1,1
Florida	1,1	1,2	1,2	1	1,5	1,1	1,1	1,1
Kansas City	2,1	2,1	2,2	2,1	2	2,1	2,1	1,1
Oklahoma City	1,1	1,1	1,1	1,1	1,1	1	1,1	1,1
Shasta	1,1	1,1	1,1	1,1	2,1	2,3	1	1,1
Stockton	3,4	8,5	3,4	4,3	2,16	4,2	6,8	4

* Bold values refer to the bold dependent variables on the left. Single values on the diagonal refer to the univariate determination.

to assure comparability of the results across pairs, a common lag structure was desired. In addition, the inclusion of unnecessary lags creates inefficient but unbiased results. The use of hypothesis tests to analyze the results makes unbiasedness a desirable characteristic of the results. Equal lags of sixteen weeks were used to estimate the model in equation 3.22 and to conduct the hypothesis tests reported in chapter 5.

Blank and Schmiesing (1990) examined the effects of data aggregation on lag selection and Granger causality test results. They noted that when price adjustment processes are being examined, data aggregation may produce misleading results. If the level of aggregation is greater than the period required for price adjustment, the dynamic adjustment process will not be captured by the empirical model. In addition, statistical techniques for lag selection may produce results which are dependent on the level of data aggregation rather than the actual adjustment process. Blank and Schmiesing (1990) found that as the level of aggregation increases, Granger causality tests are less likely to reject tests for no instantaneous causality. Thus, results which find a high degree of instantaneous adjustment using aggregated data may indicate that the data have been overly aggregated and the price adjustment process is no longer being captured.

The price data in this study are weekly averages which aggregate pricing activity occurring on a daily basis. This may cause an aggregation problem in the analysis; however sufficient information is not available to use daily prices to test whether a problem exists. Thus the results must be viewed with this cautionary note. Additionally, the hypothesis tests presented in the next chapter only rarely show instantaneous adjustment to be occurring, thus the evidence that data aggregation is masking the adjustment process is not strong.

Chow Tests for Structural Changes

The change in the method of settlement of feeder cattle futures contracts from physical delivery to cash settlement in September, 1986, may have resulted in changing the pricing relationships between locations. The model and hypothesis tests were estimated for the periods of January, 1983 to August, 1986 when futures contracts were settled with physical delivery, and September, 1986 to December, 1988 when futures contracts were under the new cash settlement system. To compare the results for significant changes in the pricing structure, Chow tests were performed.

The Chow test is used to determine whether a data set is adequately represented by a single model or by two different models. The test , as described in Pindyck and Rubinfeld (1981), is summarized here. Using the Chow test, an F-statistic is calculated from the equation

4.13
$$F_{k,\,n+m-2k} = \frac{(ESS_R - ESS_{UR})/k}{ESS_{UR}/(n+m-2k)}$$

where k represents the number of variables in the equation, n represents the number of observations in the second period, and m represents the number of observations in the first period. ESS_R is the restricted error sum of squares, calculated from the model estimated over the entire period. ESS_{UR} is the unrestricted error sum of squares, calculated as the sum of the error sum of squares from the equations for the two sub-periods. Under the lag structure used in this study, some observations and degrees of freedom are lost in the unrestricted model at the start of the September, 1986 to December, 1988 period while the lagged variables are initialized. Since the total number of observations in the restricted and unrestricted equations must be equal, the restricted model was set up defining the lagged variables, then omitting the observations during the period when the unrestricted model was re-initialized. This process is illustrated in Figures 4.21A and B.

The hypothesis tests associated with equation 3.22 were conducted using the periods prior to and after the introduction of cash settlement of feeder cattle futures contracts to identify what pricing changes among locations occurred between the two time periods.

The following results are reported in the next chapter: The average price differentials between locations, cross-correlations of the undifferenced and differenced data, hypothesis test results for the price matching models, and Chow test results for changes in pricing structures corresponding with the initiation of cash settlement of feeder cattle futures contracts.

CHAPTER 5

RESULTS

This chapter presents the results of the data analysis in three primary sections. The first section covers the eight WLMIP locations for the 1983-1988 period. The second section covers the WLMIP locations and two Arizona locations, Phoenix and Tucson, during the 1987-1988 period. The third section examines whether the model can identify any structural changes in price behavior corresponding with the change to cash settlement of feeder cattle futures contracts. The first two sections begin with a brief discussion of the price differences between locations and the distances involved. This is followed with a presentation of the price correlations for the undifferenced and first differenced data. The results of the hypothesis tests of the empirical pricing model developed in chapter 3 are presented as the third part of the first two sections. The third section presents the results of Chow tests for significant structural changes and discusses the changes found.

It should be noted again that the term "long-run" as used here is not defined in the same manner as it is usually used in economic terminology. The long-run here is only 16 weeks, approaching the length of time required for a feedlot to turn a 600-700 pound steer into a slaughter animal; however it is far shorter than the biological lags (around 16 months or more from conception) involved in producing a 600-700 pound steer to enter the feedlot and represents a fairly short time span in the life of feedlot facilities. The meaning of long-run is intended to reflect the maximum amount of time for any price interactions and feedback to occur between locations.

1983-1988

The WLMIP data were first examined over the January, 1983-December, 1988 time period. Average price differences, corss-correlations, and hypothesis tests of the empirical model of chapter 3 were calculated. These results and their implications are reported below.

Locational Price Differences

The WLMIP data were used to calculate average price differences between locations. Summary statistics of the price differences are presented in Table 5.1. Oklahoma City has the highest average prices overall, followed by Kansas City, Colorado, Amarillo, Shasta, Stockton, Clovis, and Florida. Oklahoma City was a par delivery point for feeder cattle futures contracts until September, 1986 when cash settlement was initiated. Kansas City was a delivery point at $0.25/cwt below par while Greeley, Colorado (represented by the Colorado data) and Amarillo were $0.50/cwt below par delivery points. Oklahoma City and Kansas City are also terminal markets while the others are not. The price levels of the first four locations follows their ordering as delivery points during physical delivery of feeder cattle futures contracts while the last four locations except Florida follow a pattern of declining volume. Florida, the third highest volume location but also one of the most distant from the central plains feeding region, had the lowest average price level. The standard deviations of the price differences were smallest between Oklahoma City-Colorado, Kansas City-Colorado, Oklahoma City-Amarillo, and Oklahoma City-Kansas City. The largest standard deviation was between Florida-Shasta, the two most distant markets.

Table 5.2 shows the estimated distances between locations and the resulting price differences in dollars per mile. Since transfer costs fluctuate depending on whether the truck has a load on the backhaul or not, shrinkage, and other costs, these values show the

Table 5.1 Average Weekly Price Differentials and Standard Deviations Between Locations During the Period 1983-1988.

	Amarillo	Clovis	Colorado	Florida	Kansas City	Oklahoma City	Shasta	Stockton
Amarillo		1.18*	-1.47	4.54	-1.56	-2.11	.95	1.61
Clovis	1.99		-2.74	3.43	-2.86	-3.42	- .10	.53
Colorado	2.08	2.19		6.01	- .09	- .65	2.42	3.08
Florida	3.01	3.36	3.17		-6.10	-6.66	-3.59	-2.93
Kansas City	2.38	2.48	1.60	3.09		- .55	2.51	3.18
Oklahoma City	1.76	2.06	1.57	3.11	1.90		3.06	3.73
Shasta	3.36	3.30	2.92	4.28	3.22	3.04		.66
Stockton	2.53	2.69	2.45	3.64	2.81	2.39	2.64	

*Values in the upper-right are the average weekly price differentials ($/cwt) between the location listed at the left less the location listed at the top. Values in the lower-left are the standard deviations between the location listed at the top less the location listed at the left.

Table 5.2 Approximate Distances Between Locations and Average Price Differences Per Mile of Distance ($/mile) on a Transport Cost Basis, 1983-1988.

	Amarillo	Clovis	Colorado[1]	Florida[2]	Kansas City	Oklahoma City	Shasta	Stockton
Amarillo		4.72[3]	1.20	1.20	1.04	3.25	0.25	0.50
Clovis	100[4]		1.83	0.85	1.61	3.80	0.03	0.17
Colorado[1]	490	600		1.23	0.05	0.37	0.74	1.04
Florida[2]	1510	1610	1950		1.79	2.13	0.48	0.42
Kansas City	600	710	660	1360		0.63	0.51	0.71
Oklahoma City	260	360	700	1250	350		0.70	0.97
Shasta	1500	1430	1300	3010	1960	1760		1.26
Stockton	1290	1220	1190	2790	1790	1540	210	

[1]Distances calculated to Greeley, Colorado.
[2]Distances calculated to Ocala, Florida.
[3]Calculated from the average weekly price differentials (Table 5.1) in $/cwt times an approximate 400 cwt per truckload divided by the distance.
[4]Distances are calculated using the most direct interstate and primary roadways between the locations, based on mileage estimates from Rand McNally Road Atlas, Chicago: Rand McNally & Company, 1986, and rounded to the nearest 10 miles.

average transfer rate per mile which would equalize prices between locations given the direction of the price differentials shown in Table 5.1. The highest differential on this basis lies between Clovis-Amarillo, the closest two locations, followed by Clovis-Oklahoma City, Amarillo-Oklahoma City, and Florida-Oklahoma City. The smallest differential lies between Clovis-Shasta. These calculations are based on a full truck load. If the volume at a location is insufficient to generate full loads, costs may increase substantially for carrying partial loads or for covering yardage and capital costs while full loads are assembled. The range of price differences ($0.03-$4.72) may also reflect differing amounts of shrinkage which may occur as distances vary, or other factors including costs of cattle production or feeding, feeder cattle surplus or deficit situations, differing quality or breeding characteristics, climatological differences affecting performance, sales practices (buyer competition, prevalence of direct sales, auction markets, terminal markets, or other forms of selling), the availability of products for backhauling, or slaughter cattle prices in these locations. It should be noted that cattle are not necessarily shipped between all of the locations. Furthermore, these values are <u>not</u> transport rates, but rather the maximum amount which an arbitrageur could pay, on average, to ship cattle between locations without suffering a loss.

<u>Cross-correlations</u>

Cross-correlations of prices were calculated between the eight WLMIP locations for both the undifferenced and differenced data. These values are shown in Table 5.3 and Figures 5.1 and 5.2. All correlations among the undifferenced data are quite high. The highest correlation, .98, occurs between some of the former physical delivery locations, Amarillo-Oklahoma City, Colorado-Kansas City, Colorado-Oklahoma City, and between the closest location pairing, Amarillo-Clovis. Other locational correlations are lower,

Table 5.3 Cross-correlations of Undifferenced and First Differenced Price Data, 1983-1988.

	Amarillo	Clovis	Colorado	Florida	Kansas City	Oklahoma City	Shasta	Stockton
Amarillo		.98*	.97	.93	.96	.98	.94	.96
Clovis	.28		.97	.93	.96	.97	.95	.96
Colorado	.35	.17		.93	.98	.98	.96	.96
Florida	.36	.17	.18		.93	.94	.90	.91
Kansas City	.39	.16	.32	.24		.98	.95	.95
Oklahoma City	.65	.30	.47	.33	.38		.95	.96
Shasta	.20	.15	.31	.11	.29	.38		.96
Stockton	.24	.05	.13	.22	.14	.34	.14	

*Values in the upper-right are the cross-correlations of the undifferenced data. Values in the lower-left are the cross-correlations of the first differenced data.

Figure 5.1 Cross-correlations of Undifferenced WLMIP Data for the Period 1983-1988.

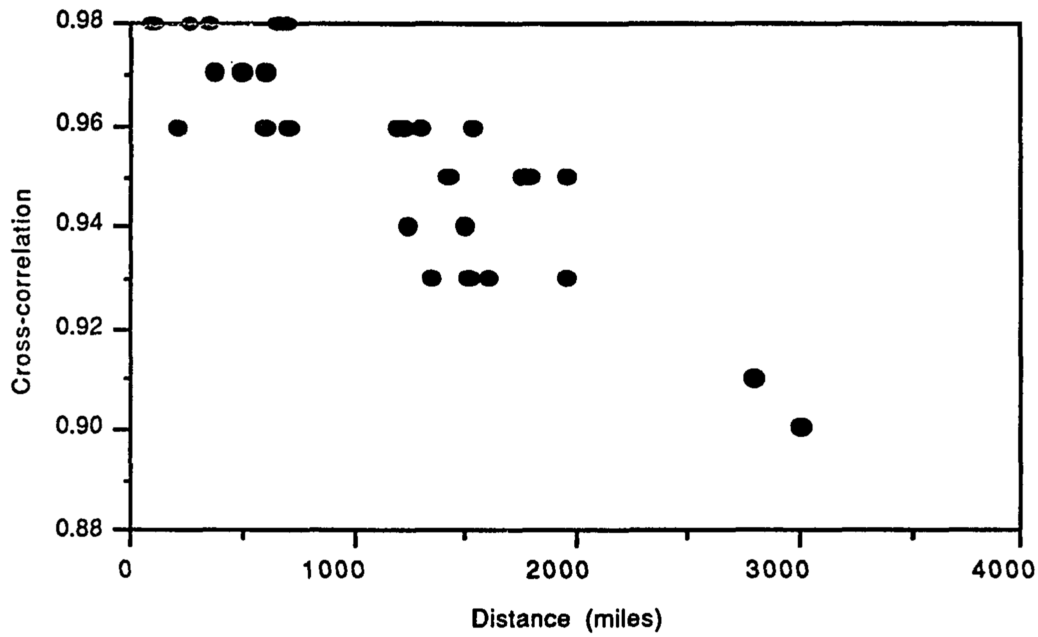
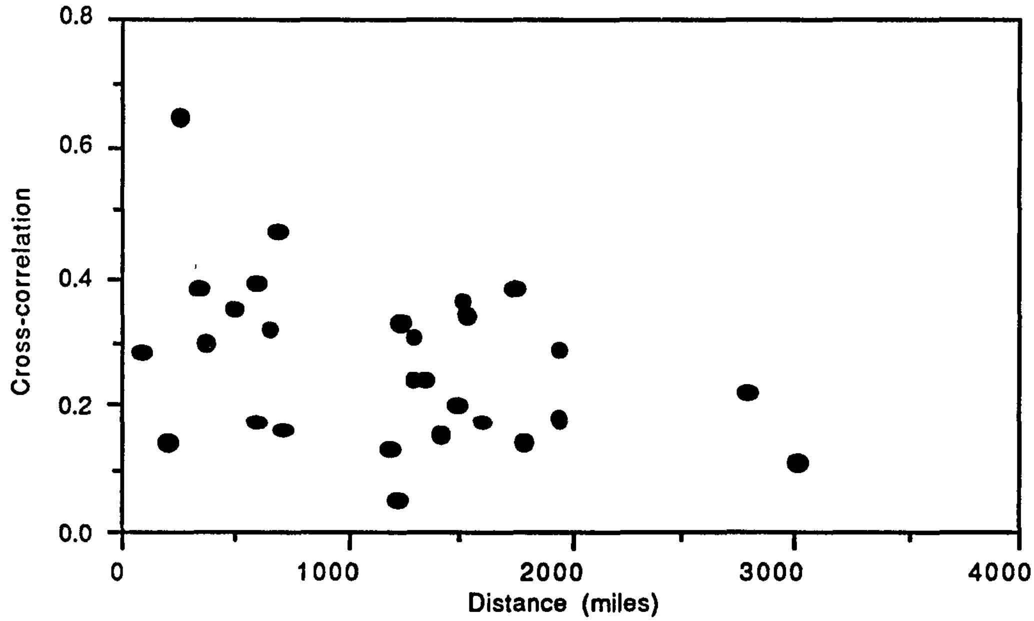


Figure 5.2 Cross-correlations of First Differenced WLMIP Data for the Period 1983-1988.



although the lowest is still .90 between Florida and Shasta, the two most distant locations. The correlations show a tendency to decline with distance, as can be seen in Figure 5.1. The lowest correlations involve Florida, the most distant location from the others.

