U.S. Beef Cattle Recipes

Preparing time dependent fundamentals of cattle futures

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By

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Management Summary

This research aims to assess, describe and model the price behavior of live cattle, live cattle futures contracts and related commodities such as feeder cattle, corn and soybean meal. Additionally the goal is to untangle underlying causes of cattle futures price fluctuations. We assess the price behavior of cattle futures from different perspectives. The scope of our work is limited to the U.S. cattle sector.

In the first place we assess the fundamental and biological relationships of cattle and related commodities by evaluating fundamental supply and demand relationships in cattle operations. The biological nature affects the production process of beef cattle. In the industry, females are valued both as consumption and as capital good to replace future beef production. We elaborate on the lifecycle of cattle by analyzing four different stages in cattle production: calves, heifers, beef cows and steers. The result is a cattle flow diagram, which forms the basis for analyzing cattle supply and demand relations. In addition we assess the cattle futures market. We discover and recognize three time effects which should be considered in futures contracts price analysis. The time effects strengthen our idea to focus on fundamental characteristics and relationships that affect supply.

We specify a cattle supply model which includes the most significant determinants of cattle supply. Via this model we untangle which forces have the greatest influence on cattle supply and ultimately its price. Four supply equations are given to estimate the supply of four different cattle categories: calves, heifers, beef-cows and steers. Linear regression is used to estimate which (lagged) variables are the most significant cattle supply drivers. We found evidence that there exist three important determinants of cattle supply: the price of corn, the price of cattle sold to the cattle buyer and the number of animals available for replacement. We found evidence of a short-run negative supply relationships for all animal categories. In other words, an increase in the price of slaughter animals would result in a decrease in the supply of slaughtered animals. When the supply of slaughter cattle rises, producers are willing to retain animals to produce animals in the future, instead of slaughtering them instantaneously. We find mixed results for the dependency of corn to cattle supply. In addition, we find evidence that the replacement inventory is positively related to the supply of cattle, for all animal categories.

Finally this research links the cash markets with the futures markets by performing two case studies. The drought of 1988 and the discovery of BSE in the U.S. alert practitioners to be cautious for the three time effects to be (simultaneously) active in the market. The case studies are good examples how cattle supply variables relate to futures prices in the cases wherein a particular subset of variables dominate.

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Introduction and Methodology

Problem introduction

The behavior of cattle futures prices is odd. Prices of cattle futures react differently to the same (news) events at different periods in time and on different time scales. The a-typical price behavior of cattle products is ascribed to the biological time lag and a "dual purpose" of cattle in the production process. In other words, there exist a time lag between the time a cattle producer decides to increase or decrease cattle production and the time resulting changes occur in the beef supply. Besides, cattle are simultaneously used as consumption good and as a capital good, to replace future beef production. Our aim is to untangle the fundamentals of cattle futures market. We do not only elaborate on the basic details of the futures markets where cattle- and cattle-related-derivatives are traded. We recognized that there is only one way to reveal these relationships: by uncovering the fundamental details of the underlying products of the industry itself.

Research objective

In this thesis we aim to *assess*, *describe* and *model,* the price behavior of live cattle and live cattle futures and related commodities such as feeder cattle, corn and soybean meal. The study is developed to discover underlying causes of cattle futures price fluctuations. More specifically, our aim is to find relationships between cattle and cattle futures prices.

Research questions

This thesis answers research questions in a sequential order. First, we elaborate on the structural and fundamental aspects of the cattle industry. Then, we describe the behavior of cattle futures prices in general. Finally, we focus on price behavior in extra-ordinary cases, wherein a specific subset of factors arguably dominates. In every question we consider the factor time as an important factor to reflect on.

- What are the fundamental characteristics (price drivers) of the cattle sector?
- Which fundamental relationships exist in cattle operations?
- Which *general* relationships exist in cattle- and cattle-related-futures prices (on different time scales and in different periods in time)?

Research approach

We assess the price-behavior of cattle related commodities from different perspectives. First, we describe the critical structural relationships of the cattle sector. By assessing biological, structural and economic constraints and relationships of commodity markets we assess commodity price behavior in the mid- and long run. Second, we estimate quantitatively whether there exist causal relationships over time between fundamental cattle variables such as: production, price, inventory and feeding costs. Then, we identify whether fundamental relationships can be considered in the cattle futures markets. Finally, we describe and analyze market prices under normal circumstances and in extreme cases by performing two case studies.

1. Futures Markets

1.1 Introduction

This chapter elaborates on the basic details of futures markets. It describes the characteristics of (cattle) futures contracts, how to trade, what are the “rules” of the trading game and how prices come together. Moreover we assess the behavior of agricultural futures contracts prices by describing three different time-effects.

1.2 Futures contracts

1.2.1 Basics

A futures contract is an agreement between two participants to buy or sell an asset at a certain time in the future for a certain price (Hull, 2006). The futures contract is a so called *derivative*, as the name already reveals it is a financial instrument which value is *derived* from the value of an underlying variable. This can be a commodity price, interest rate or stock price. Physical delivery of the underlying commodity seldom takes place with a futures contract. Buyers and sellers are required to take or make a delivery of the commodity or financial instrument represented by the contract. While delivery can take place, most traders *offset* their positions before the expiration of the contract. However, the potential for delivery is vital to linking cash and futures prices. Futures contracts are standardized according to delivery specifications, including the quality, quantity, time and location. The most essential variable is price, which is discovered, in the trading process. The standardization of contract terms is what creates trading opportunities and increases liquidity and market volume. The following example makes the main idea clear:

Example

Suppose an investor buys one corn futures contract which expires in December 2009. The contract gives the investor the legal duty to buy 5.000 bushels of corn on a given date and a given location in December 2009. To offset this position, the investor can take an opposite position equal to the initial transaction. In other words, the investor sells one (other) Corn futures contract which expires in December.

Notation

In the remainder of this thesis we will use the following notation for futures contracts: “***Live Cattle Feb 09”***
Which refers to the live cattle futures contract expiring in February 2009.

1.2.2 Zero-sum game

An important characteristic of a futures contract, is that entering the contract is like playing a zero-sum game. In the world of futures contracts, for every long position there is an equal opposite short position. In other words, one participant's gains result only from another's participant's equivalent losses. The net change in the total amount of money among participants is zero. Money is neither made, nor lost it is only shifted from one pocket to the other. Buyers and sellers should be aware that for every trade clearing fees are charged by brokers, exchanges and clearing houses.

Of course if all traders had positions only in futures contracts and they traded only with each other, then all profits and losses would sum to zero. However, we believe that this assumption would be too short sighted. We would need to assume that traders only have positions in futures markets and are not exposed to risks in other markets. We believe that the reader should not forget the profile and characteristics of the market participant. An important portion of the market participants are hedgers, who operate business in which they are exposed to certain risks (e.g., changes in commodity prices, currency- or interest rates). Those businesses actively participate in the futures market to get rid of certain price risks. On the other side there are participants willing to take over those risks. Speculators such as arbitrageurs, hedge funds and market makers that access the futures markets to hedge across different asset classes. In their role, they are searching, or willing to take over price risks. All those participants, link the cash markets to the futures markets, changing the closed system into an open-ended system, in which there does not exist a zero-sum game.

1.2.3 Exchange, Clearing & Margin

Futures contracts are fungible and are, normally, traded on an exchange. To make trading possible the exchange specifies certain standardized features of the contract. As the two parties to the contract do not necessarily know each other, the exchange provides a mechanism that gives the two parties a guarantee that the contract will be honored. By entering a futures contract, counterparty and credit risk should be considered. since defaults of buyers or sellers can occur. One of the investors simply may not have the financial resources to honor the agreement. One of the key-roles of the exchange is to organize trading so that contract defaults are avoided. To minimize the risk of a contract default ever happening, exchange clearinghouses require their members to deposit money in a so called margin account. Every end of the trading day the margin account is adjusted to reflect the investor's gain or loss of the futures contract. This practice is referred to as *marking-to-market* the account.

1.2.4 Market participants

If we take the cattle futures markets in consideration, we distinguish different market participants which participate on the futures market.

- Cattle producers: organizations that produce cattle in different life-stages (e.g., cattle feeders).
- Cattle processors: organizations that buy and process cattle to produce beef (e.g., slaughter houses).
- Speculators: organizations that are willing to accept the price risk of futures contracts (e.g., hedge funds).

The first two participants are called hedgers, since they participate in the futures market to hedge their (price) risk on a commodity they (wish to) possess. Whereas hedgers want to avoid exposure to adverse movements in the price of an asset, speculators wish to take a position in the market. Either they are betting that the price of the asset will go up, or they are betting that it will go down (Hull, 2006).

1.2.5 Position limits and price limits

For most contracts, daily price movement limits are specified by the exchange. If the price moves down by an amount equal to the daily price limit, the contract is said to be limit down. If it moves up by the limit, it is said to be limit up. Normally, trading ceases for the day once the contract is limit up or limit down. However, in some instances the exchange has the authority to step in and change the limits. The purpose of daily price limits is to prevent large price movements from occurring because of speculative excesses (Hull, 2006). Position limits are the maximum number of contracts that a market participant may hold. The purpose of the limits is to prevent individual participants from exercising undue influence on the market (Hull, 2006).

1.3 Agricultural futures contracts

The scope of this thesis is limited to agricultural futures contracts. Principally we consider live cattle, feeder cattle, corn and soybean meal futures. This section explains main details and contract specifications of the contracts which are used in our study. All contracts are traded in the United States at the Chicago Mercantile Exchange (CME) or at the Chicago Board of Trade (CBOT). The CME merged together with CBOT under the name CME Group in 2007. The merger did not had any major implications for the products traded at both exchanges. Details about the futures contracts are summarized in Table 1.

1.3.1 Live cattle futures

Live Cattle futures were introduced by the CME in 1964. One live cattle futures contract corresponds to the physical delivery of 40.000 pounds of live, fattened cattle, ready to be sent to slaughterhouses. To get an idea of the size of the underlying, 40.000 pounds of cattle is equal to approximately thirty fattened steers.

The seller of one live cattle futures contract has the obligation to deliver animals which meet a certain set of requirements. For example, no individual animal may weigh less than 1050 pounds or more than 1475 pounds. Furthermore, no cattle which are unmerchantable, e.g., crippled, sick, obviously damaged or bruised, may be deliverable.

1.3.2 Feeder cattle futures

Feeder cattle refer to the young animals that are sent to feedlots, to be fed into live cattle. In contrast with live cattle futures contracts, feeder cattle futures are cash settled. The cash settlement is linked to the CME feeder cattle index. This index is a seven day weighted average of feeder cattle (feeder steers weighing between 650 and 849 pounds) prices as calculated by the USDA. The cash settlement for feeder cattle futures began with the September 1986 contract. The Chicago Mercantile Exchange (CME) introduced cash settlement basically for several reasons. The CME introduced cash settlement as a means of eliminating physical deliveries, encouraging long participation by speculators and hedgers, and increasing hedge participation by reducing basis variation (Kenyon *et al.*,1991). For example, in a live cattle futures contract is specified that the exchange appoints an location were underlying animals should be delivered. In the United States there are several delivery points, at which the seller of the futures contract should deliver the underlying number of cattle. Because of the system of multiple delivery points, long traders never knew where delivery would occur. Hence in this system both long speculation and long hedging were discouraged. Besides cattle contracts, we also consider corn and soybean contracts. Corn and soybean are one of the major components of cattle feed.

Table 1: Futures contracts characteristics

(Source: CBOT, CME Group)

	Live Cattle Futures	Feeder Cattle Futures	Corn Futures	Soybean Meal Futures
Exchange	CME	CME	CBOT	CBOT
Product description	55% Choice, 45% Select, Yield Grade 3 live steers	650-849 pound steers, medium-large #1 and medium-large #1-2	#2 Yellow at contract Price, #1 yellow at a 1.5 cent/bushel premium #3 yellow at a 1.5 cent/bushel discount	Soybean Meal, with 48% protein level
Contract size	40.000 pounds	50.000 pounds	5.000 bushels	100 tons
Contract months	Feb, Apr, Jun, Aug, Oct, Dec	Jan, Mar, Apr, May, Aug, Sep, Oct, Nov	Mar, May, Jul, Sep, Dec	Jan, Mar, May, Jul, Aug, Sep, Oct, Dec
Pricing units	Cents per pound	Cents per pound	Cents per bushel	USD per 1 tons
Daily Price limits	$.03 per pound above or below the previous day's settlement price	$.03 per pound above or below the previous day's settlement price	$0.30 per bushel expandable to $0.45 and then to $0.70 when the market closes at limit bid or limit offer	$20 per short ton expandable to $30 and then to $45 when the market closes at limit bid or limit offer
Position limit	5400 contracts, and 300 contracts in spot month	1600 contracts and 300 contracts in spot month	13.500 contracts in one contract, 22.000 contracts in all months combined, 600 contracts in spot month	5.000 contracts in one contract, 6.500 contracts in all months combined, 720 contracts in spot month
Type of Delivery	Physical Delivery	Cash settlement / Expire to a cash index price	Physical Delivery	Physical Delivery

1.3.3 Corn futures

In the United States yellow corn is typically grown to feed livestock because of its starch content. In addition, it contains more oil than other cereal grains, so it is a high energy producer. An acre of corn yields more animal feed in both grain and forage than any other crops, although it costs no more in labor to produce and harvest. Because of the meat industry’s traditional pattern of heavy corn consumption, any significant increase or decrease in animal production forces farmers to reevaluate their corn production (CBOT, 2006). Approximately 55 to 60 percent of the cash corn crop is used as livestock feed. In recent years, corn has accounted for at least 25 percent of all livestock feed (CBOT, 2006) Corn futures are traded on the Chicago Board of Trade (CBOT). Each futures contract represents 5.000 bushels of yellow corn of different quality levels. Most production of corn in the U.S. is centered in the area known as the Corn Belt (in the states Iowa, Illinois, Minnesota, Missouri, Nebraska, Ohio and South Dakota). It is no coincidence that feedlot operators, which are highly dependent on corn as the input for animal feed, are located in the neighborhood of this corn area. Corn planting begins in early May and harvest begins in October until November. The December contract is the first futures contract traded on a new corn-crop.

1.3.4 Soybean meal futures

Soybean meal is the product remaining after extracting most of the oil from whole soybeans. The meal is high in protein and energy. As such it is a commonly used as a supplement in cattle feed. Most soybean crops are grown in and around the Corn Belt. The planting of the crop starts one month later than corn, in May or June. Harvesting takes place in September and October. Whole soybeans are hardly used, the greatest demand for the beans is as oil or meal, which are both traded as futures contracts. Approximately 98 percent of soybean meal is used as livestock feed (CBOT, 2006). Figure 1 gives an indication of the different kind of livestock categories in the United States. In which livestock is defined as all animals used for “food” of “fiber” excluding poultry. The demand of soybean meal is thus closely related to the number of livestock on feed. Soybean meal futures are traded on the Chicago Board of Trade (CBOT). Each futures contract represents 100 tons of soybean meal.

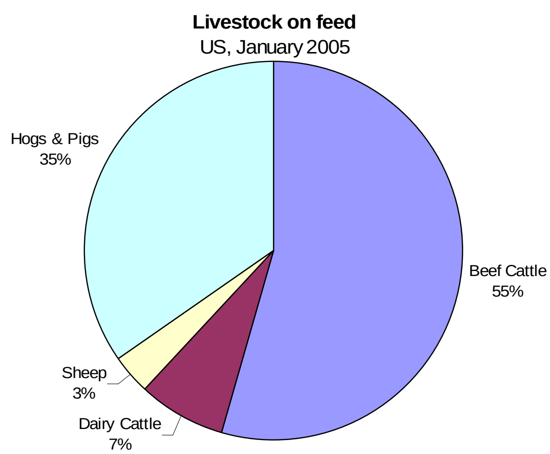


Figure 1: Livestock on feed, US, January 2005
Source: USDA, RedMeatYearbook 2005

1.4 Price behavior of futures contracts

Figure 2 shows the price behavior of three live cattle futures contracts in 2008. There is more than one contract active, every moment in time. Every contract represents a different underlying cattle herd, to be delivered at a different moment in time. For most commodities with futures markets, multiple contracts trade simultaneously. These contracts differ by the time to delivery. As time proceeds, some contracts reach delivery and cease to exist, while others are born and begin to be traded. From an econometric perspective, a set of futures prices presents a potentially large number of partially overlapping time series. Most applied researchers ignore the cross-sectional dimension and reduce the data to a single time series (Smith, 2005). A common method for such a reduction entails splicing together the nearby contracts, i.e., when a contract matures, take the next observation in the series from the contract that is the next closest to delivery. In many markets, ten or more contracts can be traded at a given point in time, so this strategy excludes most of the information about the commodity (Smith, 2005). In this thesis, we treat every futures contract individually. We never splice together futures price-series to create a single price series. We are aware that by splicing together futures price series, you neglect crucial information about the expected future prices of commodities. This information is crucial as it represents the expected value of a commodity at a different moment in time. In this thesis we are especially interested in those cases where simultaneous futures contracts behave differently.