The high correlations among the undifferenced data are not surprising given the discussion of Blyn (1973) and Harriss (1979) regarding commonality among trends or seasonal factors. The correlations are also similar to those obtained in studies of some other types of markets, such as in Leavitt, Hawkins, and Vreeman (1983), and Spiller and Huang (1986). The high correlations tend to indicate that general economic conditions (the general price level, aggregate cattle numbers, and changes in feed costs or beef demand at the national level, to mention a few) are reflected in all locations, but may not indicate much about competition at any one location, between locations, or the price adjustment process between locations.

The correlations of the first differences show much more variation between locational pairs with the highest being .65 between Oklahoma City and Amarillo, and the lowest being .05 between Stockton and Clovis. This contrasts with the low variation among the undifferenced pairs. Since the effects of more general economic conditions are removed, the differenced results are more likely to reflect the contemporaneous price interactions between locations. With this assumption, though, the interactions between locations are important in most cases yet other factors which are likely to be local in nature play a highly influential role in the price changes.

The highest correlations between pairs generally occur with Oklahoma City, the exceptions being with Florida and Kansas City, both of which are most highly correlated with Amarillo. In addition, the highest correlations between locations tend to involve

Amarillo, Colorado, Oklahoma City, and, to a lesser extent, Kansas City, as one side of the pair. Interestingly, the correlation between the two California locations, Shasta and Stockton, is quite low at .14, although the highest correlations of both locations are with Oklahoma City.

The apparent inverse relationship between correlation and distance in the undifferenced data tends to disappear in the results from the first differenced data (see Figure 5.2). The coefficient between Clovis-Amarillo lies in the middle of the range, although the lowest value is again between Florida-Shasta. Strangely, the Florida-Stockton correlation is double that for Florida-Shasta, and the Shasta-Stockton correlation is close to the lowest overall, even though the two locations are very close together geographically. It would appear that while distance may have some effect on the correlations, particularly with the undifferenced data, other factors play a much more important role in determining the correlations between locations, especially in the differenced data.

Pricing Model Results

Estimating the empirical model presented in equation 3.22 and testing the four pricing hypotheses for all combinations of the eight WLMIP locations over the January, 1983 to December, 1988 period resulted in fifty-six equations with four restrictions and corresponding hypothesis tests for each equation. The data for this period consisted of a maximum of 311 first difference observations, the first 16 being used to initialize the variables. The F-statistics, the statistic used in other empirical applications of Ravallion's model (see Ravallion, 1986, and Faminow and Benson, 1990), are presented in Table 5.4. The results are generated and presented in a different manner from most hypothesis tests in that failure to reject is not considered a negative outcome for the hypothesis. This occurs because the tests are comparing each restricted hypothesis as the null hypothesis against the general model of equation 3.22, the alternative hypothesis. The results of the hypothesis tests for independence, long-run price matching, weak form short-run price matching, and strong form short-run price matching follow.

Independence

The hypothesis of independence between location pairs is rejected in favor of the alternative hypothesis of interdependence at the 5 % level of confidence for all pairs, as shown by the F-statistics presented in column (a) of Table 5.4. Price changes are interdependent with those at other locations. The four largest F-statistics, in which independence is rejected the most strongly, occur between the Oklahoma City-Amarillo, Amarillo-Oklahoma City, Oklahoma City-Colorado, and Colorado-Oklahoma City orderings in which the first location in each pair is treated as the dependent variable. The smallest four F-statistics, in which independence is rejected the least strongly, occur between the Shasta-Florida, Shasta-Clovis, Clovis-Stockton, and Florida-Clovis orderings, again in which the first location in each pair is treated as the dependent variable. This grouping is much less symmetric than the grouping of the strongest four rejections of independence.

The location pairs comprising the four strongest rejections of independence are also the orderings which had the highest contemporaneous cross correlations of first differences in Table 5.3, Amarillo-Oklahoma City and Colorado-Oklahoma City. In contrast to this, the four pairs in which independence is rejected least strongly, in addition to being asymmetric, do not reflect the smallest contemporaneous cross correlations. The smallest F-statistic lies with the Shasta-Florida ordering, yet the

Table 5.4 F-Statistics for Price Matching Models, 1983-1988.

Independent Location Variable	Independence (a)	Long-run Price Matching (b)	Short-run Price Matching (Weak) (c)	Short-run Price Matching (Strong) (d)
		Amarillo		
Clovis[1]	4.62	18.56	124.48	19.76
Colorado[2]	6.83	*3.87	79.63	9.97
Florida[3]	4.81	20.68	144.89	13.22
Kansas City[2]	4.34	3.89	63.15	6.52
Oklahoma City[2]	17.88	*3.14	20.18	5.04
Shasta[2]	3.76	4.21	153.60	15.52
Stockton[2]	2.43	11.41	117.62	13.71
		Clovis		
Amarillo[1]	8.88	**1.68	12.49	7.21
Colorado[1]	4.95	**0.28	24.68	6.90
Florida[4]	3.77	10.30	58.32	8.22
Kansas City[1]	3.36	**1.86	27.73	5.73
Oklahoma City[1]	6.46	**0.66	11.76	5.41
Shasta[1]	2.76	*2.79	49.83	7.16
Stockton[1]	1.88	9.11	45.37	8.80
		Colorado		
Amarillo[2]	6.08	9.11	31.18	5.85
Clovis[1]	2.99	17.43	120.00	16.43
Florida[3]	2.20	16.35	134.90	11.97
Kansas City[2]	6.38	6.21	32.78	7.63
Oklahoma City[2]	10.70	10.60	19.96	5.74
Shasta[2]	5.12	6.93	71.30	10.22
Stockton[2]	3.11	16.41	112.17	14.13
		Florida		
Amarillo[3]	5.45	*2.97	17.99	3.48
Clovis[4]	2.01	10.90	69.84	9.24
Colorado[3]	2.46	**1.64	45.98	5.31
Kansas City[3]	3.83	**1.22	35.75	4.93
Oklahoma City[3]	3.74	**2.16	22.52	2.98
Shasta[3]	2.16	*2.91	85.06	8.11
Stockton[3]	2.81	6.22	60.64	7.36

*Not Rejected at the 95% Level of Confidence.
**Not Rejected at the 90% Level of Confidence.
[1](a)F(17,226),(b)F(1,226),(c)F(2,226),(d)F(33,226)
[2](a)F(17,262),(b)F(1,262),(c)F(2,262),(d)F(33,262)
[3](a)F(17,261),(b)F(1,261),(c)F(2,261),(d)F(33,261)
[4](a)F(17,225),(b)F(1,225),(c)F(2,225),(d)F(33,225)

Table 5.4 cont. F-Statistics for Price Matching Models, 1983-1988.

Independent Location Variable	Independence (a)	Long-run Price Matching (b)	Short-run Price Matching (Weak) (c)	Short-run Price Matching (Strong) (d)
		Kansas City		
Amarillo[2]	5.50	15.48	49.42	5.50
Clovis[1]	2.13	25.51	156.36	17.22
Colorado[2]	8.73	5.50	68.88	11.06
Florida[3]	2.97	21.49	136.19	12.67
Oklahoma City[2]	5.00	*3.41	44.48	5.09
Shasta[2]	4.44	12.97	108.67	11.38
Stockton[2]	2.64	18.32	126.01	14.83
		Oklahoma City		
Amarillo[2]	18.44	4.43	25.79	5.52
Clovis[1]	4.09	14.24	143.52	18.36
Colorado[2]	11.16	**0.81	65.55	9.87
Florida[3]	3.51	16.26	164.56	13.08
Kansas City[2]	5.93	*2.86	61.61	8.00
Shasta[2]	6.46	4.30	132.34	12.61
Stockton[2]	4.21	12.63	124.21	13.84
		Shasta		
Amarillo[2]	3.28	12.56	33.70	5.63
Clovis[1]	1.82	15.08	101.61	11.63
Colorado[2]	7.17	4.98	34.77	6.94
Florida[3]	1.79	17.60	109.17	9.90
Kansas City[2]	5.24	4.62	37.62	5.65
Oklahoma City[2]	5.86	8.43	18.09	3.70
Stockton[2]	3.01	14.50	71.21	10.44
		Stockton		
Amarillo[2]	5.84	**2.33	34.73	6.49
Clovis[1]	3.64	5.28	113.92	15.58
Colorado[2]	4.96	**0.95	56.85	9.11
Florida[3]	4.13	6.76	89.17	9.64
Kansas City[2]	5.18	**1.26	55.92	8.62
Oklahoma City[2]	6.50	**1.56	25.37	5.41
Shasta[2]	5.43	**2.05	84.56	11.66

*Not Rejected at the 95% Level of Confidence.
**Not Rejected at the 90% Level of Confidence.

[1](a)F(17,226),(b)F(1,226),(c)F(2,226),(d)F(33,226)
[2](a)F(17,262),(b)F(1,262),(c)F(2,262),(d)F(33,262)
[3](a)F(17,261),(b)F(1,261),(c)F(2,261),(d)F(33,261)
[4](a)F(17,225),(b)F(1,225),(c)F(2,225),(d)F(33,225)

Florida-Shasta pair has the second smallest cross-correlation in Table 5.3. The smallest cross correlation, between the Stockton-Clovis pairing, is only represented by the Stockton-Clovis ordering, which has the third smallest F-Statistic. Neither ordering for the second smallest cross-correlation, between the Colorado-Stockton pair, shows up among the smallest F-statistics for the independence hypothesis.

The strongest and weakest rejections of independence tend to reflect their strong or weak cross-correlation statistics, however the association is not exact. In addition, the contemporaneous cross correlation coefficient does not appear to provide a clear indication of strong interdependence or independence between locations. A cross-correlation coefficient of .05, as in the case of the Clovis-Stockton pair, would often be interpreted as suggesting no relationship, or at best an extremely weak relationship. This contrasts with the explicit test of the independence hypothesis, involving lags, in which independence is rejected. Direct contemporaneous interdependence may be low, however when lags are introduced to allow for an adjustment period, interdependence does become apparent.

Long-run Price Matching

The long-run price matching results, column (b), are discussed in the order in which the locations are presented as the dependent variable in Table 5.4. The hypothesis is not rejected in twenty of the fifty-six tests. Seven of these failures to reject occur only at the 5% level of confidence while the other thirteen occur at the 10% level of significance.

Amarillo

The long-run price matching hypothesis is rejected for five of the seven locations paired against the dependent variable Amarillo. The only two pairings for which it is not rejected are Colorado and Oklahoma City, the two high volume locations nearest Amarillo. It would appear that Amarillo reacts to match price changes in these two locations, maintaining its market area, as part of the spatial adjustment process. The impact of pricing changes from the other five locations does not play a large role in determining price matching activity in Amarillo.

Clovis

With Clovis as the dependent variable, long-run price matching is not rejected at the 10% level of confidence for the four more prominent locations scattered around the central and southern plains cattle feeding region (Amarillo, Colorado, Kansas City, and Oklahoma City). Long-run price matching is also not rejected, but only at the 5% level, for Shasta. The hypothesis of long-run price matching is rejected when Florida and Stockton are used as the independent variables. The pattern of long-run price matching suggests a strong price adjustment relationship with the other locations. The four locations showing the strongest relationships may also provide substantial pricing information for the smaller Clovis market to use as a basis for pricing.

Colorado

The long-run price matching hypothesis tests using Colorado as the dependent variable are rejected in all cases. Price changes in other locations are not fully matched by price changes in Colorado although the markets are still interdependent. Market conditions and price changes in Colorado may serve to lead price changes in other locations. Thus, Colorado might be seen as a leading or central market location. Alternatively, Colorado may obtain important price change information from other locations not examined here or it might be isolated enough that localized effects are far more important than price changes in the seven other locations. The smallest two F-statistics, while resulting in a rejection of the long-run price matching hypothesis, occur when Kansas City and Shasta serve as the independent variables.

Florida

When Florida serves as the dependent variable, the results show a failure to reject long-run price matching at the 10% level for three major locations, Colorado, Kansas City, and Oklahoma City. At the 5% level, the hypothesis cannot be rejected for the additional locations of Amarillo and Shasta. Long-run price matching is rejected with Clovis and Stockton.

Kansas City

The Kansas City results show that long run price matching is not rejected at the 5% level only when Oklahoma City is paired as the independent variable. Oklahoma City is the closest of the other seven locations to Kansas City. Although the hypothesis is rejected with the other locations, the second smallest F-statistic occurs with Colorado. All other F-statistics are substantially larger. It would appear that Kansas City price changes adjust to match changes in Oklahoma City or other locations not included in this study and reflect local conditions.

Oklahoma City

The tests with Oklahoma City fail to reject long-run price matching at the 10% level for Colorado and at the 5% level for Kansas City. The failure to reject the hypothesis between Kansas City and Oklahoma City, regardless of which location serves as the independent variable, would suggest a feedback relationship exists between the two locations. Each serves as an important source of competition and pricing information for the other. An additional two locations, Amarillo and Shasta, have relatively small F-statistics although they still result in rejecting the long-run price matching hypothesis.

Shasta

Shasta shows results similar to Colorado. The long run price matching hypothesis is rejected with all other locations. The smallest two F-statistics lie with the Kansas City and Colorado pairings. These results raise similar questions as with Colorado. Is Shasta a price change leader? Is Shasta fairly isolated from the other locations so that local conditions dominate price changes or do other locations not included in this study play an important role in the adjustment process? Shasta, when it serves as the independent location variable, does not show up as an important location in the long-run pricing models of Amarillo, Colorado, Kansas City, and Oklahoma City; however it does appear for the Clovis, Florida, and Stockton tests. This might suggest that Amarillo, Colorado, Kansas City, and Oklahoma City do not share competitive forces of enough importance to generate a price matching response at Shasta, however Clovis, Florida, and Stockton do find price changes in Shasta to be important competitive information resulting in a price matching response.

Stockton

Stockton shows results similar to those of Clovis and Florida. Long-run price matching cannot be rejected at the 10% level for the independent variables Amarillo, Colorado, Kansas City, Oklahoma City, and Shasta. Rejection occurs when Clovis or Florida serve as independent variables.

Short-run Price Matching

Both the weak and strong short-run price matching hypotheses were rejected in all cases (Table 5.4, (c) and (d)). This would preclude the existence of any basing-point or imperfect basing-point system.

General Results, 1983-1988

The results of the 1983-1988 hypothesis tests reject independence and both forms of short-run price matching among all pairings. The results of the long-run price matching tests show price matching linkages between locations which suggest a pattern of tiers. At the top lies Colorado, which when paired as the dependent variable, does not show a long-run price matching relationship with any of the other locations examined. Thus, it does not react to fully match price changes in other locations. On the other hand, when Colorado serves as the independent variable, long-run price matching occurs with all locations except Kansas City and Shasta. Thus, other locations do react and match price changes in Colorado.

On the tier below Colorado lie the locations of Amarillo, Kansas City, and Oklahoma City. Each location shows a long-run price matching relationship with one of the other locations and/or Colorado. Amarillo shows this price matching relationship when it is the dependent variable, but does not appear when it is the independent variable. This would suggest that Colorado, Kansas City, and Oklahoma City do not react to fully match the price changes at Amarillo, but that Amarillo does react to fully match the price changes of Colorado and Oklahoma City. Additionally, Amarillo, Colorado, Kansas City, and Oklahoma City were delivery points for feeder cattle futures contracts until September, 1986.

The Clovis, Florida, and Stockton locations form the bottom tier. The long-run price matching hypothesis is not rejected the most often with these three locations when they are represented as the dependent variable. These locations match the price changes of all the other locations, but none of the other five locations react to match the price changes in these three, suggesting that the competitive effects of these three locations are not important enough to elicit a strong response among themselves or the other five locations. Thus it would seem that the Clovis, Florida, and Stockton locations tend to follow the pricing initiatives of the other five more dominant locations.

The Shasta location is difficult to fit into the price matching hierarchy just discussed. Shasta, as the dependent variable, rejects the long-run price matching hypothesis with all of the other locations, just like Colorado does. Thus it does not adjust to fully match price changes occurring elsewhere. Contrary to the Colorado case, though, Shasta does not appear as a location which the second tier locations (Amarillo, Kansas City, and Oklahoma City) match in the long-run either. Although the second tier does not react to match price changes at Shasta, the three third tier locations (Clovis, Florida, and Stockton) all match, in the long-run, the price changes at Shasta. As a result, Shasta would appear to form a branch of the first tier, not reacting to fully match Colorado or other locations, but serving as a location for those in the third tier to match prices with.

The hypothesis test results of Shasta and Stockton are quite different. While Shasta rejects all four hypotheses for all seven locations, Stockton fails to reject long-run price matching for five of the seven locations. In addition, Shasta strongly rejects the hypothesis test for a full price matching response to changes at Stockton, but Stockton does not reject long-run price matching with Shasta. The larger volume at Shasta may have resulted in less reason to engage in price matching behavior with Stockton; however, Stockton showed a strong trend of increasing volume during the 1983-1988 period, (Table 4.1) while volume at Shasta was fairly stable.

These results indicate that all eight locations analyzed are linked together. The rejection of the weak and strong forms of the short-run price matching hypotheses indicate that none of the locations follow a basing-point relationship. Finally, the locations do react to price changes in other locations, forming a three tiered pattern of reacting to and matching the price changes in other locations.

1987-1988

The WLMIP data were re-examined over the shorter January 1987 to December 1988 period in order to include the Phoenix and Tucson auction data, available for only two years, and to examine any differences which might appear during a sub-period of the data for the WLMIP locations.

Locational Price Differences

Summary statistics of the price differences between the ten locations are presented in Table 5.5. Oklahoma City continues to have the highest prices overall, followed by Colorado, Kansas City, Shasta, Amarillo, Clovis, Stockton, Florida, Tucson, and Phoenix. These rankings are changed from the differentials shown in Table 5.1 for the entire 1983-1988 period. Colorado and Kansas City have switched positions, as have Shasta and Amarillo and Clovis and Stockton. The physical delivery system for feeder cattle futures contracts was no longer in effect during this period. As a result, any tendency for price differences at Kansas City, Colorado, and Amarillo to align with the discounts from par prices at Oklahoma City due to deliveries on futures contracts would no longer be expected.

The four smallest standard deviations were between Oklahoma City-Colorado, Kansas City-Colorado, Oklahoma City-Amarillo, and Oklahoma City-Kansas City. The largest standard deviation was between Tucson-Phoenix. The standard deviations were higher for Phoenix or Tucson paired with all other locations except for one instance (Shasta-Florida), and Phoenix had the highest standard deviations with all other locations. This may be due in part to the low volumes at the Phoenix and Tucson

Table 5.5 Average Weekly Price Differentials and Standard Deviations Between Locations, 1987-1988.

	Amarillo	Clovis	Colorado	Florida	Kansas City	Oklahoma City	Shasta	Stockton	Phoenix	Tucson
Amarillo		*.38	-2.25	4.27	-2.17	-3.43	-1.35	.46	11.99	8.62
Clovis	2.13		-2.64	3.88	-2.55	-3.81	-1.73	.08	11.61	8.24
Colorado	2.18	2.24		6.53	.09	-1.17	.91	2.72	14.25	10.88
Florida	3.70	4.28	4.46		-6.44	-7.70	-5.62	-3.81	7.72	4.35
Kansas City	2.37	2.66	1.85	4.45		-1.26	.82	2.63	14.16	10.79
Oklahoma City	1.86	2.42	1.74	4.20	2.03		2.08	3.89	15.42	12.05
Shasta	3.18	3.12	2.63	5.25	3.02	3.00		1.81	13.34	9.97
Stockton	3.04	3.21	2.88	4.98	2.63	2.85	2.63		11.53	8.16
Phoenix	5.57	5.88	5.61	5.92	6.03	5.76	5.76	5.38		-3.37
Tucson	4.41	4.56	4.60	5.22	4.45	4.48	5.17	5.18	6.64	

*Values in the upper-right are the average weekly prices ($/cwt) between the location at the left minus the average weekly prices of the location at the top. Values in the lower-left are the standard deviations of the price differentials for the corresponding two locations.

locations (both averaged less than twenty head per week) which may make price discovery more difficult and may result in a greater potential for price swings due to quality differences.

Cross-correlations

Cross-correlations between pairings of the ten locations were generally high for the undifferenced data, although the range was wide (.95-.36), as shown in Table 5.6 and Figures 5.3 and 5.4. The highest cross-correlation for pairs including Florida, Phoenix, or Tucson was .72 between Florida and Amarillo, while the lowest was .36 between Phoenix and Tucson. The range of cross-correlations for pairs not involving Florida, Phoenix, or Tucson was .95 for Colorado-Oklahoma City down to .83 for Kansas City-Stockton. Statistically, the correlations of Florida, Phoenix, and Tucson are significantly different at the 5% level of confidence from those of the other locations.[1] The plot of the correlations in Figure 5.3 shows that they occur in groupings, generally declining as distance increases.

The cross-correlations of the first differenced data showed more variation than the undifferenced data, ranging from .60 between Oklahoma City and Amarillo to -.11 between Phoenix and Clovis. Three correlations were negative, at -.04 between Phoenix and Tucson, -.10 between Clovis and Stockton, and -.11 between Clovis and Phoenix. The correlations involving Phoenix or Tucson are generally lower than those involving the other eight locations, although the difference is not statistically significant at the 5%

[1] The correlation coefficients for the twenty-four pairings involving Florida, Phoenix, or Tucson have a mean of .57 and a standard deviation of .096 while the correlation coefficients for the twenty-one pairings involving the other seven locations have a mean of .89 and a standard deviation of .035.

Table 5.6 Cross-correlations of Undifferenced and First Differenced Price Data, 1987-1988.

	Amarillo	Clovis	Colorado	Florida	Kansas City	Oklahoma City	Shasta	Stockton	Phoenix	Tucson
Amarillo		*.92	.91	.72	.90	.94	.84	.86	.50	.68
Clovis	.18		.91	.65	.88	.90	.86	.84	.48	.67
Colorado	.29	.01		.61	.94	.95	.90	.87	.51	.65
Florida	.39	.19	.17		.62	.68	.54	.58	.41	.52
Kansas City	.36	.12	.37	.22		.93	.86	.83	.45	.68
Oklahoma City	.60	.20	.44	.37	.32		.87	.88	.50	.69
Shasta	.11	.08	.37	.13	.32	.38		.90	.54	.62
Stockton	.22	-.10	.16	.22	.08	.33	.19		.59	.61
Phoenix	.06	-.11	.18	.11	.03	.08	.15	.27		.36
Tucson	.10	.20	.03	.07	.01	.08	.10	.004	-.04	

*Values in the upper-right are the cross-correlations of the undifferenced data. Values in the lower-left are the cross-correlations of the first differenced data.

Figure 5.3 Cross-correlations of Undifferenced Data for All Locations During the Period 1987-1988.

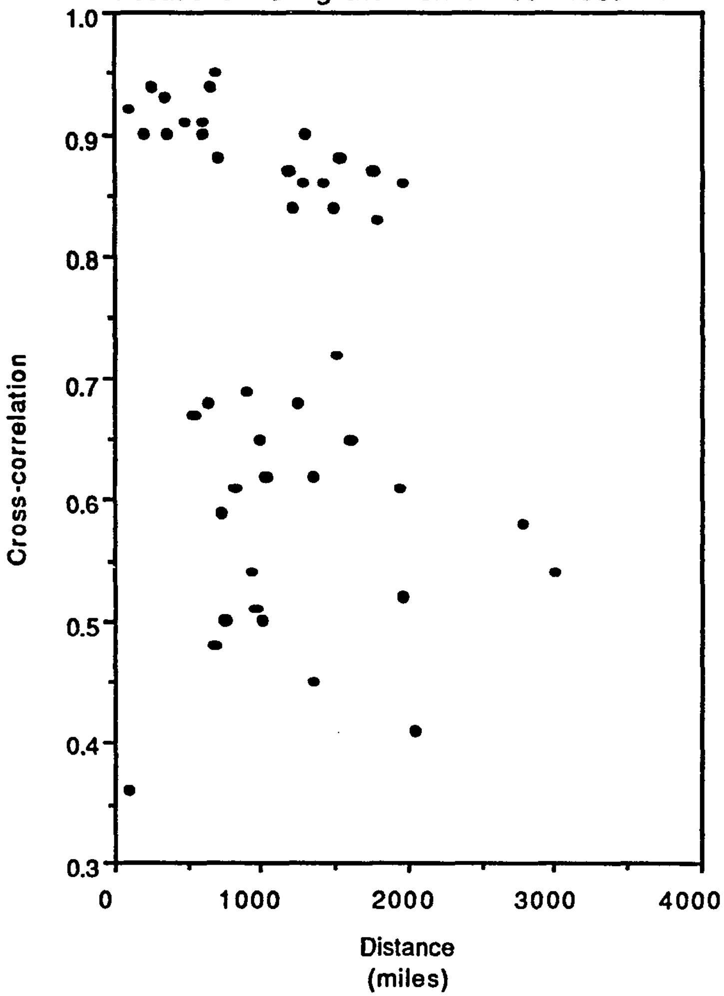
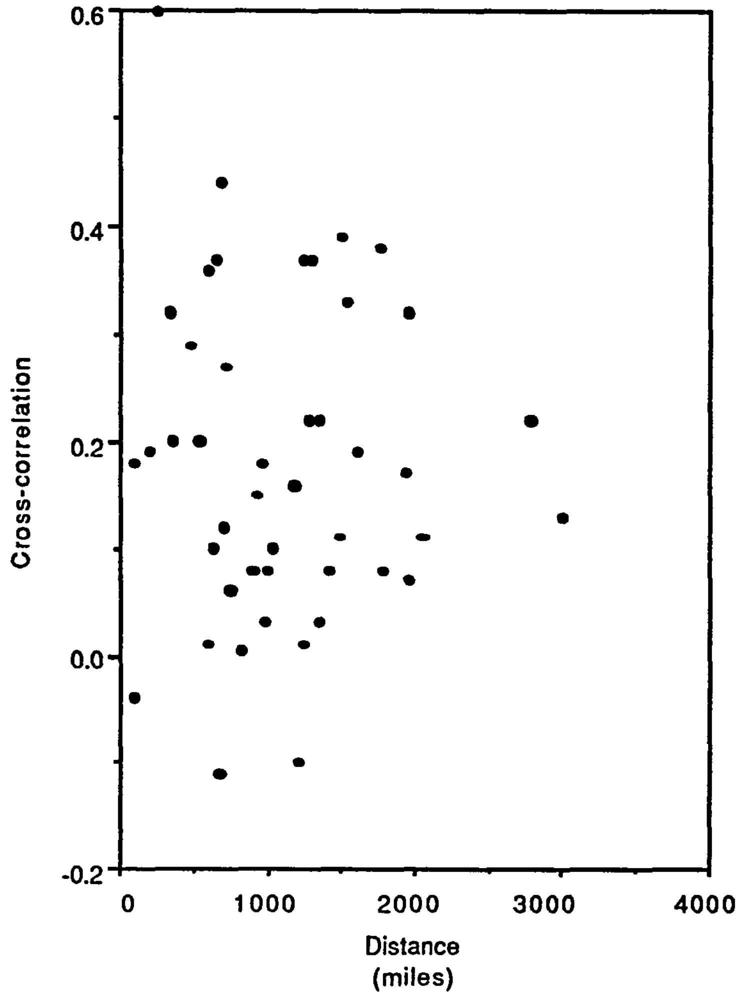


Figure 5.4 Cross-correlations of First Differenced Data for All Locations During the Period 1987-1988.



level.[2] No strong relationship between distance and the first difference correlations of locations appears to exist, as shown in Figure 5.4..

Pricing Model Results

Estimating the empirical model presented in equation 3.22 and testing the four pricing hypotheses for all combinations of the ten locations studied between January, 1987 and December, 1988 resulted in 90 equations with an additional four restrictions and hypothesis tests for each equation. The data for this period consisted of 101 first difference observations, the first 16 being used to initialize the variables.

The hypothesis of independence between location pairs is not rejected in forty-eight of the ninety tests at the 10% level of confidence and an additional eleven times at the 5% level for a total of fifty-nine times. Independence is rejected the most when Amarillo serves as the dependent price variable with rejections for seven of the nine tests. Independence is not rejected for eight of the nine tests when Florida and Shasta serve as the dependent variable. Thirty-two of the fifty -six pairs in which independence is not rejected also fail to reject the long-run price matching hypothesis. A couple of reasons may explain this seemingly odd result. The failure to reject independence may suggest that the other price matching tests are inappropriate and that the failure to reject long-run price matching is a spurious result from a misspecified equation. Alternatively, the independence and long-run price matching hypotheses are not mutually exclusive. The independence hypothesis tests whether all of the coefficients of the lagged independent location variables are zero while the long-run price matching

[2]The correlation coefficients for the seventeen pairings involving Phoenix or Tucson have a mean of .078 and a standard deviation of .091 while the correlation coefficients for the twenty-eight pairings involving the other seven locations have a mean of .24 and a standard deviation of .147.

hypothesis tests whether the sum of the coefficients of both the lagged dependent and independent location variables is one. Thus, the coefficients of the lagged independent location variables may be zero while the coefficients of the lagged dependent location variables still sum to one.