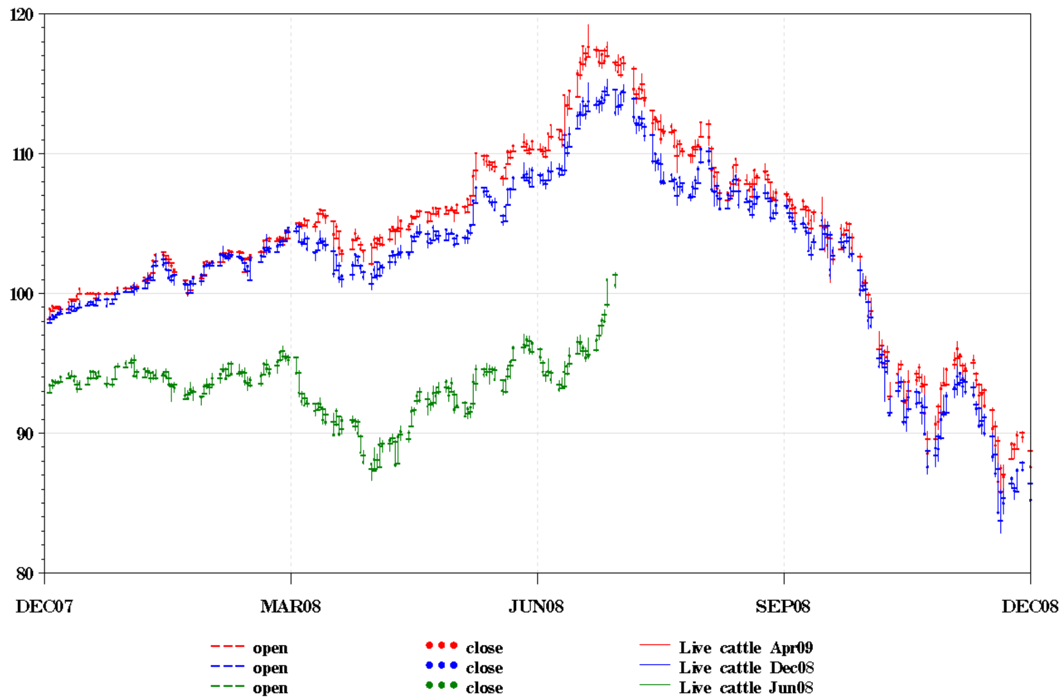


Figure 2: Price behavior of three live cattle futures contracts in 2008.
Source: Transtrend B.V.

In our study we put the factor *time* in a relative context. We consider three *time effects* as the starting point to observe price relationships between several agricultural futures contracts. The time effects are a result of the underlying fundamentals and relationships of cattle and the biological sequence of animals. We contribute to literature by describing and distinguishing three time effects of futures contracts prices. We call the time effects discrepancies. A discrepancy exists between processes which ought to be the same, the discrepancy can be small but it is usually significant.

1. Instantaneous price discrepancy

Prices of futures contracts with the same underlying asset but with different delivery months (e.g., Live Cattle Oct 09 vs. Live Cattle Dec 09) can react differently to the same news event, at the same time.

The release of news can lead to different price responses of nearby and deferred futures contracts. Main reason is that the release of news can affect the nearby underlying commodity in a different way. For example, imagine the announcement of an export-ban of US beef for the next two months. The ban on beef leads to an immediate lower demand of live cattle which results in lower cattle prices in the next two months. In the long run, we expect that the demand of beef as well as the demand of cattle will recover. In this example, the release of the news will cause nearby futures prices to decrease. In contrast, the effect will be hardly recognizable in distant futures. Apparently in this case, the release of news on live cattle leads to different price behavior of futures contracts at different maturities. In Appendix A we perform a study to this time effect where we compare casual relations in instantaneous price movements of live cattle and feeder cattle futures contracts.

2. Fundamental price discrepancy

Prices of futures contracts on different underlying assets in different stages of life (e.g. live cattle versus feeder cattle) behave differently on identical market events at the same time.

This time effect is caused by the fundamental differences and interrelations of the underlying commodity. An example makes one and another clear. Feeder cattle futures and live cattle futures relate to each other since the underlying commodity of the former are input in the production process of the latter. The time it takes before feeder cattle reaches the “live cattle stage” is approximately five months. Imagine that, due to a disease outbreak, local authorities instantaneously prohibit the transport of feeder cattle. The ban has several implications. In practice, feeder cattle are restricted to leave the farm which can lead to a surplus of animals at feeder operations. The total supply of feeder cattle will accordingly decrease, and consequently lead to an increase in feeder cattle prices. An immediate decrease in the supply of feeder cattle results in higher feeder cattle prices. Consequently, nearby feeder cattle futures contracts will respond concurrently with an upward price movement. Not only feeder cattle prices are affected. Live cattle producers are mainly affected by higher prices of feeder cattle during the ban. Since feeder cattle are fed for approximately five months, you can expect a positive price response of live cattle over five months. Expected increases within five months on live cattle prices will have an immediate positive effect on prices of deferred live cattle futures contracts. Nearby live cattle futures contracts are considerably less influenced by the ban, since the underlying products (cattle) are not affected. We observe that the biological time lag causes different price behavior of related commodity futures contracts at the same moment in time.

3. Price discrepancy in different moments in time

Price-behavior of a futures contract (e.g., Live Cattle Oct 2009), caused by one and the same market event, can lead to different price reactions, at different periods in time.

This time effect is harder to understand. The ban on beef in the first example might not only have a price effect at this moment in time. The incident may cause a price reaction of the same contract in the future. For example, it is possible that many live cattle producers go bankrupt due to the ban, resulting in a decrease in live cattle supply in the future. You may expect that the ban affects live cattle prices in the future. Apparently, the market event results in structural changes in the live cattle sector. The market event does not only lead to a price reaction at the moment the ban was announced. Besides, it results in a structural change of the sector which leads to price reactions at a different period in time. In other words, a market event can have different effects on prices of futures contract now, and in the future. A price reaction of a futures contract today can cause a (opposite) price reaction a couple of months later.

The examples are simplifications of the reality. Obviously also combinations of time effects can occur. It is not uncommon of more than one time effect to occur simultaneously. One cause may have multiple effects. A market event can cause all the three time effects. Besides, a time-effect may be the cause of price behavior now or in the future. Appendix A goes further into detail of intra-market price responses. The aim of this Appendix is to describe how futures contracts with the same underlying commodity behave concurrently in the same period in time. The existence of time effects and the different combinations of time effects possible are one of the reasons why the price behavior of cattle futures contracts is odd. We believe that the existence of the price effects is the result of the biological nature and fundamental interactions that exist in the underlying commodity. We choose to shift the focus of this thesis to the fundamental aspects of supply and demand of cattle and cattle related commodities.

1.5 Conclusions and summary

A futures contract is a standardized agreement between two participant to buy or sell an asset at a certain time in the future for a certain price. Agricultural futures of live cattle, feeder cattle, soybean meal and corn are traded on the CME and on the CBOT. Since futures contracts are standardized, market participants are able to trade futures contracts conveniently. Participants such as hedgers use futures contracts to hedge their price risk. Speculators are willing to accept the risk of the movements in the price of a commodity. We show that futures contracts with different maturities should be treated independently and individually, since they represent a different crop or cattle herd at a different moment in time. Finally we contribute to literature by describing three time effects which should be considered in futures price analysis: 1) instantaneous price discrepancy, 2) price discrepancy in different moments in time and 3) fundamental price discrepancy. In the following chapters we clarify every time effect using several examples of futures price behavior.

2. The Cattle Sector

2.1 Introduction

In this Chapter we elaborate on the underlying fundamentals of the cattle sector. We describe the most fundamental aspects of the cattle market by describing all production processes. By elaborating on cattle operations we expose causal relationships of cattle variables, such as cattle inventory, cattle on feed and feeding costs. Additionally we describe how these variables are related over time. We contribute to the literature by exhibiting beef-cattle interrelations in a flow diagram. The relations are tested in subsequent chapters. In addition we present the structure of transition matrix to exhibit how animals in different stages of their lives are interrelated. For all purposes we concentrate on the United States cattle sector.

2.2 Dairy versus beef cattle

Cattle are kept to provide beef, milk and hides. The activity of cattle breeding and the introduction of biotechnology resulted in the development of two different cattle categories: dairy cattle and beef cattle. Both categories have their own characteristics such as body weight, nutrition, lifetime, meat quality and so on. The main difference is that each category serves a different economic purpose. Beef cattle are purely bred for the supply of beef. Dairy cattle are bred for the supply of milk. During production there is little or no regard for their production of meat. However, in the breeding process still half of all the animals that are born are male calves. As such they do not have the ability to produce milk. They are either slaughtered for veal or beef production. The quality of dairy beef can not meet the level of beef cattle. Beef which is processed from dairy cattle is called unfed beef. Beef which is processed from beef cattle is called fed beef. We should be aware that (unfed) beef remains a byproduct of the dairy production process. In Appendix 3B we give an overview of the production process of dairy-cattle. In the remaining of this thesis we focus on beef cattle operations. The production of beef is the place where the beef cattle sector and dairy cattle sector, in economic terms, meet. In economic terms we are aware that there exist a relationship in price between fed beef and non fed beef.

2.3 Biological stages in beef cattle production

In the life of an animal there exists a time lag between a producer’s investment decision and sale decision. The time lag is the result of the biological characteristics of raising cattle. The lifecycle of cattle consists of several phases. The time from birth to slaughter is on average 18 months for beef cattle. Figure 3 exhibits the different stages in the life cycle of an animal. A more detailed flow diagram of beef cattle production is given in Appendix B.

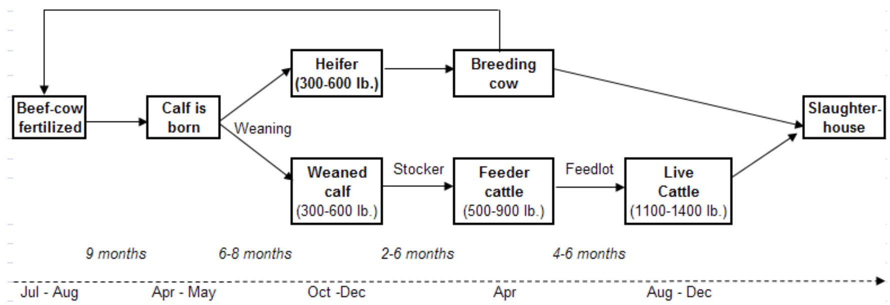


Figure 3: Stages in cattle production

Considering the cattle production process as depicted in Figure 3, you might expect seasonal price patterns. Seasonality characteristics of cattle production are discussed in Section 3.5.

2.4 Cattle operations

The agricultural industry in the United States depends heavily on beef-cattle operations. The sales of cattle and calves accounted for USD 61 billion in 2007, which is 21% of the total market value of agricultural production in the US (based on Census of Agriculture 2007 released by the USDA on February 4, 2009). The next sections elaborate on the fundamentals of three different beef cattle producers: Cow-calf operators, Stocker operators and Feedlot operators. The lifecycle of an animal ends in a slaughterhouse. The figures in Appendix B summarize all information in this section in the form of a flow diagram. The diagram is an essential ingredient of our research since we outline how cattle operations interrelate and more importantly, how cattle in different stages of their lives interrelate in time. The diagram, and of course the underlying ideas, are the starting point in drawing and checking hypotheses of cattle relations in subsequent chapters. In this way we do not only check whether biological conditions of the diagram are correct, but also whether those biological fundamentals share the same economic fundamental relationships.

2.4.1 Cow-Calf operation

A cow-calf producer breeds cows to produce young calves. Cows can become pregnant “the natural way” with the service of a bull or by an artificial insemination program. Still the natural way receives most preference. For reproduction purposes a producer runs, on average, one bull for every 23 cows for breeding (according to USDA NASS animal and Plant Health Inspection Service, 1998). Figure 4 shows the distribution of beef cows in the U.S. in 2002. Most cow-calf operations are located in and near the states Texas, Oklahoma, Missouri, Kentucky and Tennessee. Most cattle are born in the south were weather conditions are better and large grasslands are available. In a later stage of their lives, animals are sent to feedlots in the North-Mid West. This area is characterized by intensive farming practices. In this part of the country sufficient grains are available to feed large numbers of animals raised on limited land.

The average gestation period of a cow is 305 days (or 9 months). Cows are usually bred in late summer and give birth to one calf per year. During their lives cows give birth to on average nine calves. Not all cows will be held for gestation during the full ten years. Producers can make an important decision to cull a breeding cow from their herd. Cows can be culled from the herd due to failure to become pregnant, old age, drought or market conditions such as high feed costs. Cows that are culled are usually replaced by new born calves.

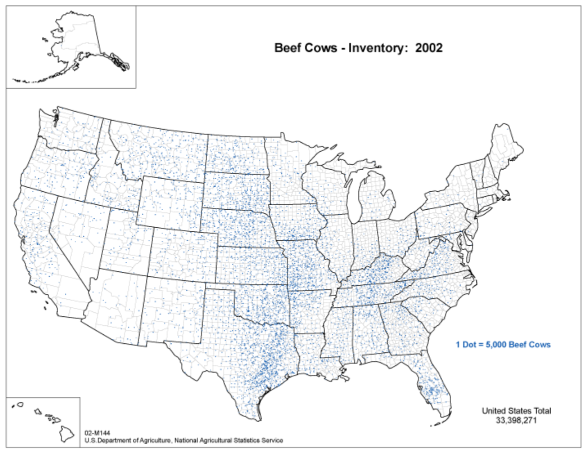


Figure 4: Distribution of beef-cows in the U.S. in 2002.
Source: Economic Research Service of the USDA.

Most calves are born in spring around March and April. The main reason is to avoid the harsh weather in the winter and to assure plentiful forage for the new calves in their first, vulnerable months of their life. Calves remain with their mothers during their first six to eight months. In the beginning they receive their feed exclusively by nursing from their mothers. After a couple of weeks their diet is supplemented with grass, hay and eventually grains. Six to eight months after birth calves are weaned from the cow. Almost all steer calves face the same destiny: being sent to a feedlot and getting ready for slaughter.

Producers face an important management decision for female calves. Either cull cows from the herd and send them to feedlots *(consumption goods)* or either retain them for breeding *(capital goods).* Jarvis (1973) was the first to characterize cattle producers as "portfolio managers" seeking the optimal combination of different categories of animals to complement their non-capital assets.

Cow-Calf operation : in brief	
Input:	Breeding cows
Output:	Weaned calves (300 – 600 lbs.)
Feed:	Hay, grass, supplements, concentrates
Time:	Gestation period: 9 months Calf feeding: 6-8 months

2.4.2 Stocker operation

Weaned steer calves and female calves are mostly sent to “stocker-” or “backgrounding-” operations to gain weight. A weaned calf weighs between 300 and 600 pounds and is fattened on pastures, waiting to be sent to feedlots as “feeder cattle”. Calves on pastures are fed by summer grass, winter wheat and/or some type of harvest roughage depending on the time of the year and location of the operation. Calves are purchased by stocker operators during the entire year. On average most of the calves are purchased in the fall. The stocker has two important functions. In the first place to raise cattle to feed them until they reach the ideal weight to be sent to feedlots. As second, the stocker has an important allocation function. The pen of a stocker consists of animals of different size, grade, age and gender. The stocker creates groups of animals, which are more easily sold to feedlots. In these herds all animal contain equal characteristics, such as the same weight class.

During the stocker operation cattle can switch ownership. The cow-calf operator sells calves to the stocker operator, or the cow-calf operator maintains ownership of cattle. In the latter case, the cow-calf operator pays a stocker operator for providing “feeding” services. Stocker operations are subject to price risk. Operators make many as cattle prices rise from the time calves are bought until they are sold as feeder cattle. They are more affected by volatility of cattle prices, since large parts of profits (or losses) depends on how cattle prices change between the moment calves are purchased and feeders are sold.

Stocker operation : in brief	
Input:	Weaned calves (300 – 600 lbs.)
Output:	Feeder cattle (500-900 lbs.)
Feed:	Forage, pasture, winter wheat, harvest roughage
Time:	2-6 months

2.4.3 Feedlot operation

After the feeder stage, cattle producers have three choices: 1) fatten up the cattle themselves at their own operation, 2) place the cattle in commercial feedlots while retaining ownership or 3) sell the cattle to another feedlot, to be fattened. No matter which choice is made, all animals (mostly steers and some heifers) are prepared for finishing. Figure 5, shows the distribution of the numbers of cattle on feed in the Mid-West. Most cattle operations are concentrated in the mid of the U.S. States with the highest concentration of feedlot operations are Kansas, Texas, Nebraska and Iowa In a period of four to six months an animal is fattened in a feedlot. The average number of days an animal is put on feed is 140 days (USDA, Economic Research Service, 2008). Depending on weight at placement, feeding conditions, and desired finish, the feeding period can be from 90 to as long as 300 days. The great variance in feeding period of animals drains away the seasonality effect for live cattle.