Hypothesis Test Results By Location

A discussion of the hypothesis test results follows by location as each takes its turn as the dependent variable, following the order in which the F-statistics appear in Table 5.7. The pairings which failed to reject both independence and long-run price matching are treated as independent in the discussion.

Amarillo

The hypothesis test results with Amarillo as the dependent variable result in a failure to reject the independence hypothesis in two cases. Of the remaining seven cases with interdependent relationships, the long-run price matching hypothesis fails to be rejected in three while both weak and strong form short-run price matching hypotheses are rejected in all cases.

The hypothesis of independence fails to be rejected at the 10% level of confidence for Phoenix and Stockton. Interdependence would result for the remaining seven locations, however interdependence without full price matching results for four of these locations, Clovis, Florida, Shasta, and Tucson. Long-run price matching fails to be rejected at the 10% level for Oklahoma City and at the 5% level for Colorado and Kansas City. These results suggest the conclusion that Amarillo price changes do not respond to price changes at Phoenix and Stockton but do adjust to changes in other locations. The adjustment shows full price matching over time with Colorado, Kansas City, and Oklahoma City.

Table 5.7 F-Statistics for Price Matching Models, 1987-1988.

Independent Location Variable	Independence (a)	Long-run Price Matching (b)	Short-run Price Matching (Weak) (c)	Short-run Price Matching (Strong) (d)
		Amarillo		
Clovis[1]	2.70	5.31	48.43	7.83
Colorado	2.43	*3.39	19.18	4.06
Florida	3.11	9.09	74.63	8.41
Kansas City	2.13	*3.10	36.06	5.15
Oklahoma City	3.25	**1.68	11.36	2.35
Shasta	2.01	4.40	67.44	8.78
Stockton	**0.89	6.88	54.66	7.30
Phoenix	**0.95	12.53	230.60	37.62
Tucson	1.86	7.32	186.45	42.92
		Clovis		
Amarillo[1]	2.15	**0.35	**1.54	1.88
Colorado	*1.78	**1.60	15.00	2.95
Florida	1.84	4.32	24.44	3.54
Kansas City	**1.60	**1.84	17.59	2.77
Oklahoma City	**1.59	**1.05	5.21	1.96
Shasta	**1.48	**2.64	22.35	3.64
Stockton	**0.90	6.28	25.66	4.42
Phoenix	**0.85	13.92	123.00	17.41
Tucson	**1.03	6.30	80.58	13.90
		Colorado		
Amarillo	2.20	**0.73	5.99	2.40
Clovis	**0.56	4.78	29.52	4.56
Florida	**0.94	4.43	48.63	4.85
Kansas City	2.74	**1.47	22.35	4.20
Oklahoma City	2.70	**0.67	7.71	2.61
Shasta	3.89	**1.70	31.46	6.39
Stockton	**1.52	5.99	50.57	6.49
Phoenix	**0.53	8.56	173.00	22.84
Tucson	**1.02	*3.89	140.36	27.68

*Not Rejected at the 95% Level of Confidence.
**Not Rejected at the 90% Level of Confidence.
[1](a)F(17,51),(b)F(1,51),(c)F(2,51),(d)F(33,51)

Table 5.7 cont. F-Statistics for Price Matching Models, 1987-1988.

Independent Location Variable	Independence (a)	Long-run Price Matching (b)	Short-run Price Matching (Weak) (c)	Short-run Price Matching (Strong) (d)
		Florida		
Amarillo[1]	1.98	**0.00	**0.00	**0.99
Clovis	**1.07	**2.26	7.02	1.77
Colorado	**0.91	**0.54	5.74	**1.15
Kansas City	**1.47	**0.30	9.77	1.90
Oklahoma City	**0.73	**0.26	*2.53	**0.58
Shasta	**0.64	**0.21	13.45	1.72
Stockton	**1.20	**0.62	9.99	2.54
Phoenix	*1.67	12.05	76.26	14.17
Tucson	**0.70	**1.42	56.18	10.15
		Kansas City		
Amarillo	*1.75	*3.52	*2.42	*1.49
Clovis	**0.68	6.06	16.34	2.64
Colorado	2.38	**0.51	4.30	2.03
Florida	**0.97	9.85	23.60	3.26
Oklahoma City	*1.69	**1.20	3.62	2.00
Shasta	1.83	*3.21	17.74	3.03
Stockton	**0.95	8.13	19.96	4.45
Phoenix	**0.81	8.52	119.37	18.64
Tucson	**1.22	9.75	100.84	19.71
		Oklahoma City		
Amarillo	3.65	**0.67	**1.71	**1.33
Clovis	*1.60	*3.54	27.36	4.49
Colorado	2.78	**1.76	6.21	2.42
Florida	**1.48	6.51	49.19	4.13
Kansas City	2.59	*3.09	23.64	4.44
Shasta	2.10	**1.35	35.64	4.08
Stockton	**1.43	5.79	33.24	4.92
Phoenix	**1.38	6.97	207.09	28.48
Tucson	3.10	6.44	190.38	38.86

*Not Rejected at the 95% Level of Confidence.
**Not Rejected at the 90% Level of Confidence.
[1](a)F(17,51),(b)F(1,51),(c)F(2,51),(d)F(33,51)

Table 5.7 cont. F-Statistics for Price Matching Models, 1987-1988.

Independent Location Variable	Independence (a)	Long-run Price Matching (b)	Short-run Price Matching (Weak) (c)	Short-run Price Matching (Strong) (d)
		Shasta		
Amarillo[1]	**1.25	*3.09	5.65	1.92
Clovis	**0.90	4.71	15.16	2.86
Colorado	3.05	**0.58	**1.34	2.19
Florida	**0.98	6.84	28.32	2.96
Kansas City	*1.77	**1.50	8.97	2.10
Oklahoma City	**1.32	**2.72	3.97	**1.16
Stockton	*1.60	6.51	13.28	3.87
Phoenix	**1.40	13.12	78.77	15.68
Tucson	**0.79	6.79	75.23	13.31
		Stockton		
Amarillo[1]	**1.30	**0.00	4.23	1.73
Clovis	2.29	**.60	32.11	5.17
Colorado	*1.82	**0.07	11.39	2.35
Florida	2.18	*2.92	21.44	3.86
Kansas City	2.53	**0.02	18.09	4.20
Oklahoma City	*1.79	**0.11	5.16	1.83
Shasta	2.86	**0.00	16.41	4.31
Phoenix	*1.77	5.54	95.69	12.72
Tucson	**1.40	**0.77	73.03	14.50
		Phoenix		
Amarillo[1]	2.03	**2.02	*2.73	2.77
Clovis	**1.32	**0.00	10.21	3.01
Colorado	**0.94	**0.10	**0.49	*1.65
Florida	1.85	**0.12	3.75	2.97
Kansas City	**1.29	**0.17	3.35	2.47
Oklahoma City	**0.89	**0.05	**0.26	1.77
Shasta	2.06	**0.17	**0.74	2.79
Stockton	**1.06	**0.17	**1.14	*1.59
Tucson	**0.36	**1.61	14.70	3.96

*Not Rejected at the 95% Level of Confidence.
**Not Rejected at the 90% Level of Confidence.
[1](a)F(17,51),(b)F(1,51),(c)F(2,51),(d)F(33,51)

Table 5.7 cont. F-Statistics for Price Matching Models, 1987-1988.

Independent Location Variable	Independence (a)	Long-run Price Matching (b)	Short-run Price Matching (Weak) (c)	Short-run Price Matching (Strong) (d)
		Tucson		
Amarillo[1]	2.64	**0.60	**0.38	3.88
Clovis	**1.28	**2.39	3.81	2.72
Colorado	*1.78	**1.96	*2.69	3.42
Florida	**1.54	10.00	8.20	3.28
Kansas City	**1.20	**1.17	**1.49	3.00
Oklahoma City	1.84	**0.42	**0.42	3.31
Stockton	**1.34	*3.14	5.19	2.98
Shasta	**1.05	4.42	*2.90	3.08
Phoenix	**1.04	9.55	33.23	6.50

*Not Rejected at the 95% Level of Confidence.
**Not Rejected at the 90% Level of Confidence.
[1](a)F(17,51),(b)F(1,51),(c)F(2,51),(d)F(33,51)

Clovis

Clovis shows a failure to reject independence with seven of the independent variable locations. Of the remaining two locations in which independence is rejected, long-run and weak form short-run price matching is not rejected for one.

Independence fails to be rejected at the 10% level for Kansas City, Oklahoma City, Shasta, Stockton, Phoenix, and Tucson, and at the 5% level for Colorado. Interdependence without full price matching results for Florida, while long-run and weak form short-run price matching cannot be rejected with Amarillo. The results for Clovis-Amarillo suggest the possibility of an imperfect basing-point pricing system. The close proximity of Clovis to Amarillo may generate a strong competitive relationship as Clovis struggles for survival against the larger Amarillo market. Additionally, Amarillo's role as a heavily reported price location may result in its use as a pricing base for determining Clovis prices in conjunction with local factors.

Colorado

Examination of the results of the hypothesis tests using Colorado as the dependent variable shows that independence cannot be rejected for five of the locations. The remaining four locations show that long-run price matching cannot be rejected, although both forms of short-run price matching can be rejected.

Independence fails to be rejected at the 10% level of confidence for Clovis, Florida, Stockton, Phoenix, and Tucson. The four locations showing interdependence, Amarillo, Kansas City, Oklahoma City, and Shasta, fail to reject long-run price matching at the 10% level. This suggests that Colorado reacts to match price changes in these other locations, a change from the results of the 1983-1988 period.

Florida

The dependent variable Florida results in a failure to reject the independence hypothesis in eight cases. In the one case where independence is rejected, the long-run, weak and strong form short-run price matching hypotheses all fail to be rejected.

Independence fails to be rejected at the 10% level for seven pairs and at the 5% level for Phoenix. In the case of Florida-Amarillo, the failure to reject the three price matching hypotheses at the 10% level suggests a possible basing-point pricing relationship. The F-statistics for the long-run and weak form short-run price matching models are particularly small.

Kansas City

The independence of price changes at Kansas City in response to price changes at other locations cannot be rejected for seven of the nine locations. For the remaining two locations, long-run price matching cannot be rejected although both forms of short-run price matching can.

Independence is not rejected at the 10% level of confidence for Clovis, Florida, Stockton, Phoenix, and Tucson and at the 5% level for Amarillo and Oklahoma City. Long-run Price matching is not rejected for Colorado and Shasta at the 10% and 5% levels, respectively. The failure to reject independence with Oklahoma City is unexpected since Oklahoma City has the highest cattle volume of the ten locations and is the nearest of the nine other locations to Kansas City.

Oklahoma City

The hypothesis tests with Oklahoma City paired against the other nine locations result in four cases in which independence is not rejected. These locations are Clovis, Florida, Stockton, and Phoenix. Interdependence would be concluded for the other five locations, Amarillo, Colorado, Kansas City, Shasta, and Tucson. Of the five locations, four fail to reject long-run price matching and one of these also fails to reject both the weak and strong form tests of short-run price matching.

The strongest evidence for independence lies with the Florida, Stockton, and Phoenix locations in which independence is not rejected at the 10% level of confidence. Independence is also not rejected with Clovis at the 5% level. Long-run price matching is not rejected at the 10% level for Amarillo, Colorado, and Shasta, and at the 5% level for Kansas City. Oklahoma City shows an interdependent relationship with Tucson, however this does not include full price matching as evidenced by the rejection of the price matching hypotheses.

The Oklahoma City-Amarillo pairing shows an interesting result since both forms of short-run price matching are not rejected. This would indicate an instantaneous response at Oklahoma City to price changes at Amarillo, although this pattern is not repeated when the ordering is reversed. The evidence suggests the possibility that Oklahoma City follows a basing-point pricing relationship with Amarillo. In addition, recall that in Table 5.6, the Amarillo-Oklahoma City pairing had the highest cross-correlation of first differences. Their relatively close proximity and status as major price reporting locations may explain this result. It may also indicate that adjustments between the two locations occur rapidly enough that the weekly data are too aggregated to capture the adjustment process.

The relationship between Oklahoma City and Kansas City has changed from the results of the 1983-1988 period. Previously, both locations displayed a long-run price matching adjustment process with the other. The results for the 1987-1988 period suggest that bi-directional price matching is no longer occurring. Instead, Kansas City is a price leader which Oklahoma City then adjusts to match.

Shasta

The hypothesis tests involving Shasta as the dependent variable result in eight failures to reject the independence hypothesis. Independence is not rejected at the 10% level for Amarillo, Clovis, Florida, Oklahoma City, Phoenix, and Tucson and at the 5% level for Kansas City and Stockton.

The remaining location, Colorado, results in a failure to reject both the long-run and weak form short-run price matching hypotheses at the 10% level. Shasta may follow an imperfect basing-point pricing relationship with Colorado although Colorado only matches price changes at Shasta in the long-run. Colorado is the closest major cattle feeding location lying east of the Rocky Mountains to Shasta.

Stockton

Stockton, as the dependent variable, shows a failure to reject independence with five of the nine independent variable locations. The remaining four locations show a failure to reject the long-run price matching hypothesis. Both forms of the short-run price matching hypotheses are rejected in all cases.

Independence is not rejected at the 10% level for Amarillo and Tucson and at the 5% level for Colorado, Oklahoma City, and Phoenix. The F-statistics for the long-run price matching tests are particularly small for Shasta and Kansas City. All of the tests of the long-run price matching hypothesis for the four interdependent locations fail to be rejected at the 10% level of confidence, except for Florida which occurs at the 5% level. The relationship between Stockton and Shasta is not surprising due to their proximity in the central California region.

Stockton shows an interesting relationship with Amarillo, Clovis, and Florida. Clovis shows a weak form short-run price matching pattern with Amarillo while Florida shows a strong form short-run price matching relationship with Amarillo, thus both Clovis and Florida respond quickly to match price changes at Amarillo. This contrasts with Stockton, which matches Clovis and Florida price changes in the long-run but then fails to reject independence with Amarillo. This result is difficult to explain.

Phoenix

Phoenix shows a failure to reject the independence hypothesis for six locations when it serves as the dependent variable. The remaining three locations fail to reject the long-run price matching hypothesis and two of these fail to reject the weak form short-run price matching hypothesis.

All six cases in which independence is not rejected occur at the 10% level of confidence (Clovis, Colorado, Kansas City, Oklahoma City, Stockton, and Tucson). The strongest evidence for independence (the smallest F-statistic) occurs with Tucson, although Tucson is the closest rival location to Phoenix. This result will be given more discussion in the General Results section.