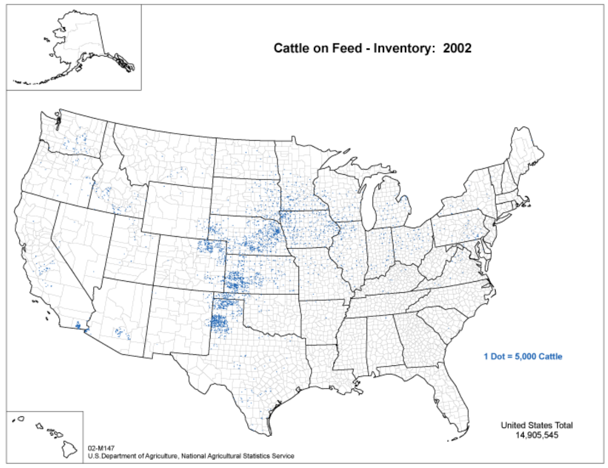


Figure 5: Distribution of cattle on feed in the U.S. in 2002.
Source: Economic Research Service of the USDA

Animals are fed a mix of high energy feed to accelerate rapid weight gain. The diet consists of different kinds of feed, depending on the time of the year, location and more importantly price. Cattle usually receive a ratio of grains (corn, wheat), protein supplement (soybean meal, cottonseed meal or linseed meal) and roughage (alfalfa, silage[1], prairie hay or other agricultural by-products such as sugar beet pulp). Feeding continues until the animal is "finished" and ready for slaughter. In other words, the animal has reached some optimum combination of weight, muscle and fat to be used for consumption.

Feedlot operation : in brief	
Input:	Feeder cattle (500-900 lbs.)
Output:	Live cattle (1100 -1400 lbs.)
Feed:	Grains, protein supplements, roughage
Time:	4-6 months

[1] Silage is fermented, high-moisture cattle feed. Silage is fermented and stored in a process called ensilage or silaging, and usually made from grass crops, including corn or sorghum or other cereals, using the entire green plant (not just the grain). Silage can be made from many field crops. Silage is made either by placing cut green vegetation in a silo, or by piling it in a large heap covered with plastic sheet, or by wrapping large bales in plastic film. The ensiled product retains a much larger proportion of its nutrients than if the crop had been dried and stored as hay (source: http://en.wikipedia.org/wiki/Silage).

2.4.4 Slaughtering and processing operation

Once cattle reach slaughter weight, animals can be sent to slaughter in two ways. Animals can either be sold through an auction, or directly to a slaughter house (via packer buyers).

A packer buys live cattle, slaughters them and then sells every item that comes from the slaughtered animals to clients such as wholesalers. As can be expected the major sources of income for the packer are sales of meat and hide. There are different ways to sell the meat. Either the packer sells the slaughtered carcass in parts to a retailer. Or he divides the carcass into major cuts and then packs them in vacuum form. This method is called boxed-beef. The carcass itself or boxes are bought by retailers and fabricated further into steaks and other cuts. In the third marketing method the packer sells the carcass in wholesale cuts (such as steaks, ribs, chucks, briskets) which can be sold directly to customers.

The process of buying an animal is done by packer buyers. They purchase cattle directly from feedlots. Packers determine their bid-prices on current meat prices and other economic factors. If a bid is accepted, the cattle are generally delivered to the packer within seven to fourteen days for slaughter, depending on the pricing method. This delivery schedule allows the packers some flexibility and enables them to schedule their kills several days in advance.[2] How these prices are calculated and negotiated is based on three different pricing methods: Formula Pricing, Forward Contracting and Grid Pricing.

Formula Pricing

Live-weight pricing is based on estimated carcass weights and quality (generally Prime, Choice, Select, and Standard) and yield grades (1 through 5) with the higher numbers representing a lower proportion of saleable retail cuts from the carcass). The price determined by these estimates is then averaged across the entire pen of cattle. Dressed weight prices are based on estimated quality and yield grades and known carcass weights. This price is not averaged across the pen as in live-weight pricing, but is calculated for each individual carcass (CME Group Livestock Futures and Options: Introduction to Underlying Market Fundamentals, 2009).

Forward Contracting

In forward contracting the packer offers a fixed price to the owner of fed cattle before the animals are ready to be slaughtered. The packer opens a forward contract with the feedlot operator. The forward contract obliges the feedlot operator to deliver a specific number of cattle at a certain delivery date for a certain price. Like formula pricing, forward contracting can be used when the cattle are sold on a live- or dressed-weight basis (CME Group Livestock Futures and Options: Introduction to Underlying Market Fundamentals, 2009). An advantage of forward contracting is that it can be used to price any number of cattle, rather than a multiple of 40.000 pounds of live cattle at live cattle futures contracts.

Grid pricing

Grid pricing is the last method to price cattle. The packer establishes a base price and then specifies premiums and discounts above and below the base for different carcass attributes, such as quality and yield grade and whether the carcasses are light or heavy. Grid pricing is also known as value-based pricing because prices are based on the known carcass weight, and quality and yield grade of each individual carcass (CME Group Livestock Futures and Options: Introduction to Underlying Market Fundamentals, 2009).

2.5 Seasonality in cattle production

Citing Hylleberg (1992) seasonality is the systematic, although not necessarily regular, intra-year movement caused by the changes of the weather, the calendar, and timing of decisions, directly or indirectly through the production and consumption decisions made by the agents of the economy. Applied cattle prices seasonal patterns are driven by climatic seasons and biological factors. Seasonality does not only occur at the supply side (e.g., driven by the time of weaning of calves in spring) but also at the demand side (e.g., driven by the seasonal demand for agricultural products). The combination of seasonality in supply and demand creates seasonal price patterns. Different classes of cattle have different seasonal patterns of animal supply. Cattle price seasonality is generally most pronounced for lighter weight animals (calves) and generally dampens in magnitude for larger animals (feeder and fed cattle) (Peel and Meyer, 2002). The majority of the calves are born in spring and sold as stocker cattle in fall, resulting in higher supply. Stocker operations increase demand of calves in the fall because the supply of forage is high. Prices of calves are thus affected by demand as well as supply factors. The result is that prices tend to be higher in the first half of the year and lower in the second half of the year (Peel and Meyer, 2002). Prices of cows are most affected by seasonal influences. The majority of the cows calf in spring and are used for weaning calves until fall. The decision to send cows to slaughter or use them for future production of new calves is made in fall. This is the reason why prices of cows show a seasonal low in the fall. Price patterns become more complicated and variations in price movements increase in a later stage of the cattle production process. Generally feeder cattle prices exhibit two low periods in the spring and fall with summer and winter peaks. Fed cattle have seasonal price lows in the summer (Peel and Meyer, 2002). Cattle price seasonality can differ based on the geographic location of the cattle production. For example, calves are usually born in fall instead of spring in the southern states. This is due to soft weather conditions and growing seasons of forage in the southern states. It is important to recognize that the great variance in feeding periods of animals drains away the seasonality effect for cattle in later stages of their lives.

2.6 Feed and costs

The costs of feeding cattle constitute the greatest part of total expenses of all cattle operators. According to studies on farm income, conducted by Kansas State University, feed costs represent the largest part of total variable costs of all cattle operators (Kansas State University, 2009, Department of Agricultural Economics). Figure 6 shows the deviations of feed costs in relation with other variable costs at different cattle operations. For example, feeding costs at feedlot operators account for 82% of the total costs. The high dependency on feeding costs suggests that all feedlot operators are highly affected by an increase in the price of feed ingredients (e.g., corn, soybean meal, meat- and bone meal, and other grains).

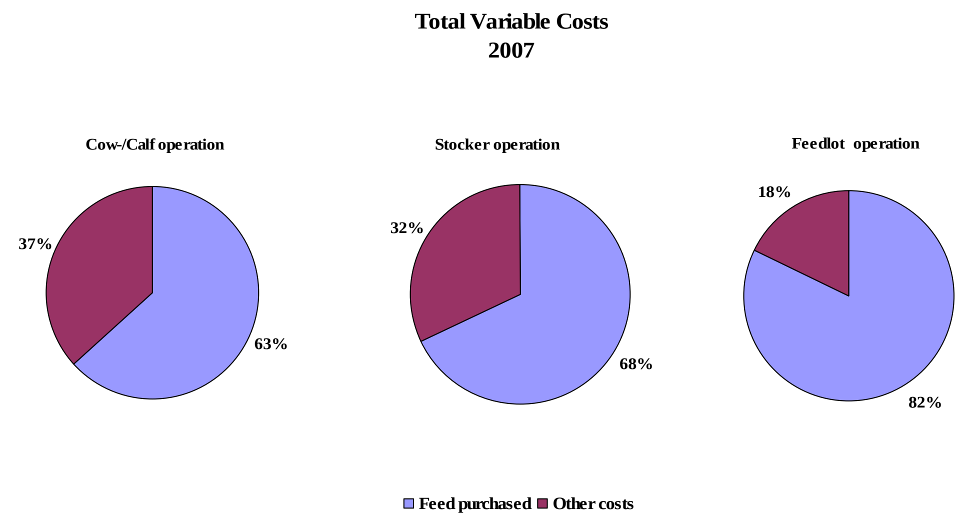


Figure 6: Total variable costs at different cattle operation in 2007. Principal other costs include: labor hired, machine hire–lease, livestock ,marketing, gas/fuel/oil, general farm insurance, utilities and veterinary medicine/drugs. Source: Kansas State University, Department of Agricultural Economics, http://www.agmanager.info/farmmgt/income/enterprise/2007)

2.7 Imports and Exports

So far we portrayed the American cattle sector as a closed system which has no interaction with its external environment. One issue which we excluded from our idealized cattle model was the import and export of live cattle to and from the U.S. The graphs in Figure 7 show U.S. cattle import and export figures. Cattle imported and exported as percentage of total beef cattle and calves marketed was lower than 5% and 1% respectively in the period 1973 - 2008. We signal a rising trend in cattle imports in the last decades. Since cattle import and export are such a small part of total head of cattle sold, we do not take import and export in consideration in the model framework of our research.

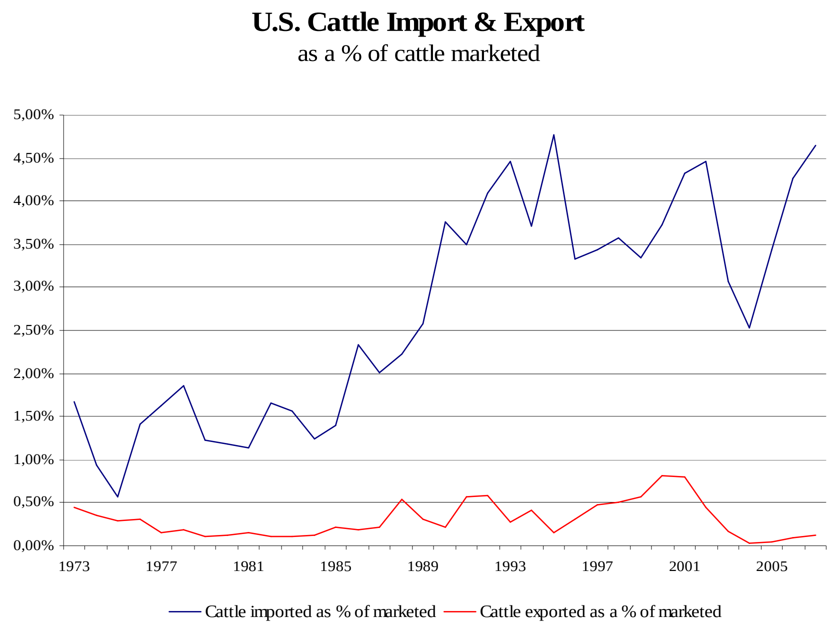


Figure 7: U.S. Cattle import and export

Measured as a % of total cattle marketed. Source: Meat Animal Production, Disposition & Income, NASS

2.8 Transition matrix – cattle movement

We illustrate transition of cattle from one category to another by using a state-transition matrix. This method enables us to show the time-dependent behavior of the cattle system. The transition matrix is derived from the described biological stages in beef-cattle production. It traces the transition of cattle from one category (state) to the other, as visualized in Figure 40 in Appendix B. At any moment in time a particular animal can only be in one state. Every entry in the transition matrix represents the number of animals in a particular category, which affects the number of cattle in another category, one moment later in time. Figure 8 gives the structure of all transitions that can take place in the beef-cattle industry. It is based on the biological sequence and fundamental characteristics of cattle operations. Cells which contain an x-mark are possible inventory flows. Cells which are left blank represent impossible flows.

For example, a female calf grows over time, until it reaches a new stage of life. Either it is culled from the herd to become feeder cattle for slaughter purposes, or it will be culled as a heifer for breeding purposes. In the matrix the number of female calves at time t, affects the number of heifers one period later (t+1) as well as the number of feeder cattle the subsequent period in time.

Besides culling an animal, which means it is labeled within another category it can be slaughtered at each moment in time. For example, in the transition matrix, the number of live cattle at a certain period (t) affects the number of live cattle (that can be slaughtered) in the next period (t+1).

The diagram shows that the total stock of feeder cattle influences the number of feeder cattle and live cattle in the future. Total quantity of beef cattle at any point in time is available for the usage of slaughter (for the consumption of beef), export (for abroad consumption of beef) or to increase inventories of cattle in the future (to meet future demand and consumption of beef). The slaughter and death columns of the matrix represent animal outflows of the system. You can argue that those columns can be presented independently of the transition matrix of the "on farm" columns. However for representation reasons we choose to keep the animal outflows in the same matrix. Besides it makes it possible to easily represent row and column totals. For computational reasons the user of these matrix may decide to only use the "on farm" transition matrix as it represents a closed system.

Figure 8: General transition matrix for beef-cattle in the U.S.

		On farm (t+1)						Slaughter (t+1)					Deaths (t+1)		
		calf (female)	calf (male)	heifer	feeder cattle	cow breeding	live cattle	calf (veal)	heifer	feeder cattle	cow breeding	live cattle	calves	cattle	Row total
On farm (t)	calf (female)	x		x	x			x					x		
	calf (male)		x		x			x					x		
	heifer			x		x			x					x	
	feeder cattle				x		x			x				x	
	cow breeding	x	x			x					x			x	
	live cattle						x					x		x	
Column total															

We use economic terms in our theoretical model to explain the transition of cattle from one category to another. Figure 8 gives an example of actual levels of inventory, marketings and slaughter rates of one state to another. The figures are based on surveys of the United States Department of Agriculture (USDA).

The six different stages are derived from the biological stages of beef cattle during their life as represented in Figure 2 and Appendix B. Differences in terminology between the matrix elements and the figures occur. The matrix represent the biological stages of an animal, which is in contrast with the figures which additionally incorporate the name of the production process. Some transitions are left blank (marked with an x) since those transitions were not consistently measured by the USDA. To come up with the complete matrix we suggest to estimate the blank fields. As we do not further use the blank fields in our analysis we do not further elaborate on those figures.

We can use the transition matrix to examine the actual transition of the beef-cattle sector from one state to another. In Chapter 4 we present a structural cattle model to describe relationships between (exogenous and endogenous variables) in the cattle sector. We use historic data to estimate the general directions of the evolution probabilities of the matrix. To examine the actual level of cattle inventory, slaughter and marketing figures we use simple supply-demand theory in the next chapter. In our analysis in the next chapter, we use the cells of the transition matrix as dependent and independent variables in the supply-demand model.

Transition Matrix U.S. Beef Cattle - 1980															
		On farm (t+1)											Deaths (t+1)		
		calf (female)	calf (male)	heifer	feeder cattle	cow breeding	live cattle	calf (veal)	heifer	feeder cattle	cow breeding	live cattle	calves	cattle	**Row total**
On farm (t)	calf (female)	13.802		x	x			1.294					1.325		16.420
	calf (male)		13.802		x			1.294					1.325		16.420
	heifer			5.942		x			9.594					372	15.908
	feeder cattle				16.049		**18.346**			1.304				372	36.071
	cow breeding	17.335	17.335			37.107					3.164			372	75.313
	live cattle						27.603					17.157		372	45.132
Column total		31.137	31.137	5.942	16.049	37.107	45.949	2.588	9.594	1.304	3.164	17.157	2.650	1.489	

Figure 9: U.S. Beef cattle transition matrix of 1980.

All figures are based on USDA Cattle on feed reports. E.g. 18.346 represents the total number of feeder cattle shifted to the live cattle stage between 1980 and 1981. Estimates are made for the distribution of cattle among gender and number of calves died during 1980. We consider the new born animals to be equally divided among gender and death rates are based on an historic average of 9,7%. Furthermore, figures about the number of calf and heifer marketings are not measured by the USDA.