The three locations showing interdependence with Phoenix are Amarillo, Florida, and Shasta. All three of these locations show a failure to reject the long-run price matching hypothesis at the 10% level of confidence. Additionally, Amarillo and Shasta show lagged price response effects with a failure to reject the weak form short-run price matching hypothesis. The failure to reject occurs at the 10% level for Shasta and at only the 5% level for Amarillo. Florida's position as a major source of feeder cattle for Arizona feedlots, or its strong form short-run price matching relationship with Amarillo may explain this long-run price matching behavior with Phoenix.

Tucson

Tucson shows an interdependent relationship with two locations, Amarillo and Oklahoma City, as evidenced by the failure to reject independence for the other seven locations. Long-run and weak form short-run price matching also fails to be rejected for these two locations, although the strong form short-run price matching hypothesis is rejected.

The failure to reject independence occurs at the 10% level for Clovis, Florida, Kansas City, Stockton, Shasta, and Phoenix, and at the 5% level for Colorado. The evidence of lagged responses to price changes in Amarillo and Oklahoma City suggests the possibility of an imperfect basing-point pricing system with these Great Plains locations.

General Results, 1987-1988

The results of the hypothesis tests are quite different and more complex for the 1987-1988 sub-period compared to the longer 1983-1988 period. The hypothesis of independence cannot be rejected in over half of the tests in the shorter period while it was rejected in all of the tests over the longer time period. The number of location pairs in which all four hypotheses were rejected declined sharply from thirty-six of the fifty-six WLMIP pairings to six of the same fifty-six pairings. These differences may be the result of changes in the pricing relationships in effect over the time period or they may result from the smaller amount of data available in the shorter time period. In addition, the WLMIP pairs which failed to reject long-run price matching during the 1983-1988 period (see Table 5.4) also tend to reappear with the same result in the 1987-1988 period. These similarities may reflect the presence of stable, competitive pricing relationships during both shorter-run and longer-run periods.

The locational pattern of price matching changed in the 1987-1988 period compared to the longer time period. The three tier system previously discussed appears to remain, although considerable movement between the tiers occurred. The first tier would be composed of Amarillo, Colorado, Kansas City, Oklahoma City, and Shasta. These five locations show unidirectional or bi-directional price matching behavior with at least one other in the tier, and also serve as locations which the other tiers match prices with. The second tier is composed of Clovis and Florida. They match prices with first tier locations which do not reciprocate, and are matched by third tier locations. The third tier is composed of Stockton, Phoenix, and Tucson. These three locations follow a pattern of matching price changes with the first and second tier locations.

The dominance of Colorado and Shasta over the entire 1983 -1988 period as locations which did not respond to match price changes in other locations but which other locations responded to, had ended, although Colorado still appears to exert considerable influence. While Colorado matches changes at Amarillo, Kansas City, Oklahoma City, and Shasta in the long-run, a weak form short-run price matching pattern is in evidence for Shasta, which matches Colorado price changes with lagged effects netting out to zero.

Phoenix and Tucson, two closely located small volume locations, did not reject the independence hypothesis tests with each other. Although very close together geographically, their price changes seem to be independent. Several factors may contribute to this result. The small volume of sales may result in large weekly price swings as cattle of variable quality pass through. Auctions at these locations are held on different days of the week. As a result, buyers are likely to look to other, larger volume locations to get daily price movements from which to form a basis for bidding on cattle in the Arizona auctions. The price changes then reflect daily fluctuations or movements in prices so that auctions operating on different days of the week may react to different market conditions, generating price changes which appear to be independent between the two auctions.

Phoenix prices show a weak form short-run price matching pattern with Shasta and Amarillo, with the F-statistics indicating that this pattern may be stronger for Shasta than for Amarillo. In contrast, Tucson prices show a weak form short-run price matching relationship with Amarillo and Oklahoma City. Thus, Phoenix prices may be more responsive to the price movements in Shasta while Tucson looks in the opposite direction towards Amarillo and Oklahoma City. As a result, the evidence for independence between Phoenix and Tucson may be a combination of the effects of local conditions, daily fluctuations in feeder cattle prices elsewhere, and a price matching pattern with higher volume locations in different geographic areas.

Effects of Cash Settlement in Feeder Cattle Futures Contracts

The change from physical delivery at selected locations to cash settlement based on cash prices at a large number of locations in feeder cattle futures contracts beginning with the September, 1986 contract presents an event in the feeder cattle industry which may have resulted in changes in the structure of price transmission and reactions between locations. Since the model and hypotheses used in this thesis are designed to reveal pricing structures, a further analysis was conducted to determine if any changes in pricing relationships corresponding with the change in contract settlement could be detected. Changes in price levels (premiums or discounts between locations) would not be detected by this method, however visual inspection of the differentials or examination of the average differentials before and after the change in contract settlement would provide evidence for or against these changes.

Under physical delivery, arbitrage can be expected to force price differences to no more than transfer costs to the delivery points, at least to the degree that futures contracts influence cash prices at the delivery points and generate cattle flows to these points. As a result, price changes at the delivery points would be expected to be matched by other locations. Four of the locations examined were delivery points under the physical delivery system, Oklahoma City, Kansas City, Amarillo, and Greeley, Colorado, as represented here by the Colorado price series.

The cash settlement system calculated a volume weighted average national price from twenty-seven states (Chicago Mercantile Exchange, 1986). These states included all of the locations examined in this study. As a result of this change, it would be expected that price movements at the delivery points would have less influence on prices in other locations, resulting in a decentralization of price matching among locations. This would occur since producers or cattle feeders holding futures contracts until delivery would no longer need to move cattle through the four delivery points (unless they normally would anyhow). Thus, price changes resulting from contract settlement activities generating competitive responses from other locations would no longer occur. Structural changes in pricing which might result should be revealed by the empirical model and hypothesis tests used here.

The model was re-estimated for the eight WLMIP locations for the January, 1983 to August, 1986 period when the physical delivery system of settlement was in effect and for the September, 1986 to December, 1988 period when cash settlement was in effect. Chow tests were performed to identify significant changes between the periods in the coefficients of the general model of equation 3.22. The hypothesis tests for the pricing structures were performed on all pairs during both periods also. The F-statistics from the hypothesis tests for all of the location pairs and the Chow tests are presented in Table 5.8 with the hypothesis test results prior to cash settlement in columns (a) through (d) and the test results after cash settlement in columns (e) through (h). The Chow tests are reported in column (i).

Thirty-two of the fifty-six location pairs showed significant changes in their pricing structure, based on the Chow test, at the 10% level of confidence or higher. The hypothesis of independence was rejected at the 5% level for all but one (Shasta-Florida) of the thirty-two pairs in the pre-cash settlement period; however independence could not be rejected in eight of these pairs after cash settlement was effected. All four hypotheses were rejected for fourteen of the pairs in the prior period, but only four times in the latter period. Long-run price matching was not rejected sixteen times before cash settlement and twenty-three times afterwards, although three of these occurrences also failed to reject independence, leaving twenty occurrences. The weak and strong forms of short-run price matching were rejected by all pairs in the pre-cash settlement period; however both failed to be rejected twice after cash settlement was initiated. Eighteen of the pairs evidenced changes in which price matching hypotheses were or were not rejected while the remaining fourteen evidenced no change in the hypothesis tests although the Chow test indicated that the parameter values differed significantly.

A review of the hypothesis tests for the location pairs showing significant parameter value changes based on the Chow tests follows by dependent location variable.

<u>Amarillo</u>

Amarillo showed three significant changes. Two of these three, Amarillo-Colorado and Amarillo-Kansas City, showed no change in the hypothesis test results with

Table 5.8. F-Statistics for Price Matching Hypotheses and Chow Tests for Statistically Significant Structural Changes Between the Periods January, 1983-August, 1986 and September, 1986-December, 1988.

Independent Location Variable	Jan., 1983-Aug., 1986: Independence (a)	Long-run Price Matching (b)	Short-run Price Matching (Weak) (c)	Short-run Price Matching (Strong) (d)	Sept., 1986-Dec., 1988: Independence (e)	Long-run Price Matching (f)	Short-run Price Matching (Weak) (g)	Short-run Price Matching (Strong) (h)	Chow Test Results (i)
Amarillo									
Clovis[1]	2.41	4.67	49.50	9.88	2.38	9.50	57.58	9.88	1.20
Colorado[2]	4.79	**0.62	33.13	6.48	2.74	*3.89	25.08	4.64	++1.49
Florida[3]	2.25	9.04	35.61	4.88	3.34	11.91	93.46	9.93	1.33
Kansas City[2]	2.57	**2.30	11.52	1.84	2.60	*3.83	42.79	5.87	+1.41
Okla City[2]	12.62	**0.33	*2.42	2.39	4.70	2.53	13.82	3.15	1.34
Shasta[2]	2.25	**0.24	35.38	6.22	2.42	6.52	87.35	10.34	+1.42
Stockton[2]	2.29	*2.94	23.37	4.67	**1.02	8.28	66.38	8.49	1.34
Clovis									
Amarillo[1]	5.28	**2.16	6.66	4.39	3.06	**0.26	4.24	2.98	0.96
Colorado[1]	2.84	**0.00	6.97	3.52	2.47	**0.95	18.81	3.77	1.11
Florida[4]	2.41	**2.59	7.68	4.06	2.46	8.11	39.32	4.86	1.36
Kansas City[1]	*1.63	**2.49	*2.56	2.41	2.20	**1.26	23.85	3.77	1.05
Okla City[1]	4.70	**0.09	**1.94	3.17	2.19	**0.92	7.82	2.74	1.12
Shasta[1]	2.53	**0.01	9.96	3.57	1.98	*3.39	27.79	4.55	++1.61
Stockton[1]	2.60	**0.68	7.48	3.48	**1.23	6.38	36.09	5.78	++1.61
Colorado									
Amarillo[2]	5.00	8.12	16.91	4.80	2.38	**1.42	8.69	2.80	+++1.77
Clovis[1]	2.52	9.74	55.52	8.99	**0.64	6.55	42.71	6.38	0.89
Florida[3]	**1.27	7.31	33.56	5.08	**1.40	7.31	78.27	7.10	1.25
Kansas City[2]	3.14	5.70	5.96	3.65	4.15	**1.58	31.57	5.77	++1.56
Okla City[2]	8.21	8.36	7.09	4.01	3.79	**1.42	9.65	3.41	+++1.88
Shasta[2]	2.86	**0.99	23.10	5.55	4.26	*3.10	40.56	7.28	+++1.93
Stockton[2]	2.80	8.77	34.73	6.70	*1.63	6.89	64.61	8.05	++++1.70

Table 5.8, cont. F-Statistics for Price Matching Hypotheses and Chow Tests for Statistically Significant Structural Changes Between the Periods January, 1983-August, 1986 and September, 1986-December, 1988.

	Jan., 1983-Aug., 1986				Sept., 1986-Dec., 1988				
Independent Location Variable	Independence (a)	Long-run Price Matching (b)	Short-run Price Matching (Weak) (c)	Short-run Price Matching (Strong) (d)	Independence (e)	Long-run Price Matching (f)	Short-run Price Matching (Weak) (g)	Short-run Price Matching (Strong) (h)	Chow Test Results (i)
				Florida					
Amarillo[3]	4.07	*3.35	34.67	4.80	2.50	**0.02	**0.06	**1.17	++1.57
Clovis[4]	2.37	4.09	65.90	11.06	**0.98	**2.75	10.64	2.16	1.10
Colorado[2]	2.46	**1.51	48.68	6.44	**0.94	**0.22	6.46	**1.26	1.08
Kansas City[3]	2.74	**1.98	15.56	3.19	*1.64	**0.04	10.91	2.02	1.20
Okla City[3]	4.24	**2.02	28.19	4.49	**0.96	**0.26	3.13	**0.64	0.98
Shasta[3]	1.80	**1.84	61.96	7.11	**0.70	**0.09	17.32	2.12	0.81
Stockton[3]	4.10	7.22	40.43	6.40	**1.49	**0.29	11.99	2.85	+++1.84
				Kansas City					
Amarillo[2]	3.37	*3.27	69.99	6.21	2.42	5.82	4.65	1.96	+++1.76
Clovis[1]	2.68	**2.44	213.74	23.86	**0.69	9.59	26.20	4.01	1.16
Colorado[2]	5.33	**1.05	104.58	13.88	3.12	**0.80	4.77	2.60	++1.58
Florida[3]	2.08	3.91	82.14	8.96	**1.34	16.05	39.77	4.62	++1.56
Okla City[2]	5.00	*3.41	44.48	5.09	2.31	**2.71	5.68	2.62	+1.44
Shasta[2]	2.76	**2.16	88.46	10.40	2.54	6.32	27.94	4.22	+++2.10
Stockton[2]	2.97	3.95	91.10	9.02	**1.11	10.33	29.80	5.77	++1.70
				Oklahoma City					
Amarillo[2]	12.45	*3.36	26.29	4.57	5.38	**0.89	*2.59	1.94	1.23
Clovis[1]	2.77	4.94	81.04	12.40	*1.76	5.82	39.46	6.31	1.07
Colorado[2]	7.59	**0.12	49.84	8.57	4.10	**1.61	8.20	3.23	++1.54
Florida[3]	*1.69	9.26	53.99	6.78	1.91	9.86	70.72	5.53	1.20
Kansas City[2]	3.31	**2.03	13.68	2.58	3.37	*3.22	29.70	5.41	++1.65
Shasta[2]	4.44	**0.87	51.41	7.83	2.80	*3.18	45.59	5.11	1.53
Stockton[2]	2.49	4.77	43.06	5.59	1.78	8.11	44.96	6.16	1.13

Table 5.8, cont. F-Statistics for Price Matching Hypotheses and Chow Tests for Statistically Significant Structural Changes Between the Periods January, 1983-August, 1986 and September, 1986-December, 1988.

Independent Location Variable	Jan., 1983-Aug., 1986				Sept., 1986-Dec., 1988				
	Independence (a)	Long-run Price Matching (b)	Short-run Price Matching (Weak) (c)	Short-run Price Matching (Strong) (d)	Independence (e)	Long-run Price Matching (f)	Short-run Price Matching (Weak) (g)	Short-run Price Matching (Strong) (h)	Chow Test Results (i)
Shasta									
Amarillo[2]	3.56	10.77	33.13	5.99	**1.42	**2.69	7.17	2.19	+++1.90
Clovis[1]	1.72	9.32	72.22	10.30	**1.09	*3.76	21.77	3.91	++1.53
Colorado[2]	4.26	9.44	39.98	7.31	3.49	**0.27	**1.24	2.40	+++1.96
Florida[3]	**0.75	9.71	51.69	6.23	**1.50	9.07	46.63	4.50	++1.65
Kansas City[2]	2.35	6.48	12.93	3.43	2.26	**0.67	11.71	2.59	1.32
Okla City[2]	4.84	7.22	11.24	3.84	1.82	**2.06	4.28	**1.41	++1.52
Stockton[2]	2.36	11.55	42.44	7.16	*1.75	4.01	19.52	4.50	++1.88
Stockton									
Amarillo[2]	5.03	*3.81	35.84	5.86	*1.74	**0.01	4.79	2.06	1.29
Clovis[1]	1.76	7.19	64.03	9.76	2.60	**1.28	45.12	6.78	++1.66
Colorado[2]	2.80	**1.62	43.56	7.62	2.22	**0.09	14.28	2.92	+1.43
Florida[3]	2.44	4.35	31.74	5.57	2.80	5.03	30.44	4.80	+++2.04
Kansas City[2]	2.46	*2.80	16.52	2.89	3.20	**0.00	24.63	5.14	+++1.86
Okla City[2]	4.76	**1.55	21.95	3.76	2.23	**0.17	6.38	2.17	+1.38
Shasta[2]	2.49	**1.47	47.67	7.69	3.11	**0.88	21.98	4.80	++1.72

*Not Rejected at the 95% Level of Confidence. **Not Rejected at the 90% Level of Confidence.
Chow test for Ho: No Change between Periods: +Rejected at the 90% Level of Confidence, ++Rejected at the 95% Level of Confidence, +++Rejected at the 99% Level of Confidence.

[1](a) F(17,105), (b) F(1,105), (c) F(2,105), (d) F(33,105), (e) F(17,71), (f) F(1,71), (g) F(2,71), (h) F(33,71), (i) F(34,176)
[2](a) F(17,141), (b) F(1,141), (c) F(2,141), (d) F(33,141), (e) F(17,71), (f) F(1,71), (g) F(2,71), (h) F(33,71), (i) F(34,212)
[3](a) F(17,141), (b) F(1,141), (c) F(2,141), (d) F(33,141), (e) F(17,70), (f) F(1,70), (g) F(2,70), (h) F(33,70), (i) F(34,211)
[1](a) F(17,105), (b) F(1,105), (c) F(2,105), (d) F(33,105), (e) F(17,70), (f) F(1,70), (g) F(2,70), (h) F(33,70), (i) F(34,175)

long-run price matching failing to be rejected in both. The significance of the failure to reject declined, however. The third pair, Amarillo-Shasta, showed a movement from long-run price matching to a rejection of all four hypotheses. Thus the price linkage appears to have declined somewhat under cash settlement.

Clovis

Clovis showed two significant Chow tests. The first pair, Clovis-Shasta, showed no change in hypothesis test results with long-run price matching failing to be rejected in both periods, although the significance declined from the 10% level before cash settlement to the 5% level afterwards. The second pair, Clovis-Stockton, showed a movement from failure to reject long-run price matching at the 5% level to failure to reject independence at the 10% level of confidence.

Colorado

Colorado showed five pairs with significant parameter value changes between the two periods. One of these, Colorado-Shasta, showed a failure to reject long-run price matching in both periods, although the significance level declined from the 10% level to the 5% level. Of the other four pairs, three (Clovis-Amarillo, Clovis-Kansas City, and Clovis-Oklahoma City) showed a movement towards greater price matching behavior, from rejection of all four hypotheses to failure to reject long-run price matching at the 10% level of confidence. The fourth pair, Clovis-Stockton, showed movement away from interdependence as the previous rejection of all four hypotheses changed to a failure to reject independence at the 5% level.

Florida

Two significant parameter changes occurred among the pairs having Florida as the dependent variable. Both resulted in changes in the hypothesis tests. Florida-

Amarillo showed a movement from failure to reject long-run price matching to failure to reject long-run, weak and strong form short-run price matching. Thus, the rate of price adjustment increased dramatically, becoming consistent with basing-point pricing after cash settlement began. Florida-Stockton showed a movement from rejecting all four hypotheses to failure to reject independence and long-run price matching, both at the 10% level of confidence. These two hypotheses are not mutually exclusive; however their combined evidence would suggest that independence is more likely than long-run price matching. Amarillo appears to have gained substantial influence with Florida prices under cash settlement while the influence of Stockton may have declined.

Kansas City

Six of the pairings with Kansas City as the dependent location variable showed significant changes between the two periods. Two of the pairs, Kansas City-Colorado and Kansas City-Oklahoma City showed a failure to reject long-run price matching in both periods. The significance level remained unchanged at 10% with Colorado but increased from 5% to 10% with Oklahoma City. The remaining four pairs showed declines in price matching. Kansas City-Amarillo and Kansas City-Shasta moved from a failure to reject long run price matching to rejection of all four hypotheses in favor of interdependence without full price matching. The Kansas City-Florida and Kansas City-Stockton pairings moved from rejection of all four hypotheses to failure to reject independence at the 10% level.

Oklahoma City

Oklahoma City showed two significant changes between periods based on the Chow test. Both pairs, however, showed no change in the individual hypothesis tests. Oklahoma City-Colorado and Oklahoma City-Kansas City failed to reject long-run price matching in both periods. The changes which occurred at the other former delivery points suggest that Oklahoma City should have also shown changes. However, Oklahoma City remained the highest volume location, thus any changes may be overshadowed by the importance of the size of the Oklahoma City market.

Shasta

Six pairs showed significant parameter changes between the two periods when Shasta served as the dependent location variable. The Shasta-Florida pair showed no change in the hypothesis test results with independence failing to be rejected in both periods.

Shasta-Colorado and Shasta-Oklahoma City showed an increase in price matching, moving from a rejection of all four hypotheses to a failure to reject both long-run and weak form short-run price matching with Colorado and a failure to reject long-run price matching and strong form short-run price matching with Oklahoma City. The Shasta-Oklahoma City pairing continued to reject weak form short-run price matching in the second period. This result is unexpected since the strong form test is a more restricted form of the weak form test. Thus, if the strong form test is not rejected, the weak form test should not be rejected either. Considering the number of hypothesis tests conducted, it is not outside the range of probability that the failure to reject strong form short-run price matching is a spurious result if the rejection of the weak form is correct, The same thing occurs for the weak form if the strong form test result is correct. In either case, it does appear that the Shasta-Oklahoma City pair does show greater price matching activity after cash settlement than before.

Three pairs, Shasta-Amarillo, Shasta-Clovis, and Shasta-Stockton showed a decline in price matching activity after the start of cash settlement, moving from rejection of all four hypotheses to failure to reject independence. The first two pairs also failed to reject long-run price matching; however as discussed previously, these two hypotheses are not mutually exclusive if independence is correct.

Stockton

Stockton showed six pairs having significant changes in parameter values between the two periods. Five of these pairs, though, showed no change in the hypothesis test results. Stockton-Colorado, Stockton-Kansas City, Stockton-Oklahoma City, and Stockton-Shasta failed to reject long-run price matching in both periods. Stockton-Florida rejected all four hypotheses in favor of interdependence in both periods. The sixth pair, Stockton-Clovis, showed increased price matching, changing from a rejection of all four hypotheses to failure to reject long-run price matching in the second period.

General Results

The location pairs having significant parameter value changes, based on the Chow test, between the physical delivery and cash settlement periods show mixed tendencies towards increased or decreased price matching activity. Of the thirty-two pairs showing a significant change, eleven showed decreased price matching and interdependence while seven showed increased price matching activity. Of the remaining fourteen having significant parameter changes but no change in the hypothesis test results, the level of significance decreased for five, remained unchanged for seven, and increased for two.

The tendency of change in the hypothesis test results was more similar among specific dependent location variables. Amarillo and Clovis showed a general decline in matching price changes at other locations. Colorado and Florida showed an increase in activity with other former physical delivery locations and a decline with smaller volume locations. Kansas City and Shasta showed less price responsiveness to changes at

Amarillo and the lower volume locations of Clovis and Stockton, while Shasta showed increased price matching activity with the higher volume locations of Colorado and Oklahoma City. Oklahoma City and Stockton showed little overall change in price matching activity.

The results of the tests for changes in pricing structures corresponding with the start of cash settlement show similarities with the results of the 1983-1988 and 1987-1988 periods if the Chow tests are disregarded. The hypothesis test results in the pre-cash settlement period, January, 1983-August, 1986, are similar in appearance to the January, 1983-December, 1988 test results in that independence, weak form and strong form short-run price matching hypotheses are rejected. The hypothesis test results of the September, 1986-December, 1988 period after the start of cash settlement are similar to those of the January, 1987-December, 1988 period. The similarity of the latter data periods may have contributed to this result, although it is interesting to note that all pairs which failed to reject independence in Table 5.8 also failed to reject independence in the 1987-1988 period shown in Table 5.7. The results of the 1987-1988 tests in Table 5.7 may better reflect pricing structures following the start of cash settlement, allowing for a four month period for structural pricing relationships to adjust to the change in futures contract settlement.

If the results of the Chow tests are disregarded, the general tendencies do not change much. Tables 5.9 and 5.10 summarize the results of the hypothesis tests during the physical delivery and the cash settlement periods. Table 5.9 indicates the number of times the hypotheses failed to be rejected when the named location served as the dependent variable. This is interpreted as showing whether the location responded to price changes occurring at the other locations.

Table 5.9 Summary of the Hypothesis Test Results Showing the Effects of Price Changes Initiated at Other Locations on the Named Location Before and After Cash Settlement Began. Numbers Refer to the Number of Times Each Result Was Found for the Named Location, Maximum of Seven.

	January, 1983-August, 1986					September, 1986-December, 1988				
	Strong Form[1]	Weak Form[2]	Long-Run[3]	Inter-dependence[4]	Independence	Strong Form[1]	Weak Form[2]	Long-Run[3]	Inter-dependence[4]	Independence
Amarillo	0	1	4	1	1	0	0	2	4	1
Clovis	0	0	5	0	2	0	0	5	1	1
Colorado	0	0	1	5	1	0	0	4	0	3
Florida	0	0	5	2	0	1	0	0	0	6
Kansas City	0	0	5	2	0	0	0	2	2	3
Oklahoma City	0	0	4	2	1	0	1	3	2	1
Shasta	0	0	0	6	1	0	1	2	0	4
Stockton	0	0	5	2	0	0	0	5	1	1
Totals	0	1	29	20	6	1	2	23	10	20

[1]Indicates additional failures to reject weak form short-run and long-run price matching for the pair.
[2]Indicates an additional failure to reject long-run price matching for the pair, does not count failures to reject which occurred as part of a failure to reject the strong form hypothesis.
[3]Does not include pairs which also failed to reject the strong or weak form hypotheses.
[4]Refers to pairs which rejected all four hypotheses.

Amarillo shows a reduction in price matching responsiveness to interdependence without full price matching. Clovis shows little change in its activity. Colorado changed from being mainly interdependent without full price matching to an increase in long-run price matching with several locations and a move to independence with a couple of others. Florida moved away from long-run price matching or interdependence to a strong form short-run price matching structure with one location and independence with all others. Kansas City shows a decline in the number of locations having a long-run price matching relationship to a corresponding increase in independence. Oklahoma City changed from a long-run price matching response with four locations to a weak form short-run price matching relationship with one location and continued long-run price matching with the remaining three. Shasta moved strongly away from interdependence without full price matching to one occurrence of weak form short-run price matching, two occurrences of long-run price matching, and three additional occurrences of independence. Stockton shows little change, with one location pair moving from interdependence to independence.

Table 5.10 indicates the number of times the hypothesis tests failed to be rejected when the named location served as the independent variable. This is interpreted as showing the effects of price changes at the named location on price changes at the other locations. Amarillo shows a large change, from long-run price matching and interdependence relationships at other locations to a strong form short-run price matching, a weak form short-run price matching, and a couple independence relationships at other locations. Clovis price changes showed decreasing effects on prices at other locations, moving from five occurrences of interdependence without full price matching to five occurrences of independence. Colorado showed only a small

Table 5.10 Summary of the Hypothesis Test Results Showing the Effects of a Price Change at the Named Location on Other Locations Before and After Cash Settlement Began. Numbers Refer to the Number of Times Each Result Was Found for the Named Location, Maximum of Seven.

	January, 1983-August, 1986					September, 1986-December, 1988				
	Strong Form[1]	Weak Form[2]	Long-Run[3]	Inter-dependence[4]	Independence	Strong Form[1]	Weak Form[2]	Long-Run[3]	Inter-dependence[4]	Independence
Amarillo	0	0	5	2	0	1	1	2	1	2
Clovis	0	0	1	5	1	0	0	1	1	5
Colorado	0	0	6	1	0	0	1	5	0	1
Florida	0	0	1	3	3	0	0	0	4	3
Kansas City	0	0	4	2	1	0	0	6	0	1
Oklahoma City	0	1	4	2	0	0	0	5	1	1
Shasta	0	0	7	0	0	0	0	4	2	1
Stockton	0	0	1	5	1	0	0	0	1	6
Totals	0	1	29	20	6	1	2	23	10	20

[1]Indicates additional failures to reject weak form short-run and long-run price matching for the pair.
[2]Indicates an additional failure to reject long-run price matching for the pair, does not count failures to reject which occurred as part of a failure to reject the strong form hypothesis.
[3]Does not include pairs which also failed to reject the strong or weak form hypotheses.
[4]Refers to pairs which rejected all four hypotheses.

change, moving to one weak form short-run price matching relationship and to one case of independence. Florida also shows a small change, moving from one long-run price matching relationship to an additional case of interdependence without full price matching. Kansas City gained importance as a location whose price changes are matched by others with two additional occurrences of long-run price matching. Oklahoma City showed the break-up of a weak form short-run price matching structure with one location and another location showing independence with Oklahoma City price changes. The impact of price changes at Shasta also declined, with two locations moving from long-run price matching to interdependence without full price matching and another location moving to independence. Stockton showed a large decline as a location which other locations match prices with, moving to reject long-run price matching with all locations and a failure to reject independence with an additional five locations.

The totals show that one location moved towards a strong form short-run price matching structure, consistent with a basing-point pricing pattern, two locations moved towards a weak form short-run price matching structure, consistent with an imperfect basing-point pricing pattern, and fourteen moved to independence.

Chapter 6

CONCLUSIONS

This chapter presents the conclusions about the spatial integration and competitiveness of feeder cattle prices which can be drawn from the empirical analysis and the spatial theory presented in chapter 3. The conclusions leave unanswered questions about pricing relationships, so suggestions for further research are also presented.

Evaluation of the Model

The Ravallion model, as used here, is not interpreted as measuring the efficiency of feeder cattle price transmission in terms of the speed with which it occurs. Instead, the model presents evidence regarding the process of adjustment (instantaneous, instantaneous with minor lagged effects, lagged, none) as evidenced by the price matching hypotheses, and through these the pricing structures in effect. The pricing structures revealed have implications for the spatial efficiency of the prices observed in terms of interlocational competition and how well the prices reflect supply and demand in different locations and promote an efficient allocation of resources.

The results of the model, while sensitive to the speed of adjustment, also provide evidence as to whether data aggregation may be a problem or whether, as a separate issue, too few lagged price changes are being included. If strong form short-run price matching is found to occur frequently and further research fails to provide evidence of a basing-point or collusive system, the data may be overly aggregated, masking the adjustment process.[1]

The spatial theory in chapter 3 suggests that time will be needed for the price adjustment process to occur across space, forming a basis for the interpretation of the pricing structures revealed by the hypothesis tests. The definition of the proper units of time (hours, days, weeks, months, etc.) to measure the adjustment process, however, are not identified in the theory. Thus, other factors must be used to determine the appropriate units of time. If the ability to engage in physical delivery between locations or biological lags are needed to complete the adjustment process, then longer units of time such as weeks or months may be necessary. Alternatively, if only prices need to be communicated, which may occur very rapidly with modern technology, then shorter units of time may be more appropriate.