2.9 Conclusions and summary

The biological nature of cattle affects the production process of beef cattle. We elaborate on four different stages in cattle production by presenting a flow diagram representing the total cattle cycle. This flow diagram forms the basis in drawing (economic) relations in cattle supply in subsequent chapters. First, cow-calf producers breed cows to produce young calves. On average calves are given birth in spring, when enough pastures are available to feed young calves and breeding cows. After that the weaned calves are raised at stocker-operations. When they reach sufficient weight they are sent as feeder cattle to feedlot operators where they are fed until they reach some optimum combination of weight, muscle and fat to be finished in slaughterhouses. In the entire production process, feeding costs are the foremost part of the total expenses of all cattle operations. This makes all cattle producers highly vulnerable to changes in prices of feed and its ingredients such as corn and soybean meal. The biological and seasonal influences in cattle production lead to seasonal effects in supply and demand. Cattle price seasonality is generally most pronounced for lighter weight animals (calves) and generally dampens in magnitude for larger animals (feeder and fed cattle). Finally this chapter illustrated transitions of cattle from one category to another by using a state-transition matrix. All these biological characteristics of cattle operations cause some unique relationships in terms of supply and demand, which are considered in the following chapter.

3. Literature on commodity & cattle market modeling

3.1 Introduction

Having introduced the fundamentals of the biological sequence of cattle and the cattle sector, this chapter describes previous work on commodity relationships in general and cattle relationships in specific. First we describe a general economic commodity framework to show how commodity supply, demand, capacity and external influences are interrelated. Then we describe some characteristics of food- and agricultural systems and finally we briefly discuss Jarvis (1974), which explains the negative price response of cattle in the short run.

3.2 Economic framework

The main components of a domestic commodity market are represented in Figure 10. It illustrates the interdependence among commodity demand, supply, inventories and prices in a domestic market. The demand for a commodity depends on its price as well as other external influences, such as economic activity and the level of technology. It is evident that end-use demand influences the commodity demand. For example, the demand for cattle is driven by the demand for beef. Supply is responsive to commodity prices, crop yields, technology and weather conditions. Changes in capital stock also affect commodity production. Inventories normally exist on the demand and supply sides of the model and these are held for precautionary, transactions or speculative motives. Depending on the elasticity of supply, inventories play a smaller or greater role in price adjustments. The relationships as given in Figure 10 involve feedback effects. Demand and supply are determined by prices, but the effects of demand and supply on prices are also included (Labys and Polak, 1984). Commodity demand and supply are interrelated through commodity prices and commodity inventories.

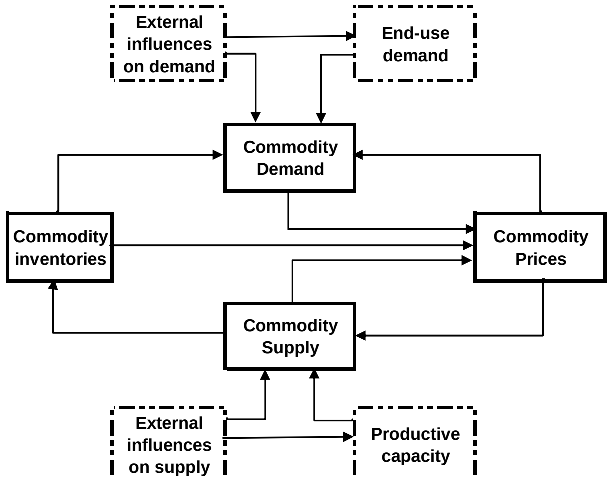


Figure 10: Model representation of a commodity market.
Source: Labys and Polak, 1984.

Güvenen *et al.* (1991) describe five characteristics of the food system which are linked with commodity prices: inelastic demand for food, slow growth in total demand, competitive market structure, significant technological change, and the tendency of resources to become fixed within the agricultural sector, serve as the basis for constructing models of agricultural commodity markets. For example, a transitory increase in export demand will increase wholesale prices of beef. This will cause an increase in cattle slaughter prices, resulting in a rise in the factor inputs used in cattle production. However, when export demand falls back to its initial level, the inelastic demand for food results in lower prices.

Since production of agricultural products is not instantaneous and it is dependent upon investment decisions, the production observed in any period tends to be greatly affected by decisions made in the past. As an example, for beef cattle about one year is required between breeding and weaning of a female calf. One additional year is needed before the heifer can be bred and a third year is required before the heifer will wean a calf intended for slaughter. Finally an additional 15-16 months are required to fatten offspring for delivery to the market. Thus an identifiable lag exists between the time when the essential signal to increase production is perceived, for example an increase in price, and the time when the herd is expanded to produce more animals (Güvenen *et al.*, 1991). This biological nature of the cattle market heavily influences the specification of relationships useful for market models. Important dimensions are the stages of growth and development of the commodity, physical and economic factors that affect output, and the existence of time lags between production and sale decisions (Lord, 1991). Bearing these biological characteristics in mind, we pay special attention to fundamental relationships over time of cattle production.

3.3 Price theory

We explain a very simple but rather fundamental economic theory to clarify how prices of goods (or services) originate. The price of a product is discovered by changes in its supply and demand. *Supply* is the relationship between a product's price and the amount of that product sellers are willing to provide. Supply can be graphed as a curve with *quantity* shown on the horizontal axis and *price* shown on the vertical axis (see Figure 11). When prices are high, sellers are willing to provide larger quantities of their products to the market.

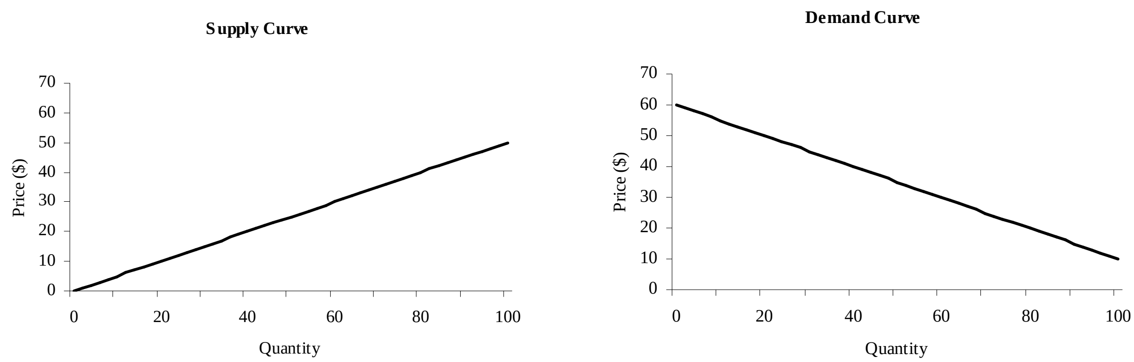


Figure 11: Supply and demand curves

At lower prices, sellers are willing to deliver smaller quantities to the market. For several economic reasons, prices can increase or decrease, thus shifting the supply curve. Examples are changes in production costs, and the number of sellers in the market.

Besides supply, there also exists demand. Demand is the relationship between a product's price and the amount of that product that buyers are willing to purchase. Demand can be graphed as a curve with quantity shown on the horizontal axis and price on the vertical axis (see Figure 12). Several factors can cause demand to increase or decrease. Factors are for example changes in personal income, prices of substitute goods, and the number of buyers in the market.

In a competitive market, the price of a product depends on the relationship between supply and demand. If the supply and demand curves of a product are placed on the same graph, the point at which they intersect is the product's market price, also known as the equilibrium price (Figure 12). On this point, the quantity of goods supplied equals the quantity of goods demanded. As market factors change, e.g., good weather conditions, enlarge agricultural production; the supply curve will shift to the right, and the market price will fall. So far it looks obvious that market prices adjust to the point were supply and demand curves cross. However, there is a high probability that there exist time lags before prices adjust to new levels.

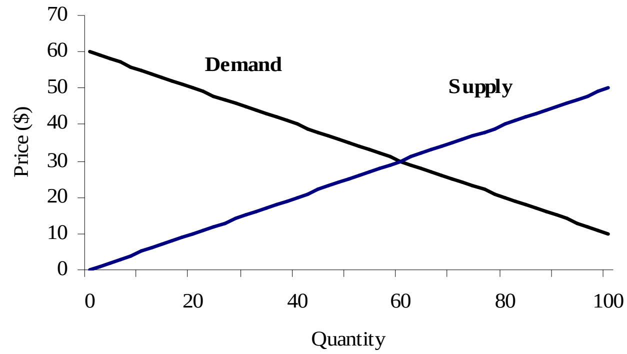


Figure 12: Supply-demand curve

For example, if cattle feed prices rise sharply the supply curve will be affected (the curve shifts to the left). Cattle producers face lower profit margins, which lead to the drop out of some cattle producers. Other cattle operators will cut back production. In terms of the curves, prices should rise and quantity will drop. Nevertheless, what will actually happen is that initially prices drop and quantities rise. The higher feeding costs encourage farmers to temporarily send more animals to slaughterhouses. Our prediction will ultimately be correct in the long run. Apparently there exists a time lag in the adjustment process of supply and demand. We cannot generally assume that markets are always in equilibrium. We should be aware that if market-factors change adjustment time should be considered before a market reaches a new equilibrium level.

3.4 Investment vs. consumption goods

The possibility of a negative supply response in agricultural markets is an intriguing concept. The theory states that for animal industries (such as cattle or hogs) where females are valued both as a capital good and a consumption good, an increase in the market price may actually induce producers to reduce the supply of the animal going to market. If the price increase is sufficiently permanent, then producers may optimally retain a larger than average number of females to add to the breeding stock to take advantage of higher prices in the future. The result, at least in the short run, is that we may observe a negative relationship between price and quantity supplied (i.e., a downward-sloping supply curve). In the long run, the supply relationship will eventually turn positive as the larger breeding stocks produce more animals destined for the market (Aadland, Bailey, 2001).

One of the first works which pays special attention to the biological nature of cattle in constructing a market model for the cattle sector is Jarvis (1974). The results expose, according to us, the foremost important characteristic of the cattle sector. The central theme of Jarvis (1974) is simple. Cattle are considered to be capital goods which are held by producers as long as their capital value in production exceeds their slaughter value. Cattle are simultaneously used as consumption good, for beef production, and as a capital good, to replace future beef production. According to Jarvis (1974) producers become “portfolio managers” seeking the optimal combination of different categories of animals to complement their non-capital assets, given existing conditions and future expectations. Animals of different age, sex and breeding ability have different economic functions within the herd, and their productive values will accordingly be affected differentially by exogenous shocks to the system. Jarvis (1974) explains that at any point in time there is a fixed supply of animals in the herd for which there exist two types of demand: consumer and producer. As long as a producer is willing to outbid the consumer to retain the animal as a productive asset, the animal remains in the herd. When the consumer "wins", the animal is slaughtered. In our research we question how the demand of different types of animals (in different stages of their lives) varies with exogenous shocks to the system, for example due to increasing corn prices. The cattle sector presents an interesting feature insofar as the slaughter of animal categories responds negatively to a price increase in the short run. This behavior contrasts with the supply response of most other agricultural products, whose expected outputs are both expected to rise immediately in response to a price increase (Jarvis, 1974). Because cattle production can be increased only by increasing the size of the breeding herd and/or withholding animals for further fattening, producers must bid animals away from consumers to increase the capital stock which is the source of future beef production. And the slow rate of biological reproduction causes the negative supply response to persist for some time (Jarvis, 1974). The model implies that the immediate slaughter response is negative for all cattle categories in the short-run. An important detail is that the slaughter response is different from the production response. In addition Jarvis (1974) shows that in the long-run the elasticity of slaughter is positive. He explains that a reduction of slaughter one year increases the size of the herd in the next (and therefore the permanent slaughter rate). In the long run, slaughter rates of all animal categories respond positively to an increase in prices. This unique behavior of the cattle market is the reason why we pay special attention to untangle the fundamental relationships in the cattle market.

Jarvis performed his research on the Argentine cattle sector in the period 1937-1967. In our research we shall replicate the ideas of his research approach to discover whether the American cattle sector shows similar slaughter response to price reactions in the short- and long run.

3.5 Conclusions and summary

In terms of an economic commodity framework we described six components that intertwine and influence commodity markets: external influences on supply, commodity supply, commodity demand, capital inventory, productive capacity and commodity prices. Due to the biological time lag in the production of cattle some unique relationships exist in terms of price- supply relationships. The slaughter of all animal categories respond negatively to a price increase in the short run. In the long run, animal slaughter is positively related to price increments. The strange economic behavior of cattle is enough reason to pay special attention to fundamental relations in cattle research. Moreover we have to pay special attention to the time effects of relationships. A change in an economic variable, for example feed prices, can have different effects on slaughter rates in the short run than in the long run.

4. Fundamental Cattle Supply Relationships

4.1 Introduction

In the preceding chapters we explained and examined the underlying fundamentals, and dynamics of cattle breeding, feeding and ultimately slaughtering. We showed that cattle production is a flow operation: output of one operation is input for the next one. In this chapter we try to answer which variables provide the best explanation of cattle supply fluctuations. We specify a cattle supply model which includes the most significant determinants of cattle supply. Our goal is to untangle which (lagged) fundamental forces have the greatest influence on cattle supply.

4.2 Research approach

Fundamental characteristics of cattle operations gave us an idea which determinants are appropriate to include in a supply model. In this chapter we initially propose a limited number of supply determinants. Then, we use statistical analysis to select the determinants which are the most relevant for specifying cattle supply. We prefer this approach because we can hardly suggest, without the analysis, which supply determinants are most appropriate to estimate cattle supply in the future.

We develop a supply equation for every cattle category (steers, heifers, breeding cows and calves). First, we specify which variables we believe to provide the best explanation of cattle supply fluctuations. Then we perform stepwise regression analysis on each of the supply series. It results in a selection of variables that are the most relevant for specifying cattle supply. We report the estimation results per category in tabular and equation form. Finally, we interpret the results by focusing on the sign of the determinants. A positive (negative) sign suggests that a determinant is positively (negatively) related to the supply of a particular cattle category.

4.3 Model specification

In prior chapters we described the characteristics of cattle operations. Fluctuations in the supply of cattle categories arise from a number of measurable influences. With help of the flow diagram of cattle production (Appendix B) we hypothesize that there exist three important determinants of cattle supply changes. Figure 13 gives a simple version of the production process of a cattle producer. The flow diagram is applicable to every cattle operation. The aim of this chapter is to test whether the cattle relationships mentioned hold and how they hold over time.

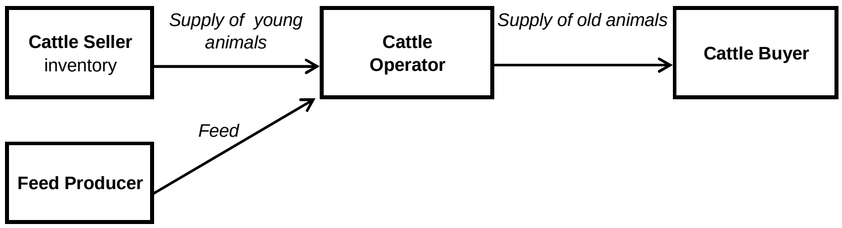


Figure 13: Simplification of flow diagram of cattle operator

A cattle operator uses two important sources of input to raise animals. In the first place the operator receives young animals from another cattle operator. Secondly, he buys feed from a feed producer. Finally, a cattle operator sells its animals to cattle buyers, this can be either a slaughter house or another cattle operator. The total number of cattle in inventory of the cattle seller represents the replacement inventory of the cattle operator. To make the model complete we can include a death loss rate to affect the supply relationship. Since the death loss rate is almost constant over time, we do not take into account death rates into our supply relationships. The following cattle supply model was developed on the basis of these relationships. We believe that the mentioned determinants are most relevant for the supply of cattle.

Summarizing, we expect that monthly cattle supply responds mostly to changes of three variables: 1) the price of corn, 2) the price of cattle sold to the cattle buyer and 3) the number of animals available for replacement (inventory of the cattle seller).

So far we presented the essential cattle supply determinants. We express all determinants in quantifiable variables. Supply can be measured as the total weight of all animals being slaughtered (S^{animal}). Supply responses to changes in three variables:

- price of slaughtered animals (P^{animal})
- price of input costs, corn prices, (P^{corn}),
- replacement inventory, number of animals on stock, (Inv^{animal}).

We assume that variables in the supply equation are linear dependent. We express the explanatory supply equation as:

$$\textbf{4.1} \qquad S^{animal} = f\,(P^{animal}, P^{corn}, Inv^{animal})$$

In total we use four supply equations to explain the supply-dynamics of four different categories of cattle. To test whether relationships exist between the variables on the left- and right hand side of the supply equation, we use a linear regression technique based on ordinary least squares (OLS). According to Alexander (2003), linear regression models are based on a relationship of the form:

$$\textbf{4.2} \qquad Y = \alpha_1 X_1 + \alpha_2 X_2 + \ldots + \alpha_k X_k + \varepsilon$$

On the left-hand side, Y is the dependent variable and on the right there are k independent variables X_1, X_2,…, X_k. These are also called explanatory variables. The coefficients α_1, α_2,…, α_k are model parameters and each one measures the effect that its associated independent variable has upon Y. It is conventional to assume X_1=1, so that the model has k coefficients, including a constant α_1. Besides the error term is expressed as ε. The purpose of the regression is to find estimates of the true parameter values and predictions of the dependent variable using data on the dependent and independent variables (Alexander, 2003). Our explanation of price-theory in Section 3.3 states that supply and demand can be in equilibrium via a price variable. There is one quantity and one price wherein supply and demand is in equilibrium. To find the equilibrium level of supply you plug in the equilibrium price into the supply equation. In the first equation we consider that a combination of different independent variable levels is reflected in the supply of animals slaughtered. We write the supply equation (4.1) in the form of the regression equation (4.2). This gives us the supply equation (4.3).

$$\textbf{4.3} \qquad S_t^{animal} = \alpha_0 + \alpha_1 P_t^{animal} + \alpha_2\, P_t^{corn} + \alpha_3\, Inv_t^{animal} + \varepsilon_t$$

Our aim is to estimate values of the model parameters (α_0, α_1, α_2 and α_3) to measure whether the independent variables (P^{animal}, P^{corn}, Inv^{animal}) show strong relationships with the dependent variable (S^{animal}). Supply equation (43) estimates the relations of independent variables to slaughter supply in or near equilibrium. We assume that markets are in or near equilibrium at a certain level. Nevertheless, markets and supply levels are not always near equilibrium. It is through a shift in independent variables that the market equilibrium changes and reaches a different supply level. We want to assess how markets behave towards new equilibrium levels. In other words, we question whether a positive (negative) shock of an independent variable can lead to a shock in the dependent variable. Consequently we modify the supply equation (4.3) by considering the percentage differences in price- and volume changes (Δ). Where

$$\Delta = \frac{P_t - P_{t-1}}{P_{t-1}}$$

In other words we consider the percentage difference in price and volumes of the dependent variable variable (S^{animal}) and all independent variables (P^{animal}, P^{corn}, Inv^{animal}). The change-supply equation (4.4) is a transformation of equation (4.3). Due to the transformation we remove the intercept parameter.

$$\textbf{4.4} \qquad \Delta S_t^{animal} = \beta_1 \Delta P_t^{animal} + \beta_2\, \Delta P_t^{corn} + \beta_3\, \Delta Inv_t^{animal} + \varepsilon_t$$

General model

So far, we presented a supply equation (4.3) specifying which variables provide the best explanation of cattle supply fluctuations. We believe that supply determinants can affect supply over time. In other words, a change of a supply determinant at time t-1 can affect supply at time t. Moreover we believe that a change of a supply determinant at time t can affect cattle supply at different moments in time in a different way (see the time effects in Section 2.4.1). These ideas are in line with Jarvis (1974) on cattle supply relationships. Following this line of reasoning, a positive change in cattle slaughter prices at time t leads to a negative change in the supply of cattle at time t+1 (negative short-run supply relationship). On the other hand, a positive change in cattle slaughter prices at time t leads to a positive change in the supply of cattle at time t+12 (positive long-run supply relationships). We question which lagged supply determinants are suitable in determining supply fluctuations.

As a result, we create a set of supply determinants including all independent variables, with a time lag up to five time periods, at the right side of the supply equation (4.5).

$$\begin{aligned} S_t^{animals} = \alpha_0 &+ \sum_{i=0}^{i=4} \alpha_{1,i} P_{t,i}^{animal} \\ &+ \sum_{i=0}^{i=4} \alpha_{2,i} P_{t,i}^{corn} \\ &+ \sum_{i=0}^{i=4} \alpha_{3,i} Inv_{t,i}^{replace\,animals} \end{aligned} \quad \textbf{4.5}$$

We use statistical analysis to decide which (lagged) variables to include in the supply equation. By introducing time-lags we can estimate which lagged factors show the strongest relationships with cattle slaughter numbers. The result is a supply equation which only includes those (lagged) variables that provide sufficient explanation of cattle supply. The method to decide which (lagged) variables we include in our model is called backward elimination. First we run a regression where we include all candidate variables. Then we test them one by one for statistical significance, deleting any that are not significant. The most crucial aspect of operating the stepwise method is to decide which variables to exclude in the supply equations. In Section 4.4 we describe this procedure. But first we describe the four supply equations for every animal category.

We aggregate our data into three different time scales before we start our estimation procedure: quarter, semi-annual and annual. We simply sum up slaughter numbers during three months to generate quarterly data. We aggregate data since monthly prices and slaughter numbers fluctuate heavily. By aggregating data into larger time intervals we smooth out incidental price and supply changes. The advantage is that we can focus on structural price- and slaughter volume changes. On every time scale different forces can be involved or come to surface. As a result we perform the same regression-estimation for each animal category supply-equation on three different time scales. Based on equation (4.5), we construct supply equations for every animal category (steers, heifers, breeding cows and calves) of which the USDA gathers sufficient data regarding inventory, slaughter prices and slaughter numbers. Our main interest is to examine, for each cattle category, which (lagged) variables provide sufficient explanation of cattle supply. Since quarterly data on animal inventories is not measured by the USDA and not available we do not take the animal inventory variable (Inv^{animal}) into account in the quarterly equations.

Equations (1a-1c, 3a-3c, 5a-5c, 7a-7c) represent all supply equations of different animal categories in absolute values. Since we measure slaughter volumes and prices they are titled volume-price equations. Besides equations (2a-2c, 4a-4c, 6a-6c, 8a-8c) represent all supply equations of different animal categories in relative values. We measure the slaughter volume changes and price changes in percentage differences (Δ).

Steer slaughter

	Volume-Price Equation		*Difference Equation*
1a - quarterly	$SStr_t = \alpha_0 + \sum_{i=0}^{i=4} \alpha_{1,3i} PSStr_{t-3i} + \sum_{i=0}^{i=4} \alpha_{2,3i} PCrn_{t-3i}$	**2a - quarterly**	$\Delta SStr_t = \alpha_0 + \sum_{i=0}^{i=4} \alpha_{1,3i} \Delta PSStr_{t-3i} + \sum_{i=0}^{i=4} \alpha_{2,3i} \Delta PCrn_{t-3i}$
1b - semi annual	$SStr_t = \alpha_0 + \sum_{i=0}^{i=3} \alpha_{1,6i} PSStr_{t-6i} + \sum_{i=0}^{i=3} \alpha_{2,6i} PCrn_{t-6i} + \sum_{i=0}^{i=3} \alpha_{3,6i} InvAllStrs_{t-6i}$	**2b - semi-annual**	$\Delta SStr_t = \alpha_0 + \sum_{i=0}^{i=3} \alpha_{1,6i} \Delta PSStr_{t-6i} + \sum_{i=0}^{i=3} \alpha_{2,6i} \Delta PCrn_{t-6i} + \sum_{i=0}^{i=3} \alpha_{3,6i} \Delta InvAllStr_{t-6i}$
1c - annual	$SStr_t = \alpha_0 + \sum_{i=0}^{i=2} \alpha_{1,12i} PSStr_{t-12i} + \sum_{i=0}^{i=2} \alpha_{2,12i} PCrn_{t-12i} + \sum_{i=0}^{i=2} \alpha_{3,12i} InvAllStrs_{t-12i}$	**2c - annual**	$\Delta SStr_t = \alpha_0 + \sum_{i=0}^{i=2} \alpha_{1,12i} \Delta PSStr_{t-12i} + \sum_{i=0}^{i=2} \alpha_{2,12i} \Delta PCrn_{t-12i} + \sum_{i=0}^{i=2} \alpha_{3,12i} \Delta InvAllStr_{t-12i}$

With i= {0,…,4},

where

$SStr_t$	=	Total weight of steers slaughtered in 100.000 pounds, at time t in months
$PSStr_{t-i}$	=	Slaughter price of steers per 100 pounds in US dollars, at time (t-i) in months.
$PCrn_{t-i}$	=	Price of corn per bushel, in US dollars, at time (t-i) in months.
$InvAllStrs_{t-i}$	=	Number of steers > 500 pounds in inventory × 1000 units, at time (t-i) in months

Heifer slaughter

	Volume-Price Equation		*Difference Equation*
3a - quarterly	$SHfr_t=\beta_0+\sum_{i=0}^{i=4}\beta_{1,3i}PSHfr_{t-3i}$ $+\sum_{i=0}^{i=4}\beta_{2,3i}PCrn_{t-3i}$	**4a - quarterly**	$\Delta SHfr_t=\beta_0+\sum_{i=0}^{i=4}\beta_{1,3i}\Delta PSHfr_{t-3i}$ $+\sum_{i=0}^{i=4}\beta_{2,3i}\Delta PCrn_{t-3i}$
3b - semi annual	$SHfr_t=\beta_0+\sum_{i=0}^{i=3}\beta_{1,6i}PSHfr_{t-6i}$ $+\sum_{i=0}^{i=3}\beta_{2,6i}PCrn_{t-6i}$ $+\sum_{i=0}^{i=3}\beta_{3,6i}InvClv_{t-6i}$	**4b - semi-annual**	$\Delta SHfr_t=\beta_0+\sum_{i=0}^{i=3}\beta_{1,6i}\Delta PSHfr_{t-6i}$ $+\sum_{i=0}^{i=3}\beta_{2,6i}\Delta PCrn_{t-6i}$ $+\sum_{i=0}^{i=3}\beta_{3,6i}\Delta InvClv_{t-6i}$
3c - annual	$SHfr_t=\beta_0+\sum_{i=0}^{i=2}\beta_{1,12i}PSHfr_{t-12i}$ $+\sum_{i=0}^{i=2}\beta_{2,12i}PCrn_{t-12i}$ $+\sum_{i=0}^{i=2}\beta_{3,12i}InvClv_{t-12i}$	**4c - annual**	$\Delta SHfr_t=\beta_0+\sum_{i=0}^{i=2}\beta_{1,12i}\Delta PSHfr_{t-12i}$ $+\sum_{i=0}^{i=2}\beta_{2,12i}\Delta PCrn_{t-12i}$ $+\sum_{i=0}^{i=2}\beta_{3,12i}\Delta InvClv_{t-12i}$

With i= {0,…,4},
where

$SHfr_t$	=	Total weight of heifers slaughtered in 100.000 pounds, at time t in months
$PSHfr_{t-i}$	=	Slaughter price of heifers per 100 pounds in US dollars, at time (t-i) in months
$PCrn_{t-i}$	=	Average price of corn per bushel, in US dollars, at time (t-i) in months.
$InvClv_{t-i}$	=	Number of calves in inventory × 1000 units, at time (t-i) in months.

Beef cow slaughter

	Volume-Price Equation		*Difference Equation*
5a - quarterly	$SCow_t = \gamma_0 + \sum_{i=0}^{i=4} \gamma_{1,3i} PCow_{t-3i} + \sum_{i=0}^{i=4} \gamma_{2,3i} PCrn_{t-3i}$	**6a - quarterly**	$\Delta SCow_t = \gamma_0 + \sum_{i=0}^{i=4} \gamma_{1,3i} \Delta PCow_{t-3i} + \sum_{i=0}^{i=4} \gamma_{2,3i} \Delta PCrn_{t-3i}$
5b - semi annual	$SCow_t = \gamma_0 + \sum_{i=0}^{i=3} \gamma_{1,6i} PCow_{t-6i} + \sum_{i=0}^{i=3} \gamma_{2,6i} PCrn_{t-6i} + \sum_{i=0}^{i=3} \gamma_{3,6i} InvCow_{t-6i}$	**6b - semi-annual**	$\Delta SCow_t = \gamma_0 + \sum_{i=0}^{i=3} \gamma_{1,6i} \Delta PCow_{t-6i} + \sum_{i=0}^{i=3} \gamma_{2,6i} \Delta PCrn_{t-6i} + \sum_{i=0}^{i=3} \gamma_{3,6i} \Delta InvCow_{t-6i}$
5c - annual	$SCow_t = \gamma_0 + \sum_{i=0}^{i=2} \gamma_{1,12i} PCow_{t-12i} + \sum_{i=0}^{i=2} \gamma_{2,12i} PCrn_{t-12i} + \sum_{i=0}^{i=2} \gamma_{3,12i} InvCow_{t-12i}$	**6c - annual**	$\Delta SCow_t = \gamma_0 + \sum_{i=0}^{i=2} \gamma_{1,12i} \Delta PCow_{t-12i} + \sum_{i=0}^{i=2} \gamma_{2,12i} \Delta PCrn_{t-12i} + \sum_{i=0}^{i=2} \gamma_{3,12i} \Delta InvCow_{t-12i}$

With i= {0,…,4},

where

$SCow_t$	=	Total weight of beef cows slaughtered in 100.000 pounds, at time t in months
$PCow_{t-i}$	=	Slaughter price of cows per 100 pounds in US dollars, at time (t-i) in months
$PCrn_{t-i}$	=	Price of corn per bushel, in US dollars, at time (t-i) in months.
$InvCow_{t-i}$	=	Number of breeding cows in inventory × 1000 units, at time (t-i) in months.

Calf slaughter

	Volume-Price Equation		*Difference Equation*
7a - quarterly	$SClv_t = \mu_0 + \sum_{i=0}^{i=4} \mu_{1,3i} PSClv_{t-3i} + \sum_{i=0}^{i=4} \mu_{2,3i} PCrn_{t-3i}$	**8a - quarterly**	$\Delta SClv_t = \mu_0 + \sum_{i=0}^{i=4} \mu_{1,3i} \Delta PSClv_{t-3i} + \sum_{i=0}^{i=4} \mu_{2,3i} \Delta PCrn_{t-3i}$
7b - semi annual	$SClv_t = \mu_0 + \sum_{i=0}^{i=3} \mu_{1,6i} PSClv_{t-6i} + \sum_{i=0}^{i=3} \mu_{2,6i} PCrn_{t-6i} + \sum_{i=0}^{i=3} \mu_{3,6i} InvCow_{t-6i}$	**8b - semi-annual**	$\Delta SClv_t = \mu_0 + \sum_{i=0}^{i=3} \mu_{1,6i} \Delta PSClv_{t-6i} + \sum_{i=0}^{i=3} \mu_{2,6i} \Delta PCrn_{t-6i} + \sum_{i=0}^{i=3} \mu_{3,6i} \Delta InvCow_{t-6i}$
7c - annual	$SClv_t = \mu_0 + \sum_{i=0}^{i=2} \mu_{1,12i} PSClv_{t-12i} + \sum_{i=0}^{i=2} \mu_{2,12i} PCrn_{t-12i} + \sum_{i=0}^{i=2} \mu_{3,12i} InvCow_{t-12i}$	**8c - annual**	$\Delta SClv_t = \mu_0 + \sum_{i=0}^{i=2} \mu_{1,12i} \Delta PSClv_{t-12i} + \sum_{i=0}^{i=2} \mu_{2,12i} \Delta PCrn_{t-12i} + \sum_{i=0}^{i=2} \mu_{3,12i} \Delta InvCow_{t-12i}$

With i= {0,…,4},

where

$SClv_t$	=	Total weight of beef calves slaughtered in 100.000 pounds, at time t in months
$PSClv_{t-i}$	=	Slaughter price of calves per 100 pounds in US dollars, at time (t-i) in months
$PCrn_{t-i}$	=	Price of corn per bushel, in US dollars, at time (t-i) in months.
$InvCow_{t-i}$	=	Number of breeding cows in inventory × 1000 units, at time (t-i) in months.

4.4 Estimation Procedure

To estimate the unknown coefficients (e.g. α_0, $\alpha_{1,3i}$, $\alpha_{2,3i}$, $\alpha_{3,3i}$) in the multiple regression equations 1a-8b we use the ordinary least squares (OLS) estimation procedure. OLS minimizes the sum of squared distances between the observed data, and the fitted responses from the regression model. In Chapter 5 we elaborate on the expected values of the estimation parameters and show the results of the estimation procedure.

We have to make sure that our estimation results are valid by checking whether all assumptions (as proposed by Brooks (1972)) that are made for the ordinary least squares estimator are satisfied. The following assumptions are checked in Appendix E:

Assumption 1: Model is linear in parameters.

Assumption 2: The data are a random sample of the data generating process.

Assumption 3: The errors are statistically independent from one another.

Assumption 4: The independent variables are not too strongly collinear.

Assumption 5: The expected value of the residuals is zero.

Assumption 6: The residuals have constant variance.

Assumption 7: The residuals are normally distributed.

We use the statistical software package SAS for all statistical analysis including the backward elimination procedure. We obtain estimations of all coefficients, α_i, from the OLS regression procedure. The result is a regression output with all explanatory variables. Our next step is to exclude those variables that do not have significant explanatory power. Since we are dealing with different independent variables, we test whether variable X_i significantly improves the model, given that all other variables are included.