The results reported in this study find few cases in which strong form short-run price matching, or full contemporaneous price adjustment, cannot be rejected, thus the use of weekly average prices does not appear to be masking the adjustment process.

The empirical model may also provide evidence for the amount of time required to complete the adjustment process. If the number of lags in the model is insufficient to capture full price matching adjustments, the three price matching hypotheses are more likely to be rejected, resulting in the conclusion that prices are interdependent without full price matching, or in the extreme, independent. The results indicate a large number of location pairings in which the three price matching hypotheses and independence are rejected (36 of the 56 pairings) during the 1983-1988 period. The independence

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[1]Further research would involve an examination of the behavior of buyers and sellers at and between locations showing strong form short-run price matching. Interlocational price differences would also be examined for constant equality with transfer costs.

hypothesis also fails to be rejected a large number of times (52 out of 90 pairings fail to reject independence and an additional 6 pairings reject all four hypotheses) during the 1987-1988 period. It seems unlikely, however, that the sixteen weekly lags are insufficient to capture any adjustment process which might be occurring, and the Q-statistics indicate that the residuals are white noise. The empirical model does not provide any evidence regarding the possibility of too many lags, which will reduce the statistical efficiency of the model.

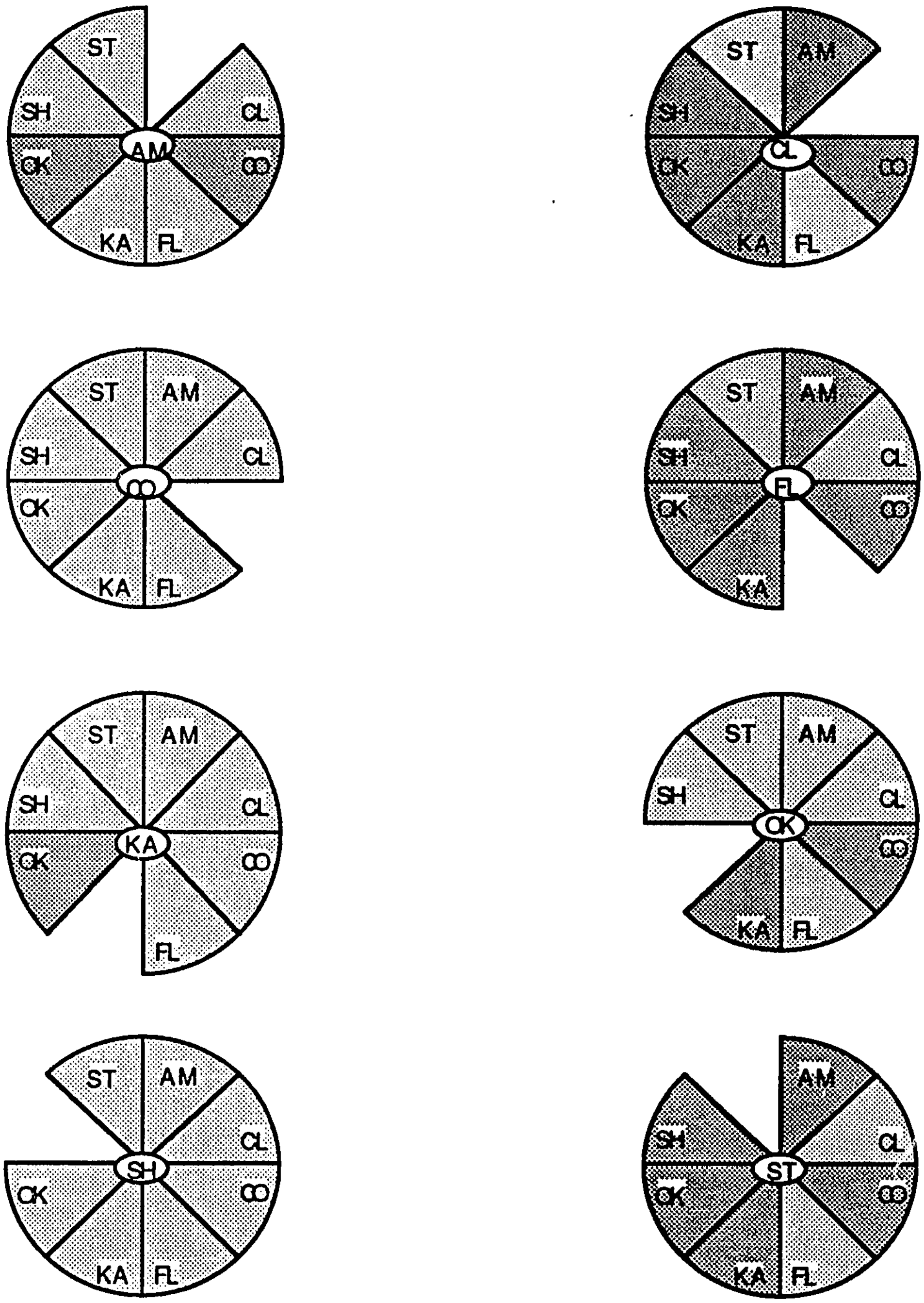
The Ravallion model, in effect, includes some degree of built-in diagnostic evidence for the specification of the model in terms of whether the data are overly aggregated or have too few lags. Some other methods of testing integration, such as contemporaneous correlations, do not have this ability. Thus, in view of the results of the analysis, the model appears to be quite useful in analyzing pricing within a spatial framework.

1983-1988 Model Conclusions

The results of the hypothesis tests using the WLMIP data over the January, 1983-December, 1988 period suggest several conclusions about the structure of feeder cattle pricing between locations. The primary conclusion is that, since the independence hypothesis was rejected by all pairs, all locations are integrated into a larger market. Buyers and sellers at one location do not act with disregard to conditions at other locations. The hypothesis test results are summarized in Figure 6.1.

Both short-run price matching hypotheses were rejected for all pairs during the six year period. The rejection of the strong form indicates that there is no evidence for a basing-point pricing arrangement between the markets or that less than one week is required for full price adjustment. The rejection of the weak form hypothesis also

Figure 6.1 Summary of the Hypothesis Test Results for the 1983-1988 Period. Location in Center is the Dependent Variable.



Explanatory Notes are in Figure 6.4.

indicates that incomplete basing-point pricing was not present. Incomplete basing-point pricing might occur if some locations were involved in a basing-point pricing relationship and other locations weren't, resulting in a short period of adjustment with the non basing-point locations, or if a cartel arrangement were in tacit, rather than overt, operation. Any local monopolies or monopsonies, if they should exist, are limited by the competitive effects of firms at other locations. No monopolistic or monopsonistic behavior can be detected. The theoretical model presented in chapter 3 and the findings of interdependence and rejection of monopolistic behavior indicates that the locations examined can be described as linked spatial oligopolies.

The long-run price matching hypothesis fails to be rejected by twenty of the fifty-six pairings. The pairs which fail to reject the hypothesis imply a competitive adjustment process between these locations. Price changes at one location result in a series of further adjustments as a new equilibrium is achieved. The results also show which pairs display strong competitive linkages. Linkages are most common when they involve Amarillo, Colorado, Kansas City, or Oklahoma City as the independent variable and the remaining locations of Clovis, Florida, and Stockton as the dependent variables. The effects of price changes at smaller volume locations or those outside the central plains feeding area may have a relatively small impact on the Amarillo, Colorado, Kansas City, or Oklahoma City locations since these locations must compete with other large volume locations and many smaller locations which are not included in this study. The rejection of all four pricing hypotheses by some pairs indicates that large volume locations are interdependent with the smaller volume locations, however full price matching doesn't occur. On the other hand, smaller volume locations must match price changes at the large volume locations because the relative impact of a shift in market boundaries may be much larger.

The Amarillo, Colorado, Kansas City, and Oklahoma City locations ring the dominant cattle feeding region of the United States and are likely to have the most intense competition. They also have the highest prices, which may be due to many factors such as more competition, economies of size, lower transfer cost to feedlots compared to more distant locations, or a more stable distribution of qualities, reducing the relative impact of a few low quality lots of cattle on the weekly average price. Many of the forces affecting feeder cattle markets may be generated and reflected in the region since cattle from other parts of the U.S. are routinely shipped in for feeding. Price changes in one of these high volume locations (and high cattle density over the space between locations) may result in relatively large shifts in the market area served by each location when compared against the shift with a small volume location Thus the failure of central locations (Amarillo, Colorado, Kansas City, or Oklahoma City) to match price changes at peripheral locations (Clovis, Florida, Shasta, or Stockton) may be due to the relative impacts of a shift in volume. As an additional consideration, complete volume information is not available, nor are all sales locations in the United States included, thus important alternative locations may be omitted.

Colorado and Shasta show interesting results, since they reject long-run price matching with all other locations, but many of the other locations do match price changes at Colorado and Shasta. This suggests that they may act as price leaders, or they may interact with such a large number of rivals that full price matching with a single location doesn't occur. The pairwise tests do not directly measure adjustments occurring through other locations, thus the latter possibility cannot be tested under the empirical model formulation used in this study.

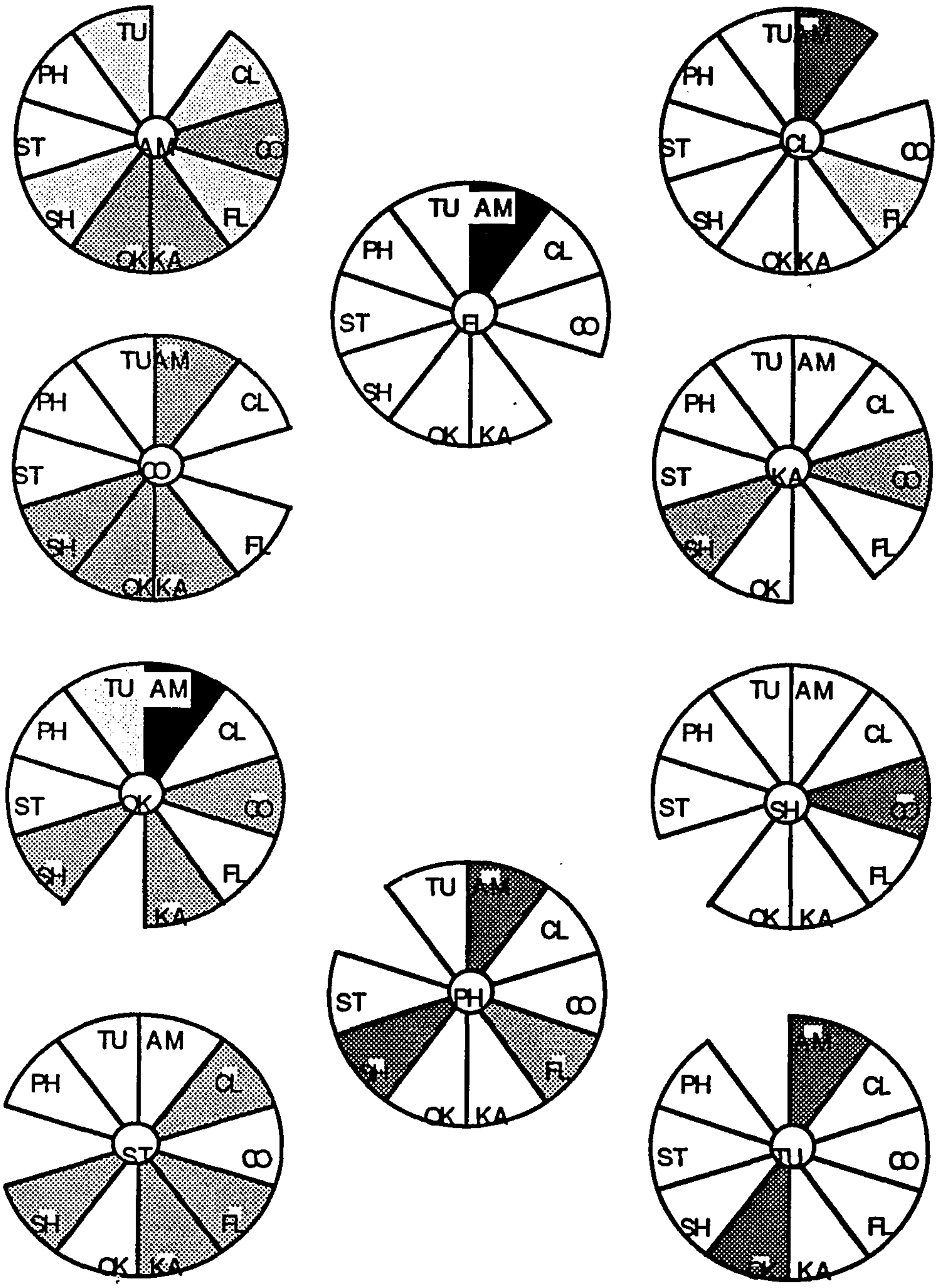
The rejection of all four hypotheses by thirty-six of the fifty-six pairings implies several possible conclusions. The number of lags may be insufficient for the adjustment process to be completed, as previously mentioned. Alternatively, the hypothesis tests are being rejected in favor of the general model of interdependence without full price matching. This may imply that the locations are sufficiently distant from each other so that intermediate locations serve to dampen the price response or that full price matching does not occur within the lag structure of the model.

The results over the six year period indicate that all of the locations are interdependent and competitively linked into a single, large market showing a price adjustment process characterized by feedback. Larger volume locations surrounding the central plains feeding region appear to be dominant although all are linked, either directly or through other locations.

1987-1988 Model Conclusions

The results of the hypothesis tests over the two year period of January, 1987 to December, 1988 show substantially different results from the longer 1983-1988 period. These results are summarized in Figure 6.2. The change to cash settlement from physical delivery of feeder cattle futures contracts, a potentially important structural change, occurred four months before this analysis started. The hypothesis of independence fails to be rejected by thirty-two of the fifty-six WLMIP pairs. Independence also fails to be rejected by twenty-seven of the thirty-four pairs which involve Phoenix or Tucson as either the dependent or independent variable. This

Figure 6.2 Summary of the Hypothesis Test Results for the 1987-1988 Period. Location in Center is the Dependent Variable.



Explanatory Notes are in Figure 6.4.

contrasts markedly with the results of the entire six year period when all of the WLMIP pairs rejected independence.

The failures to reject independence may be partially explained by the patterns of pricing structures displayed by the locations. All locations reject independence with at least one other location. Failure to reject long-run price matching occurs between ten of the twelve pairings among the central plains locations of Amarillo, Colorado, Kansas City, and Oklahoma City, which will be referred to as the central locations hereafter. The central locations, as the dependent variable, show a weak relationship with price changes at the peripheral locations (as Clovis, Florida, Shasta, Stockton, Phoenix, and Tucson will be referred to hereafter), rejecting the three price matching hypotheses or failing to reject independence. The peripheral locations fail to reject independence in twenty-two of the thirty pairings among themselves, however they always reject independence and fail to reject long-run and/or short-run price matching with at least one central location.