Multiple linear regression and backward elimination

Multiple linear regression is a standard statistical tool that regresses p independent variables against a single dependent variable. The objective is to find a linear model that best predicts the dependent variable from the independent variables (Beal, 2005). The purpose of variable selection procedures is to select or help select from the total number of p candidate variables a smaller subset of, say, p-1 variables. An efficient procedure to find the best linear model is the backward elimination procedure (Sen and Srivastava, 1990).

Backward elimination tries to examine only the “best” regressions containing a number of variables (Draper and Smith, 1998). Backward elimination starts with all variables in the model and eliminates the less important ones one by one. The procedure, as performed in the computer package SAS, computes the partial F’s corresponding to each variable, given the list of variables included in the model at that step. If the lowest F value falls below a preset number (the 100x α per cent point for the *F* distribution with the appropriate degrees of freedom, where α is set at 5% in our case) the corresponding variable is deleted.

After each variable is deleted, partial F's are recomputed and the entire step is repeated with the variables still remaining in the model. The procedure stops when no partial F falls below the appropriate preset number (Sen and Srivastava, 1990). In short, the backward elimination procedure in SAS goes as follows (Draper, Smith, 1998).

Backward elimination

Step 1: A regression equation containing all variables is computed.

Step 2: The partial F-test value is calculated for every predictor variable treated as though it were the last predictor to enter the regression equation.

Step 3: The lowest partial F-test value, say F_L, is compared to a preselected significance level to stay in the model (SLS), say F_0.

a) If $F_L < F_0$, remove the variable X_L, which gave rise to F_L, from consideration and recomputed the regression equation in the remaining variables; reenter step (2).

b) If $F_L > F_0$, adopt the regression equation as calculated.

Example

An example makes clear how the backward elimination technique is used. Assume there are three independent variables X_1, X_2, X_3.

Step 1. Fit a model with all variables: $Y = \beta_0 + X_1\beta_1 + X_2\beta_2 + X_3\beta_3 + \varepsilon$

Step 2. Calculate $F(X_1 | X_2, X_3)$, $F(X_2 | X_1, X_3)$ and $F(X_3 | X_1, X_2)$.

Step 3. Suppose $F(X_2 | X_1, X_3)$ is the smallest and its p-value > SLS then delete X_2. Then reenter step 2 with a new model with 2 variables: $Y = \beta_0 + X_1\beta_1 + X_3\beta_3 + \varepsilon$

Repeat steps 2-3 until all the variables in the models have p-values ≤ SLS

Calculating the partial F-test value

We calculate the partial F-test statistic by

$$F = \frac{\dfrac{\text{SS (reduced model)} - \text{SS (full model)}}{k}}{\dfrac{\text{SSE (full model)}}{n - k - 1}} \sim F_{\alpha,k,n-k-1}$$

where

SS (full model) =	Sum of squares of the full model
SS (reduced model) =	Sum of squares of the reduced model
SSE (full model) =	Sum of squares due to error of the full model
k =	Number of variables taken out
n =	Number of observations
$F_{\alpha,k,n-k-1}$ =	Upper α=5% point of an *F* distribution with *k* and n – k –1 degrees of freedom

Next we use a statistical approach to assess whether to exclude the variable X_i from the regression equation. In other words we test whether β_i is zero, by testing the hypotheses $H_0 : \beta_i = 0$ against $H_1 : \beta_i \neq 0$. We reject H_0 if $F \geq F_{\alpha,k,n-k-1}$ and we accept H_1 if $F < F_{\alpha,k,n-k-1}$. To test the hypothesis we use the F-value as the test statistic. We use a one-sided F-test since the test statistic can only be positive as the sum of squares of the reduced model is always bigger than the sum of squares of the full model. This F-value reflects the variable's contribution to the model if it is excluded. The F-value is compared to a critical value, in our case the critical value lies at the upper 5% level (following the F-table, using the corresponding degrees of freedom). If F is greater than the critical value we reject the null-hypothesis. Results and interpretations of the backward elimination procedure conducted at all cattle models are presented in Chapter 5.

Points of discussion

Regression is a powerful tool in model building and economic analysis. However we have to be cautious since it can cause misleading results. First of all the used regression technique can only be applied if we assume that relationships between variables are linear. As second, we have to take care of outliers or extreme values. OLS regression is very sensitive to outliers especially in the case of small sample-sizes. Situations where in extreme observations come to light are described in our case studies in Chapter 6. An outlier can significantly affect the intercept and parameters of the estimated equations. A straightforward method is to drop the observation with large residuals out of the dataset and reestimate the equation. This method is arguable since the data of the outliers can provide important information. Another solution is to obtain more data rather than drop observations. Another method is to construct a dummy variable representing an observation suspected to be an outlier and include it in the regression. At last, we can use an alternative method for OLS such as Weighted Least Squares (WLS) or Two-Stage Least Squares (2SLS) regression analysis.

4.5 Data

4.5.1 Sample period and target population

In this study we use monthly time series data for a period of 35 years, beginning at the 1st of January 1970 and ending at the 31st of December 2005. Monthly data are collected from several publications of the United States Department of Agriculture (USDA) during this period. We only apply our research to this period because the USDA counted and published data in the same manner during this period of time.

4.5.2 Data collection

Animal prices and slaughter numbers are collected from the monthly USDA “Cattle-on-Feed Report” and the USDA “Redmeat Yearbook”. The Cattle-on -Feed report is a monthly publication that reports data on the number of cattle in U.S. feedlots, the number of cattle being placed in feedlots, and the number being marketed for slaughter. The report is published by USDA's National Agricultural Statistics Services (NASS). The cattle-on-feed report is released generally on the third Friday of the month, and reports numbers as of the beginning of that month. In January and July, NASS surveys all known feedlots with 1000+ head capacities in all states. While the monthly cattle on feed report provides a breakdown of inventory data on a state basis for the 17 major feeding states, cattle on feed data for all states is obtained from the yearly red meat yearbook report, also published by the USDA.

We consider monthly, quarterly, and annual data on commercial livestock slaughter and meat production, livestock and meat prices, and inventories of cattle in different stages of their lives (calves, heifers, steers, beef-cows). All these data are published in the Red Meat yearbook is yearly published by the Economic Research Service of the United States Department of Agriculture (ERS-USDA).

Data collected on a monthly basis are:

- Number of commercial slaughter of cattle (by category),
- Average dressed weight of cattle (by category),
- Prices of commercial livestock slaughter (by category) and
- Corn prices.

Source: Red Meat Yearbook, ERS-USDA, 1970-2005

Data collected on a semi-annual basis are:

- Cattle inventory (by category);

Source: "Cattle-on-Feed Report", NASS-USDA, 1970-2005

We compute the total amount of steers slaughtered (in pounds) by multiplying the number of steers slaughtered with the average dressed weight of a steer. Corn is the main ingredient of cattle feed, and is actively traded and as such cash-prices are actually quoted. Prices of corn are quoted at different locations and for different quality levels. We focus on the Corn #2 Yellow prices at Central Illinois for the whole sample period. This corn is widely used in the production of cattle feed and above all its cash prices have been reliably measured during the last 35 years by the ERS-USDA.

Time scales

Different structural forces can be active at different time scales. By aggregating over longer time periods, we can focus on structural price- and slaughter volume changes. We aggregate our data into three levels before we start our estimation procedure: quarter, semi-annual and annual. We simply sum up slaughter numbers during three months to generate quarterly data. We aggregate our data since monthly prices and slaughter numbers fluctuate heavily.

Cattle slaughter

Cattle slaughter (Figure 14) shows a cyclical pattern wherein an increase of slaughter weight in one quarterly period is followed by a decrease in the next period. Fed steers bring for sure the highest quantity of beef. Besides steers, also heifers and cows are slaughtered. Calves are slaughtered for its veal, and shows significant lower slaughter-quantities.

Slaughter cattle prices

Beef that we eat comes from steers, heifers and cows. Prices of beef from different animal-categories (Figure 15) move in parallel. Since heifer and steer beef has got the same quality, prices move in parallel and at the same level. Cow beef is of lower quality and, as such, lower in price. Veal is produced from calves and shows considerable higher prices for two reasons. The first reason is demand-oriented. Veal has a different taste which can increase demand, and increases its price. As second, calves can be used as capital good (for the production of beef in a later stadium of its life) as well as a consumptive good (as veal). This dual economic purpose increases the demand for calves as well as its price.

Corn price

Corn prices (Figure 16) fluctuated heavily in the last three decades. Corn is the main ingredient of cattle-feed. The high volatility in corn prices is dependent on the planting season, the weather conditions and the crop quality (which can be different every crop).

Cattle in inventory

The number of cattle in inventory (Figure 17) fluctuates around a different constant level for steers and calves. Remarkable is that the number of breeding cows rapidly declined since the mid ‘70s. There are three possible causes for the decline. First of all it is possible that cow breeders became more efficient. It suggests that breeding operators needed to use on average less breeding cows, to deliver the same number of calves every year. In other words, producers fertilized their cows e.g. every year instead of every second year. The second reason can be that the import of calves increased during the years. The third and last explanation would be that the dairy sector became a more important supplier of cattle for the beef industry.

What we do observe is that besides the rapid decline in breeding cows, cattle slaughter prices (Figure 15) show a significant increase in the same period. A smaller amount of cattle in inventory can lead to higher slaughter prices since less animals are available for slaughter in the short run. In the long run the lower number of breeding cows available can lead to structural higher slaughter prices as the total supply of cattle diminishes.

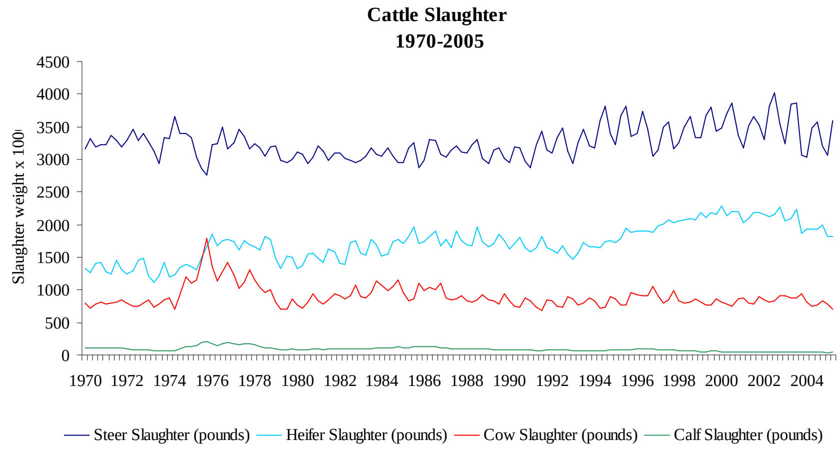


Figure 14: Cattle slaughter
Measured in total weight of cattle slaughtered in pounds per animal category, quarterly data.
Source: USDA, RedMeat Yearbook

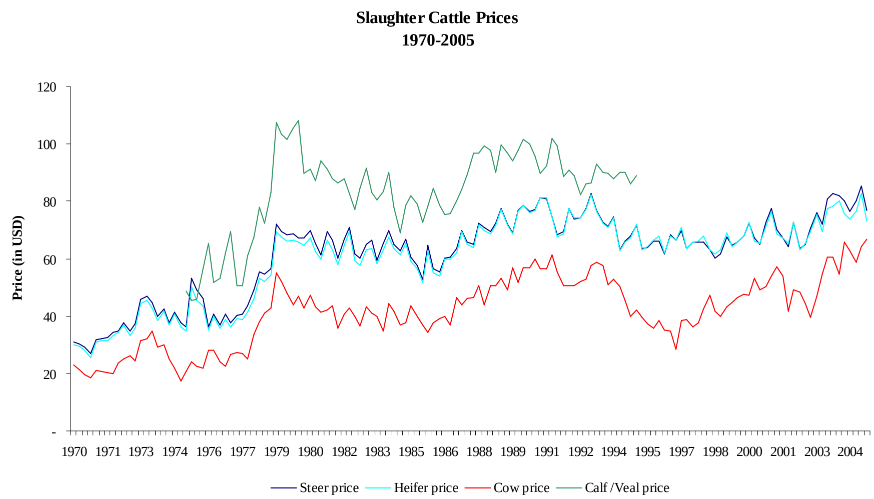


Figure 15: Slaughter cattle prices,
Calf prices are discontinued and data are available until 1995, quarterly data.
Source: USDA, RedMeat Yearbook

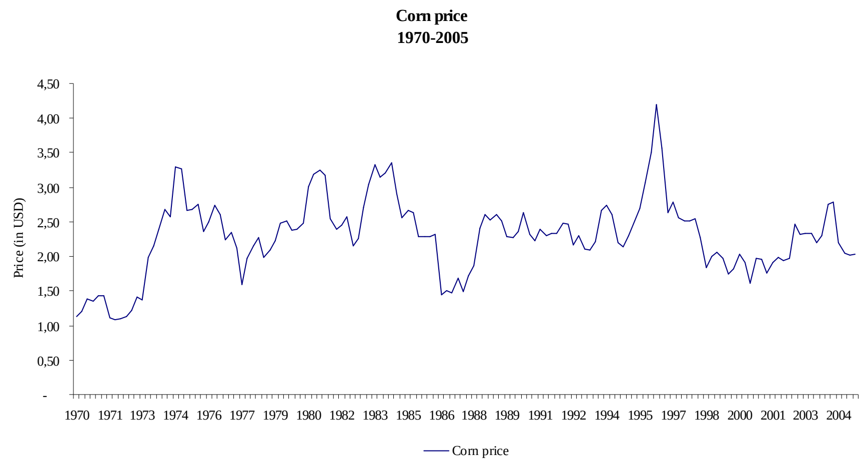


Figure 16: Corn prices,
Central Illinois, #2 yellow corn, quarterly data Source: USDA RedMeat Yearbook

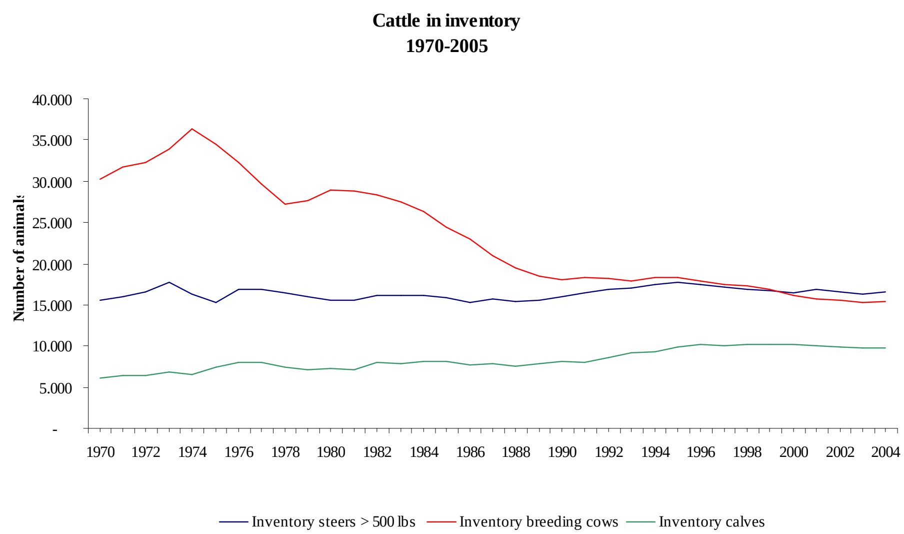


Figure 17: Number of animals in inventory,
Data measured on the 1st of January, annual data.
Source: USDA, cattle-on-feed report

4.6 Results

We perform the backward elimination technique to select the ultimate most significant estimation model for cattle supply at different stages of their lives. Ultimately, we have left those variables with significant explanatory power. Results and interpretations of the results are described in the Chapter 5.

4.7 Conclusions and summary

Main objective of this chapter was to describe the procedure of how to uncover relationships between (changes in) the total weight of cattle slaughtered and (changes in) the exogenous variables: slaughter cattle prices, feed costs and number of cattle in inventory. Moreover we put main effort in uncovering relationships with respect to the factor time. For this reason we modeled the relationships with different time lags and time scales (quarterly, semi-annually and annually). First, we estimated parameters for the models containing all independent variables. Then, we estimated, using backward elimination techniques, which variables to eliminate from the model. As result we build two times 12 different models to estimate cattle slaughter of a particular category (steers, heifers, cows and calves) aggregated at three different time scales (quarterly, semi-annually and annually). We compared our results with four general hypotheses based on our structural cattle fundamentals. Some hypotheses seem to be backed by our empirical analysis. For some other statements we can not give enough evidence to back the hypotheses. The next chapter tests whether our hypotheses are considered to be true in situations wherein specific subsets of factors arguably dominate.

5. Results and interpretations

5.1 Introduction

This chapter summarizes the results of applying stepwise regression methods to the supply equations of four different animal categories. The statistical method results in a selection of variables that are the most relevant for specifying cattle supply. Before we present our results we describe our hypotheses per animal category. Since at every animal category different fundamental forces are active, we believe that every supply equation consists of different supply determinants. Then we summarize the results after we performed the stepwise regression procedures. For every animal category we present three supply equations, each at a different time scale. Finally we give our interpretation of the results. The overall result is that we have a better understanding which (lagged) variables provide the best explanation of cattle supply fluctuations.

5.2 Hypotheses

Before we describe the estimation results of the structural supply equations, we hypothesize on the expected signs of the estimated parameters. We split up our hypotheses in the three independent variables used in our supply equations. In addition, we hypothesize that there exist deviations between estimated model parameters of different animal categories. Besides, we expect that deviations exist between the different time lags of the independent variables. For example, the time it takes before the effects of an operational decision (e.g. to slaughter a large part of the cows) come to surface is dependent on the type of operation. Cow-calf producers can make a breeding cow pregnant or sent an animal to slaughter. There exists a large time lag of nine months between the time of the (investment) decision (fertilizing the cow) and the time the decision takes effect (birth of young calf). For other cattle producers such as live cattle operators the time lag is considered to be smaller; since investment decisions can be made in a shorter notice.

Slaughter prices

The total weight of animals slaughtered is largely predetermined by past decisions. Cattle producers will tend to keep animals on feed if the marginal cost of feeding is equal to or less than prices of slaughter steers. As a consequence, the total weight of steers slaughtered is affected by slaughter prices. Following Jarvis (1974), we expect that slaughter rates of all animal categories respond negatively to an increase in prices in the short run and responds positively to an increase in slaughter prices in the long run. This means that steer slaughter prices ($PSstr_t$) as well as slaughter price changes ($\Delta PSstr_t$) are negatively related in the short run ($\alpha_{1,i=0}<0$ and $\alpha_{1,i=-3}<0$) and positively related in the long run ($\alpha_{1,i=-6} > 0 \ldots \alpha_{1,i=-24} > 0$). We assume that effects in the short run are instantaneously visible (at time t=0) or within the first period after the effect occurred (e.g. at time t = -3 for quarterly data, t = -6 for semi-annual data and t = -12 for annual data).

Prices of corn

With an increasing price of corn, producers would expected to substitute to a different feed ingredient or would probably market animals earlier, leading to a decrease in the total weight of steers slaughtered (since animals are slaughtered on lighter weights). In other words we might expect that slaughter rates respond negatively to a higher corn price or corn price increases. In the long run we expect that higher corn prices lead to lower slaughter rates of steers. When feeding costs reach higher levels, producers can decide to slaughter animals earlier in their lives or to produce a lower amount of slaughter steers, since profit margins diminish. In other words we expect that corn prices and corn price changes are negatively related to slaughter rates in the short run ($\alpha_{2,i=0} > 0$ and $\alpha_{2,i=-3} > 0$) and negatively related in the long run ($\alpha_{2,i=-6} < 0 \ldots \alpha_{2,i=-24} < 0$). You can argue that since calves are not fed with corn, calf-slaughtering is not affected by change in corn prices. However, also calves can be considered capital goods (Jarvis, 1974). Calves will become upcoming consumers of corn when they reach the status of feeder cattle, live cattle or breeding cows. In other words, higher feed prices put profit margins of cattle operators under pressure, which affects current demand for calves. This linkage of cattle operations makes higher corn prices affect cow-calf operators indirectly.

Replacement inventories

Semi-annual inventories of all steers on stock ($InvAllStrs_t$) represent the replacement inventory for future cattle slaughter. Variations in this inventory will in consequence have an impact on the total weight of slaughtered animals in the future. The slow rate of biological reproduction causes that a low level (or negative change) of the replacement inventory has a negative effect on future slaughter rates. There is a small amount of animals available to meet up future cattle production. In other words, we expect that the replacement inventory is positively related to the total weight of slaughter cattle ($\alpha_{3,i=-3} < 0 \ldots \alpha_{3,i=-24} < 0$). Since the larger the inventory of animals in stock, the greater the total weight of animals that can be slaughtered in the future. The time lag depends on the time it takes before the replacement inventory is used by the cattle operator. We expect greater time lags for calf-cow breeding operations than for cattle feeders.

Investment good vs. consumption good

Cattle are used as investment good, to breed new animals in the future, or as consumption good, to be slaughtered. Breeding cows serve a dual purpose. Cows (as well as female calves and heifers) are retained to raise new animals and finally to be slaughtered for beef. Contrary, steers are used as a consumptive good. They are retained to be slaughtered in the near future. We argue that there exist differences in the supply relationships of investment vs. consumption goods. When the price of cows and heifers rises, producers will retain animals to produce more cattle in the future, instead of selling them to slaughterhouses. Instead of liquidating cows when the price is favorable, cattle producers retain their breeding cows to produce more animals in the future. As a result, an increase in the price of slaughter cattle will result in a decrease of slaughtered animals in the near future. In terms of our supply equations, we expect that for breeding cows, heifers and calves slaughter prices are negatively related to the total weight of animals slaughtered in the short run. For steers, which only serve as consumption good, we do not have reason to expect a short run supply relationship to exist.

Table 2 summarizes our hypotheses how the independent variables are related to the total weight of slaughtered animals, in the short run and in the long run, following our cattle models.

Table 2: Hypotheses structural cattle supply relationships

	Short run	**Long run**
Slaughter prices …	Negatively related to the total weight of slaughtered animals	Positively related to the total weight of slaughtered animals
Prices of corn …	Negatively related to the total weight of slaughtered animals	Negatively related to the total weight of slaughtered animals
Replacement inventories …	- Positively related to the total weight of slaughtered animals - Larger time lags for cow-calf operators	- Positively related to the total weight of slaughtered animals - Larger time lags for cow-calf operators
Investment goods … (calves, heifers, breeding cows)	- Negative price-supply relationship	- Positive price-supply relationship
Production goods … (steers)	- Positive price-supply relationship	- Positive price-supply relationship

5.3 Results

We present results of the stepwise regressions on all supply equations in equation form and in tabular form (in Appendix C and D). First we show results of the first step in the stepwise regression, where all independent variables are included in the model (Appendix C). Then, we delete one for one the less predictive independent variable. Assumptions made in the OLS regression are checked in Appendix E. Finally we present the results of the last step in the stepwise regression in tabular form (Appendix D) and in equation form (in this section).

The reader may find it difficult to interpret the results as presented in the next section. Difficulties can arise since we performed regressions on different categories of data and on different time scales. For reading purposes it is necessary to keep in mind three distinctions of the supply equations:

1. We distinct four different animal categories (steers, heifers, calves and beef-cows)
2. We distinct between absolute supply levels and relative/percentage changes of supply.
3. We distinct and aggregate data on three different time-scales (quarterly, semi-annual and annual).

As a result we perform estimations for in total 24 different supply regression equations. The reader should be aware that there exist differences in the interpretation of the supply equations and the supply change equations. The former tries to estimate supply with the help of independent variables expressed as absolute levels, wherein market prices and volumes are assumed to be in equilibrium. The latter estimates changes of supply with independent variables expressed as percentage changes.

In the next section we present results of the regression procedures. The reader should be aware that results from the regression equations are primary statistical. The equations show which variables taken individually or together, provide the best explanation of cattle supply. Every animal category is presented at a different page. First we treat the absolute regression results then we present the change-results. For every regression we present the results in the form of the supply equation including the estimated parameters. All equations were obtained after eliminating those variables that show the smallest contribution to the model.

Under every equation we show the t-statistics between brackets for every estimated variable. The t-value gives an indication whether the estimated parameter is significantly different from zero. A very high t-statistic indicates that a parameter is a very highly significant determinant of future slaughter rate. The t-value is the estimate divided by the standard error or in formula:

$$t = \frac{\hat{b} - b}{se}$$

Where $\hat{b}$ is the (estimated) observed parameter, *b* is the parameter under the null-hypothesis (in our case b=0) and *se* is the standard error. We only show the t-statistics as the partial F statistic is the square of the t statistic corresponding to each variable. Hence the probabilities obtained and the decisions taken are identical to using the t statistic.

Furthermore we give for every regression equation the R-squared (R^2). This value measures the percent of variation in the dependent variable that can be accounted for or “explained” by the independent variables. A low R-Squared can signal that our equation is not explaining the variability of the dependent variable. Appendix D provides the correlation matrices to show whether the variables on the right hand sight of the equation are independent of each other.

Steers supply equation - Estimates of structural equations

Quarterly: absolute levels - Observations = 138

$SStr_t = 3521 - 14.3 \cdot PSStr_t + 15.2 \cdot PSStr_{t-6} - 130.3 \cdot PCrn_{t-9}$

(30.29) (-4.28) (4.65) (-3.46)

R^2=0.17, F=10.41

Semi-Annual: absolute levels - Observations = 63

$SStr_t = 4146 + 14.3 \cdot PSStr_{t-18} - 331.7 \cdot PCrn_{t-6} + 0.15 \cdot InvAllStrs_{t-12}$

(3.83) (2.54) (-2.89) (2.60)

R^2=0.18, F=4.31

Annual: absolute levels - Observations = 32

$SStr_t = 1682 + 0.692 \cdot InvAllStrs_{t-12}$

(0.65) (4.37)

R^2= 0.38, F= 19.13

Quarterly: Percentage differences - Observations = 138

$\Delta\ SStr_t = -0.40 \cdot \Delta PSStr_t$

(-6.83)

R^2= 0.25, F=46.79

Semi-Annual: Percentage differences - Observations = 62

$\Delta\ SStr_t = -0.16 \cdot \Delta PSStr_t - 0.17 \cdot \Delta PSStr_{t-6} + 0.07 \cdot \Delta PCrn_t + 0.22 \cdot \Delta InvAllStrs_t$

(-4.06) (-4.26) (2.89) (6.02)

R^2= 0.56, F=20.63

Annual: Percentage differences - Observations = 32

$\Delta\ SStr_t = -0.19 \cdot \Delta PSStr_t$

(-2.81)

R^2= 0.18, F=7.87

With i = {0,…,4},

where

$SStr_t$	=	Total weight of steers slaughtered in 100.000 pounds, at time t.
$PSStr_{t-i}$	=	Slaughter price of steers per 100 pounds in US dollars, at time (t-i)
$PCrn_{t-i}$	=	Price of corn per bushel, in US dollars, at time (t-i)
$InvAllStrs_{t-i}$	=	Number of steers > 500 pounds in inventory x 1000 units, at time (t-i).

Heifer supply equation - Estimates of structural equations

Quarterly: Absolute levels - Observations = 138

$SHfr_t = 1269 – 11.1 \cdot PSHfr_{t-6} – 93.1 \cdot PCrn_t$

(30.29) (-4.28) (4.65)

R^2=0.31, F=30.32

Semi-annual: Absolute levels - Observations = 63

$SHfr_t = -985 + 73.2 \cdot PSHfr_{t-6} – 0.20 \cdot PCrn_t + 0.29 \cdot InvClv_t + 0.27 \cdot InvClv_{t-6}$

(-2.29) (2.77) (-3.18) (9.84) (8.77)

R^2=0.78, F=56.85

Annual: Absolute levels - Observations = 32

$SHfr_t = 1876 – 450 \cdot PCrn_t + 73.5 \cdot InvClv_{t-12}$

(3.05) (-2.91) (13.50)

R^2=0.87, F=101.99

Quarterly: Percentage differences - Observations = 138

$\Delta SHfr_t = -0.28 \cdot \Delta PSHfr_t + 0.26 \cdot \Delta PSHfr_{t-6} – 0.20 \cdot \Delta PSHfr_{t-12}$

(-4.32) (4.26) (-3.24)

R^2= 0.34, F= 24.67

Semi-annual: Percentage differences - Observations = 62

$\Delta SHfr_t = -0.38 \cdot \Delta PSHfr_t – 0.23 \cdot \Delta PSHfr_{t-12} + 0.19 \cdot \Delta PCrn_{t-18} + 0.19 \cdot \Delta InvClv_t$

(-4.50) (-2.76) (3.84) (3.44)

R^2= 0.43, F=12.56

Annual: Percentage differences - Observations = 32

$\Delta SHfr_t = 0.14 \cdot \Delta PCrn_{t-24} + 0.68 \cdot \Delta InvClv_{t-12}$

(4.11) (3.93)

R^2= 0.49, F=16.35

With i = {0,…,4},

where

$SHfr_t$	=	Total weight of heifers slaughtered in 100.000 pounds, at time t.
$PSHfr_{t-i}$	=	Slaughter price of heifers per 100 pounds in US dollars, at time (t-i)
$PCrn_{t-i}$	=	Average price of corn per bushel, in US dollars, at time (t-i)
$InvClv_{t-i}$	=	Number of calves in inventory x 1000 units, at time (t-i).

Beef cow supply equation - Estimates of structural equations

Quarterly: Absolute levels - Observations = 138

$SCow_t = 902 - 87.8 \cdot PCow_{t-12} + 88.6 \cdot PCrn_{t-6} + 65.2 \cdot PCrn_{t-12}$

(16.3) (-9.69) (3.26) (2.48)

$R^2=0.48$, $F=42.92$

Semi-Annual: Absolute levels - Observations = 63

$SCow_t = 845 - 10.6 \cdot PCow_{t-6} + 0.4 \cdot InvCow_{t-6}$

(1.60) (-2.83) (3.57)

$R^2=0.56$, $F=39.90$

Annual: Absolute levels - Observations = 32

$SCow_t = -1461 + 384.5 \cdot PCrn_{t-12} + 0.12 \cdot InvCow_{t-24}$

(-2.28) (3.04) (6.86)

$R^2=0.65$, $F=31.73$

Quarterly: Percentage differences - Observations = 138

$\Delta SCow_t = -0.36 \cdot \Delta PCow_t - 0.29 \cdot \Delta PCow_{t-3} - 0.39 \cdot \Delta PCow_{t-12}$

(-4.50) (-4.32) (-4.98)

$R^2= 0.42$, $F=33.73$

Semi-Annual: Percentage differences - Observations = 62

$\Delta SCow_t = -0.31 \cdot \Delta PCow_{t-12} + 1.74 \cdot \Delta InvCow_{t-6}$

(-4.60) (3.96)

$R^2= 0.57$, $F=42.19$

Annual: Percentage differences - Observations = 32

$\Delta SCow_t = -0.31 \cdot \Delta PCow_{t-12} + 0.24 \cdot \Delta PCrn_{t-12} + 1.05 \cdot \Delta PCrn_{t-24}$

(-5.21) (3.96) (2.59)

$R^2= 0.69$, $F=25.28$

With $i = \{0,\ldots,4\}$,

where

$SCow_t$	=	Total weight of beef cows slaughtered in 100.000 pounds, at time t
$PCow_{t-i}$	=	Slaughter price of cows per 100 pounds in US dollars, at time (t-i)
$PCrn_{t-i}$	=	Price of corn per bushel, in US dollars, at time (t-i)
$InvCow_{t-i}$	=	Number of breeding cows in inventory X 1000 units at time (t-i).

Calves supply equation - Estimates of structural equations

Quarterly: Absolute levels - Observations =138

$SClv_t = 270 - 1.36 \cdot PClv_{t-3} - 0.63 \cdot PClv_{t-12}$

(26.5) (-7.73) (-4.09)

R^2=0.79, F=139.81

Semi-Annual: Absolute levels - Observations =63

$SClv_t = 446 - 1.2 \cdot PClv_t - 2.5 \cdot PClv_{t-6} + 2.3 \cdot InvCow_{t-18}$

(9.51) (-2.13) (-5.33) (3.30)

R^2=0.85, F=67.51

Annual: Absolute levels - Observations =32

$SClv_t = 503 - 4.7 \cdot PClv_t + 0.01 \cdot PClv_{t-24}$

(3.55) (-3.79) (5.14)

R^2=0.80, F=24.61

Quarterly: Percentage differences - Observations =138

$\Delta\ SClv_t = -0.50 \cdot \Delta PClv_{t-3}$

(-6.34)

R^2= 0.35, F=4.51

Semi-Annual: Percentage differences - Observations =62

$\Delta\ SClv_t = -0.33 \cdot \Delta PClv_t - 0.46 \cdot \Delta PClv_{t-6} + 0.15 \cdot \Delta PCrn_{t-6} - 0.09 \cdot \Delta InvCow_t$

(-4.05) (-6.02) (2.80) (-4.03)

R^2= 0.70, F=21.95

Annual: Percentage differences - Observations =32

$\Delta\ SClv_t = -0.63 \cdot \Delta PClv_t - 0.41 \cdot \Delta PClv_{t-12}$

(-6.49) (-4.20)

R^2= 0.78, F=30.30

With i = {0,…,4},

where

$SClv_t^k$	=	Total weight of beef calves slaughtered in 100.000 pounds, at time t,
$PSClv_{t-i}$	=	Slaughter price of calves per 100 pounds in US dollars, at time (t-i)
$PCrn_{t-i}$	=	Price of corn per bushel, in US dollars, at time (t-i)
$InvCow_{t-i}$	=	Number of breeding cows in inventory X 1000 units, at time (t-i).