These results suggest that the peripheral locations tend to act independently of most locations but also fully match the price changes of a few alternatives, including at least one central location. The central locations show a more integrated structure among themselves; however, they do not directly match price changes in the periphery. This pattern suggests that prices tend to be discovered at the central locations, then feed out to the peripheral locations. This type of structure may be less efficient than a structure in which all locations are interdependent, as discussed in chapter 3.

In the theoretical model, failure to reject independence is consistent with price discrimination and constant marginal costs. Further research into the behavior of firms and pricing would be needed to arrive at any conclusion that discriminatory pricing is occurring. Additionally, other reasons may explain these results which indicate that many locations are segregated.

In addition to a larger number of failures to reject independence, the two forms of short-run price matching fail to be rejected on occasion. Strong form short-run price matching, consistent with basing-point pricing, fails to be rejected by two pairings. Both of these pairs involve Amarillo as the base-point. An additional six pairings fail to reject weak form short-run price matching, consistent with imperfect basing-point pricing . The six pairings involve a peripheral location as the dependent variable matching a central location as the independent variable.

Oklahoma City and Florida both failed to reject long-run, weak, and strong form short-run price matching with Amarillo, indicating that these two locations instantaneously adjust to match Amarillo price changes without lagged effects. Long-run and weak form short-run price matching failed to be rejected with Clovis, Phoenix, and Tucson, all having Amarillo as the base. Shasta served as a base for prices at Phoenix, while Colorado served as a base for Shasta.

The appearance of structures consistent with basing-point or imperfect basing-point pricing systems fits in with the additional failures to reject independence. If some form of basing-point pricing were occurring, locations not participating in the basing-point system would likely appear to be independent. Thus as a location develops a structure of rapidly matching the full price changes of a second location, responsiveness to price changes at other locations would be expected to decline.

The pricing relationships indicated by the hypothesis test results for the 1987-1988 period differ markedly from the results of the 1983-1988 analysis. On the surface, this might suggest that the model is not consistent. However, the results of the

1983-1988 period may better reflect the long-run (allowing all factors to be variable) tendency of the market, while shorter periods reveal disequilibria which are corrected over longer periods as more complete economic adjustments occur. The results of the analyses of the data over the six year period and the shorter two year subset then indicate that the central locations generally maintain a competitive, price matching structure with adjustment while peripheral locations tend to match prices with only a few of the central locations and display independence with the rest. Over longer periods of time, all locations appear to be integrated. In a study of Indiana hog markets, Stout and Feltner (1962) found differentials in prices over two week observation periods, however these differences disappeared when all two week periods were examined together. Disequilibria may be expected in a dynamic market in order to spur an adjustment to regain equilibrium. Studies which find disequilibria (imperfections) using data over relatively short periods of time should not be too alarming from a policy perspective unless these disequilibria fail to disappear in a longer-run analysis.

An additional analysis over the period September, 1983 to August, 1985, the same length of time as the 1987-1988 analysis, was conducted. The hypothesis test results, not reported here, showed a pattern of failure to reject independence and some of the short-run price matching hypotheses similar to the 1987-1988 results, although the location pairs showing these results were generally different. Thus, short-run disequilibria may be revealed by analysis over shorter time periods, although longer periods show that adjustments occur to correct the disequilibria.

Cash Settlement Effects

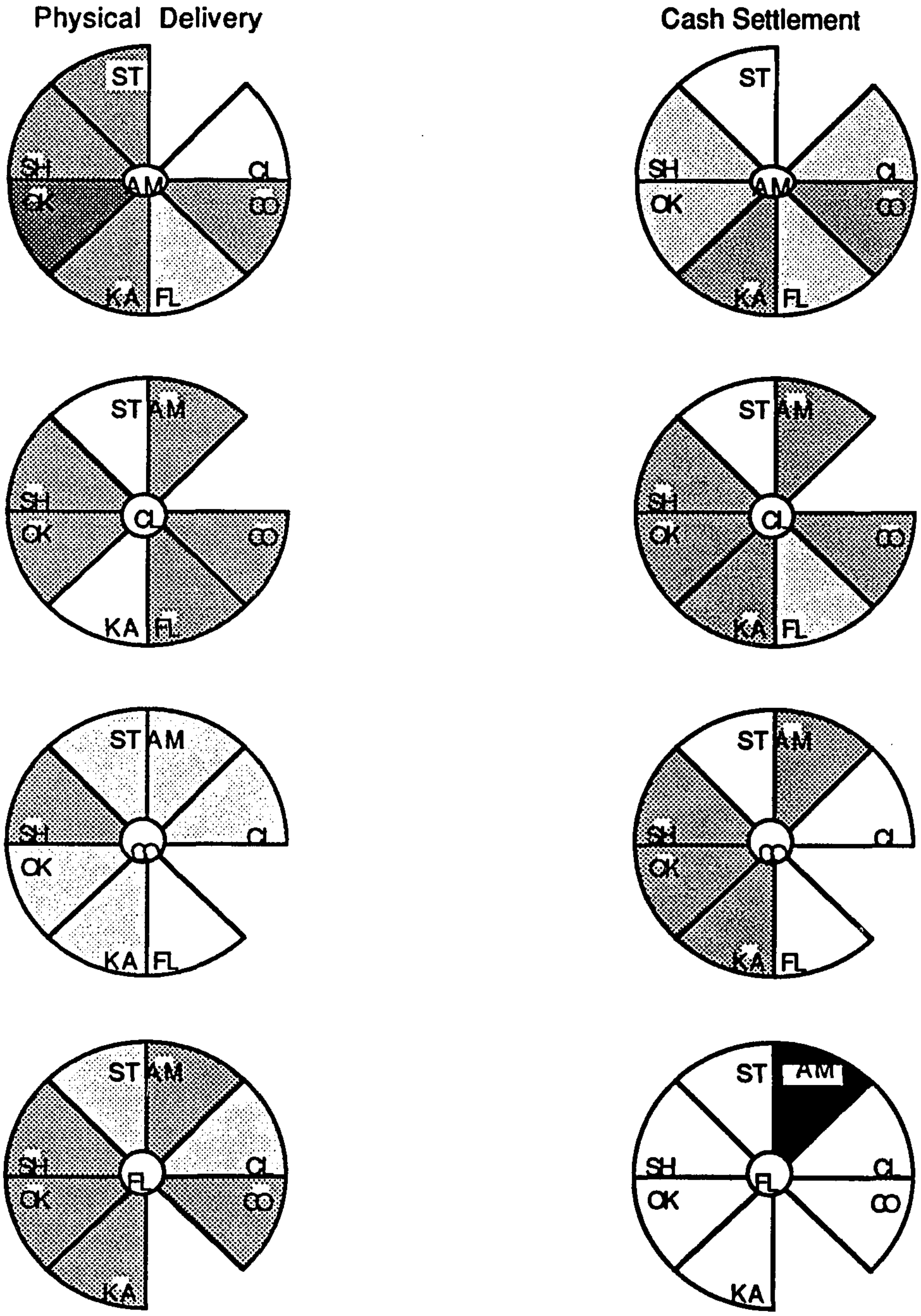
The analysis of pricing structures before and after the change to cash settlement of feeder cattle futures contracts indicates that over half of the location pairs had significant changes in parameter values. Chow tests rejected the null hypothesis of no change in parameter values in the general model for thirty-two of the fifty-six pairs. Of these thirty-two pairs in which parameter value changes were indicated, fourteen had no change in the hypothesis test results, leaving only eighteen of the fifty-six pairs (one third) showing changes in the price matching hypothesis test results. The hypothesis test results of the pre and post cash settlement periods are summarized in Figure 6.3.

Amarillo, Kansas City, and Oklahoma City, comprising three of the four locations which were delivery points before cash settlement, showed little change in hypothesis test results among themselves or with Colorado. The fourth delivery location, Colorado, when serving as the dependent variable, showed significant changes, from rejecting all four pricing hypotheses in the physical delivery period to a failure to reject long-run price matching with the other three former physical delivery points after cash settlement was effected.

The relationships of the four former delivery points, as the dependent variable, with the peripheral locations (Clovis, Florida, Shasta, and Stockton) showed a general movement from long-run price matching towards independence. Most of the Chow tests between these pairs, however, were not significant.

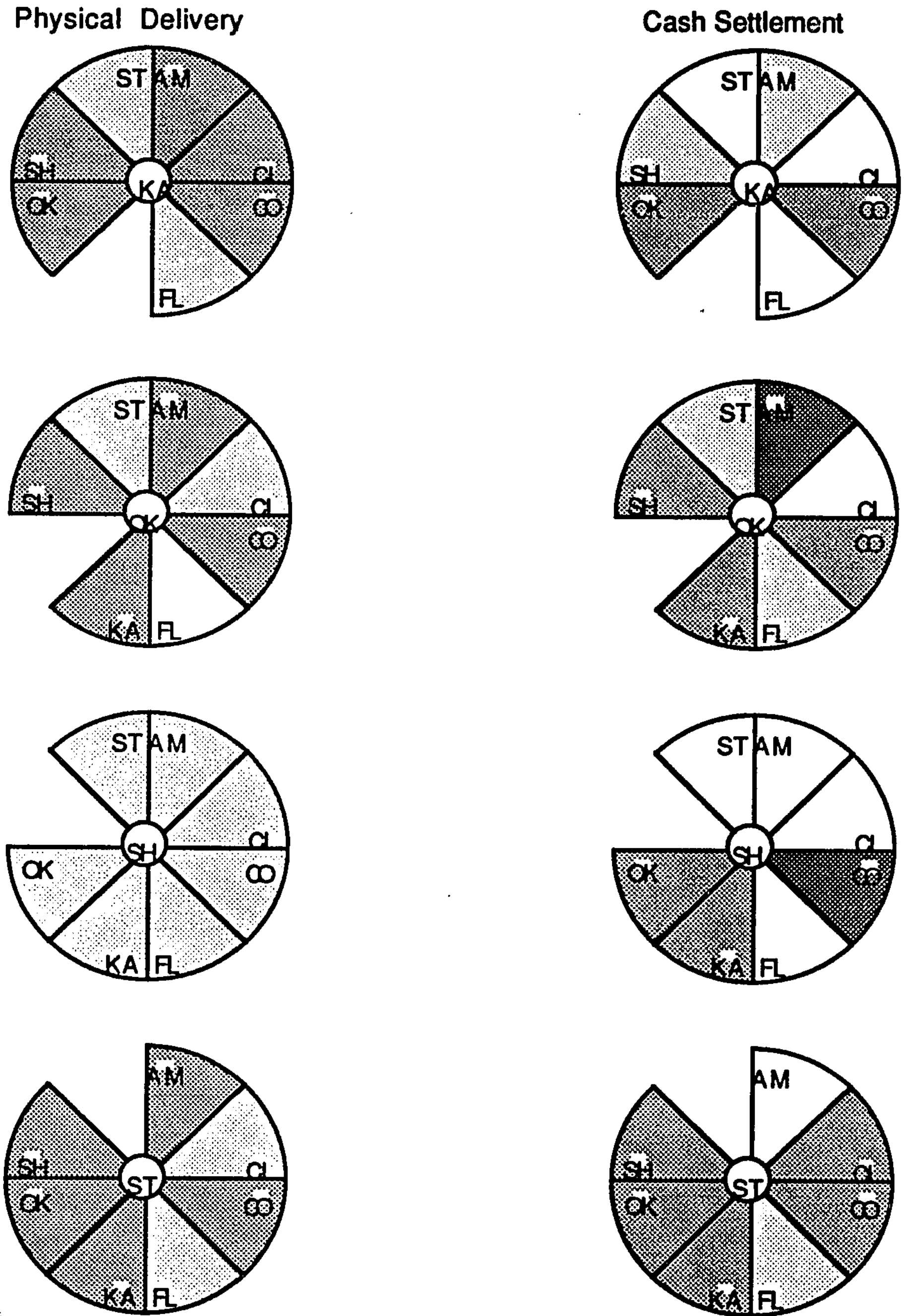
The peripheral locations, as the dependent variable, did not show much change in the price matching hypotheses where the Chow test indicated that a change in parameter values had occurred. The greatest change was a move towards independence for dependent variable Shasta in conjunction with the development of a weak form short-run price matching relationship between Shasta-Colorado. Florida also changed, moving to a

Figure 6.3 Summary of the Hypothesis Test Results Before and After the Beginning of Cash Settlement. Location in the Center is the Dependent Variable.



Explanatory Notes are in Figure 6.4.

Figure 6.3 cont. Summary of the Hypothesis Test Results Before and After the Beginning of Cash Settlement. Location in the Center is the Dependent Variable.



Explanatory Notes are in Figure 6.4.

Figure 6.4 Explanatory Notes for Figures 6.1 to 6.3.

= Failure to Reject Independence.

= Rejection of All Four Hypotheses.

= Failure to Reject Long-run Price Matching.

= Failure to Reject Weak Form Short-run and Long-run Price Matching.

= Failure to Reject Strong and Weak Forms of Short-run Price Matching as Well as Long-run Price Matching.

AM= Amarillo
CL= Clovis
CO= Colorado
FL= Florida
KA= Kansas City
OK= Oklahoma City
SH= Shasta
ST= Stockton
PH= Phoenix
TU= Tucson

strong form short-run price matching relationship with Amarillo and independence with other locations.

Overall, the evidence indicates that central locations continued, or in the case of Colorado, moved towards, long-run price matching among themselves and moved towards independence with the peripheral locations. The peripheral locations showed little change except when a strong or weak form short-run price matching system developed with a larger volume or central location, corresponding with a move towards independence with other locations.

The locations continue to be interdependent, although the change to cash settlement corresponds with a reduction in price matching among peripheral locations, resulting in individual linkages to a smaller number of central locations. The peripheral locations may be linked, although the linkage occurs indirectly through the competitively linked central locations.

Further Research

The model of pricing structures used here appears to provide useful information about spatial pricing relationships. Further work can be done, however. The pairs which failed to reject strong form short-run price matching should be investigated further to determine the cause of this result and answer several questions. Is basing-point pricing or collusion occurring? Is the data suffering from too much aggregation? A further analysis using daily price data rather than weekly averages might help clear up some of these questions.

Additional investigations into the possible effects of the change to cash settlement would be informative. The price differentials between locations might be examined. An analysis of pricing structures might be conducted using a feeder cattle futures contract price series. Feeder cattle prices at different locations may be closely linked with futures contract prices rather than prices at delivery points. Thus the change to cash settlement based on an average of prices in many locations throughout the United States may have resulted in direct changes in price matching structures with futures prices, which then appear as the changes in pricing structures between the locations analyzed here.

Pricing structures may also change seasonally with changes in cattle movements. The information on cattle movements into and out of Arizona in chapter 2 shows that considerable variations occur over the course of a year in the sources of cattle imports and the destinations of cattle exports. An examination of pricing structures corresponding with seasonal cattle movements between geographic areas may reveal additional information about spatial pricing relationships in the industry.

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