5.4 Interpretation of results

The stepwise regression procedure resulted in the formation of structural supply equations. Some variables were included and some were not (based on significance levels). The procedure yielded estimated coefficients for all supply variables. Our main focus lies on the sign of the coefficients, which suggest whether a variable is negatively or positively related to the independent variable. Finally we check whether relationships as proposed in the cattle model (see the flow diagram in Appendix B) hold, how animal supply within the model is related over time and which determinants are most significant.

For the regression-models of absolute data we have found slightly different results than in our relative data regression models. We faced higher correlations between the dependent variables for the absolute aggregate data. Correlation tells us how one variable corresponds to changes of another. Highly correlated variables in the regression model can upset the model and lead to false interpretations and conclusions.

Some of the regression models are more significant than others. Moreover we faced high t-values for the intercepts at the minority of the equations. The latter is most worrisome; since we can interpret that most variation can be assigned to the intercept and not to the dependent variables. In the results we primarily focus on those models which are statistically significant, illustrated by a high adjusted R-squared.
We were surprised by extreme high R-squares, for some models up to 0,87. It suggests that the explanatory value of the dependent variables is extremely good. Also the residual plot did not reveal any problems. In our perspective we believe that these results show that we are at the right direction of choosing those variables which are a good predictor of future cattle supply. In the following section we primarily focus on the signs of the estimated regression parameters. We show whether our research results match our expectations and hypotheses.

Supply of slaughter steers equation

The coefficient of the slaughter price of steers was surprising since it yielded an unexpected sign. Our regression results suggest that price changes of slaughter steers are negatively related to the supply of slaughtered steers in the short run. This result is not in line with our expectations. It suggests that steers, which are actually consumption goods, face the same price-supply relationships as animals that are used as investment goods. The signs of the price of corn coefficients showed mixed results. They were not included in all supply equations. Furthermore the sign of the price of corn is negative in the absolute (equilibrium) supply equation and positive in the change supply equation. A negative corn price – supply relation indicates that an increase in the price of corn results in a decrease in the supply of steers. The signs of the total inventory of steers are positive, which is in line with our expectations of Section 5.2.

Supply of slaughter heifers equation

We find mixed signs of the coefficients of estimated price in the heifer supply equation. Signs of the coefficients are mixed; they are either negative or positive in the long run and in the short run and do not confirm our expectations. We find negative coefficients for the price of corn in the short run. This confirms our expectations of Section 5.2. In other words we find evidence that high corn prices result in a lower total weight of slaughter heifers in the short run. Replacement inventories are statistically significant and a positive sign is estimated for coefficients in the long and short run. In other words, an increase in the total inventory of calves leads to an increase in the total weight of heifers slaughtered in the long and in the short run. We remark that the absolute heifer regression shows an extremely high R-squared, suggesting that the proposed model fits very well for the semi-annual and annual models.

Supply of slaughter beef cows equation

Coefficients of the price of beef cows are negatively related to the supply of beef cows in the short run. This result meets our expectations. Lagged beef price changes are not only negatively related on the short run, but also on the long run (time lag up to 12 months). This time lag is considered to be larger than expected. Apparently there exists a negative price-supply relation with a greater time lag than other animals. This large time lag is arguable since beef cows are considered to be investment goods. The time it takes before a decision takes effect can be as long as the gestation period of the cow (9 months). The time lag of the cow price variable is considerably greater than other animals.

Also the signs of the prices of corn coefficients were different than our expectations. The signs of the price of corn were negative in all cow supply equations in the long run. In other words, if the price of corn increases, then the total supply of beef cow decreases in the long run. A rise in the price of corn results in lower profit margins for cattle producers if the beef price stays the same. In effect, beef-cow producers might reduce their herds in the short run. In the long run cow producers have left fewer animals for slaughter purposes. Lagged replacement inventories are positively related to the total weight of beef cows slaughtered. The signs of these last variables are in line with our expectations.

Supply of slaughter calves equation

All calves supply equations show high adjusted r-squares. In other words, the variation in the dependent variable can be explained with a high degree by the dependent variables. The estimated signs of the calf-price coefficient are negative. This is in line with our expectations. Calves consist of female and male calves. Female calves serve a dual purpose, they are either used as capital good or as consumption good. The dual purpose character of this animal group can be a clarification for the negative price-supply relationship to exist. The corn price variable is excluded in most of the structural supply equations. Which can give evidence that the corn price variable does not have a significant relationship with the supply of slaughter calves. This is in line with our expectations, since calves are less dependent on corn than other animals. Most calves are weaned by their mothers and fed on the nutrition of grass from grasslands.

5.5 Conclusions and summary

This chapter aims to give a better understanding about which (lagged) variables provide the best explanation of cattle supply fluctuations. The overall objective was to obtain a better understanding of the fundamental causes of cattle supply fluctuations. We identify, measure and analyze the most significant determinants of cattle supply. Based on a structural cattle supply model we estimated the dependency of (lagged) variables (price of slaughter animals, price of corn and the size of the replacement inventory) to the independent variable (cattle supply). The analysis is based on fundamental data obtained from the USDA in the period 1970-2005. First we draw expectations in what manner dependent variables relate to cattle supply.

We find evidence for a short-run negative price-supply relationship for all animal cattle categories. Surprisingly also steers show a short-run negative supply relationship. When the price of slaughter cattle rises, producers are willing to retain animals to produce animals in the future, instead of slaughtering them instantaneously. An increase in the price of slaughter animals would result in a decrease in the supply of slaughtered animals. We find that the short run negative supply relationship affects the total life cycle of cattle. Animals that serve a dual purpose (calves, heifers and calves) and animals that serve a single purpose (steers) show negative price-supply relationships.

We find mixed results for the relation of corn to cattle supply. In line with our expectations corn is omitted from the calves supply equation. Since calves are not dependent on feed prices, as calves are raised by their mothers and mainly fed by summer grass. For all other animal categories we find mixed results.

The sign of the dependent relation is in line with our expectations. We find a positive relationship between replacement inventory and the supply of cattle, for all animal categories. In the long run a positive supply response is less evident for all cattle categories. Moreover we find evidence for a positive supply response to changes in cattle inventory. In the last chapter we will elaborate on implications of the estimated supply equations for cattle traded at futures markets.

6. Case Studies

6.1 Introduction

In this section we describe two events that had significant market impact on cash and futures prices of cattle- and cattle related products. The first event is weather related: a severe drought in the summer of 1988 heavily affected cattle operations. The second event is disease related: the discovery of BSE within the borders of the US. Before we begin our case study we give an overview which relationships and hypotheses we will consider and test on the data in the time of the extreme event. Finally, we consider whether the relationships of fundamental cattle supply discovered hold, as found in Chapter 5.

Final goal of this chapter is to check whether relationships (over time) of our proposed cattle model hold (see flowchart in Appendix B). The goal of Chapter 4 and Chapter 5 was to check whether the proposed supply relationships hold (over time) in the cash market. In the next section we incorporate the futures markets in the cattle model. Our goal is to test whether cattle relationships as proposed in the flow diagram not only hold at cash markets but also in futures markets.

Price research of cattle futures can take place in many forms. For example we can use a broad variety of econometric techniques, mathematics or simply imagination to uncover relationships between prices. It makes it possible to find that there exists a strong form of relationship in price movements: e.g., in all cases that the price of a nearby live cattle futures contract shifts, the feeder cattle futures moves in tandem. We can measure the strength and direction of a linear relationship between futures prices by calculating the correlation value of two futures contracts. These techniques have some important limitations. One problem of the research technique described, is that price behavior of futures is explained on an average basis. Besides we neither know whether price changes are the result of some random behavior or white noise. We claim that during an extreme event a specific subset of factors arguably dominates. The dominant factors expressed as variables can then be easily measured. For example in most “average” situations, changes of variables do not come to surface since they are recognized as white noise or random behavior. The effect of an extreme event can be measured more efficiently. In normal market situations, prices are influenced by other markets, news feeds, and all other phenomena which affect supply and demand. In case of an extreme event, it is easier to ascribe a particular cause and its price reaction at a particular moment in time (excluding all noise). In extreme events, it might occur that relationships in commodity prices come to surface.

6.2 Case Study: the drought of 1988

Weather conditions are of great importance to the total supply and quality of a crop and ultimately its price. Uncertainty and weather go hand in hand. Agricultural products like grains and cattle can be struck by heavy moisture, droughts, winds (hurricanes), floods and many more catastrophes. In this section we elaborate on a drought incident which hit large parts of the U.S. agricultural sector, the drought of 1988.

Droughts in general

Following the USDA's definition, droughts are moisture shortages leading to damaged crops or pastures, high wildfire risk or water shortages. Drought is a normal, recurrent feature of climate. It occurs almost everywhere, although its features vary from region to region. When a drought occurs, the impacts are felt first by those most reliant on annual rainfall, farmers and ranchers. Drought can affect the cattle sector in several ways. Animals are hit by extreme temperatures directly and by limited water supplies. Indirectly, animals can be hit by shortages of grains (feed) affected by the drought. We distinguish cow-calf operations from feedlots. The former depend on feed from grass-lands and use very little grains. The latter are highly dependent on grains in the feeding process.

An effective method to reduce negative side effects of the drought is to reduce inventory. First, most vulnerable animals can be sent to slaughter, such as old breeding cows and animals that are unproductive. Second, other vulnerable animals are cows and calves on cow-calf operations. Extreme droughts can affect pastures, resulting in insufficient grass and forage as feed for all animals on farms. The decision to slaughter cows and calves is easily made with higher feed prices on the horizon. The last group of animals which are affected by the drought, are those animals dependent on feed crops, such as corn and soybeans. Lower corn and soybean supply will drive prices up, which affects feeding costs in the future. Feedlot operators can decide to send steers to slaughter earlier, since higher feeding costs suppress profit margins.

Measurement of drought

To objectively assess and show a regions weather conditions we use the Palmer Drought Severity Index (PDSI). Following Palmer (1965), the PDSI is a reflection of how much soil moisture is currently available compared to that of normal or average conditions. The PDSI incorporates both precipitation and temperature data. The index accounts not only for supply, such as the levels of rain or snowfall water equivalent. It also accounts for demand, such as how much water is lost through the movement of water through the air, soil, consumption by plants, agriculture and industry. The PDSI is commonly calculated at monthly time steps, and is published by the National Oceanic and Atmospheric Administration National Climatic Data Center.

The drought of 1988

Every year parts of the United States are affected by droughts. The drought of 1988 was not only exceptional because of its length, high temperatures, and low humidity. It was maybe more extreme since it hit almost all agricultural regions in the United States. Figure 18 makes clear, using the PDSI, that almost all agricultural regions of the United States faced extreme weather conditions in the summer of 1988. During the summer months 45% of the US were experiencing drought or severe drought conditions, measured with the PDSI (see Figure 18).

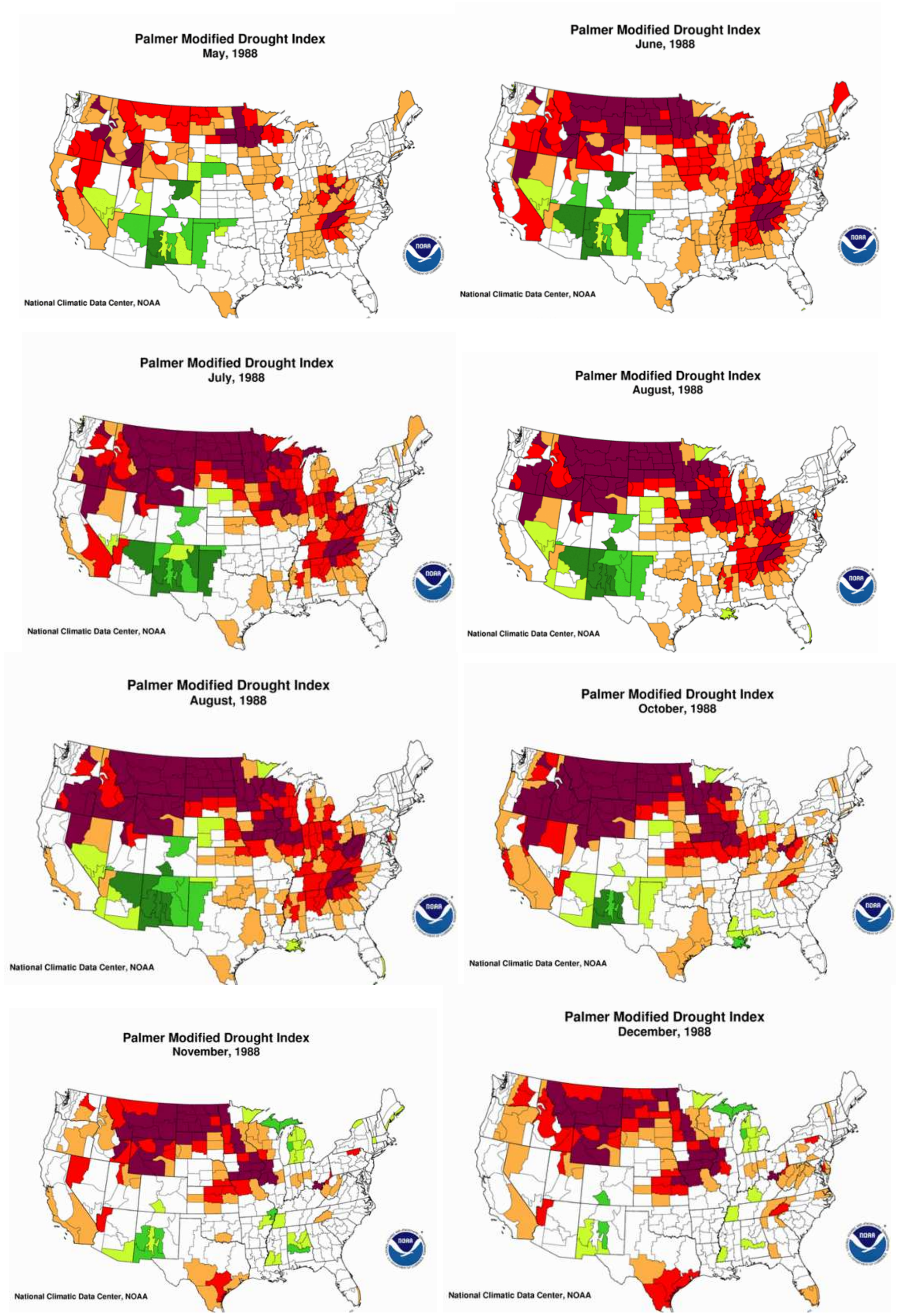


Figure 18: PDSI U.S. drought index maps
Maps showing the most affected regions by drought from May until October 1988. The map is based on the Palmer Drought Severity Index. The legend can be found on the next page. Source: National Oceanic and Atmospheric Administration National Climatic Data Center, www.ncdc.noaa.gov.

The Drought of 1988

The next chronologic summary of events surrounding the 1988 drought is based on Cook *et al.*, 2007 and the Minnesota Department of Natural Resources and Division of Waters report published in 1989. In the winter of 1986 the North American climate appeared to change. During the previous decade, the United States experienced some of the most humid conditions in history. During those years, not drought, but flood was the predominant weather related concern for farmers in the US. Unexpectedly, conditions changed in the winter of 1986-1987. Several states suffered some of the warmest and driest weather in history. Farmers were prepared for the worst in the summer of 1987. However conditions turned towards them, when in July 1987 heavy rainfalls supported high yields of crops. Also in April 1988, many states suffered unusual dry weather. In the following months weather conditions got worse, leading to the worst drought ever. Historic temperatures and humidity records were set. It took until the first week of August 1988, for wet weather conditions to change a little bit. However, this was too late to save large parts of US crops.

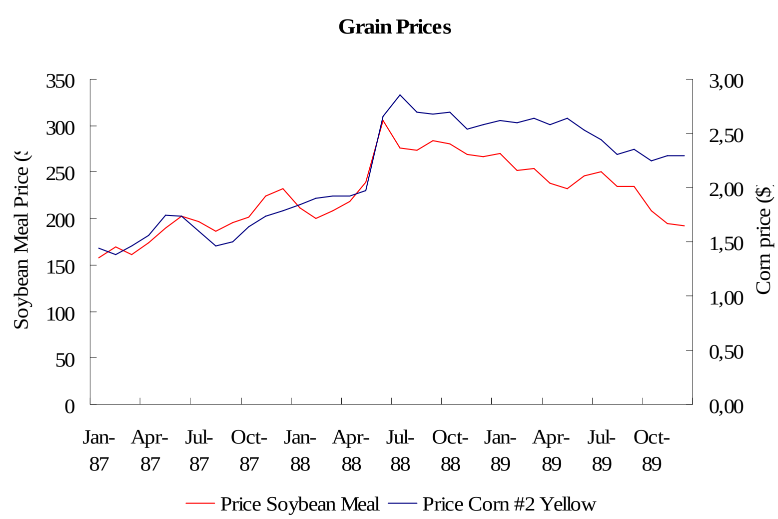


Figure 19: Grain prices, soybean meal and corn
Source: USDA

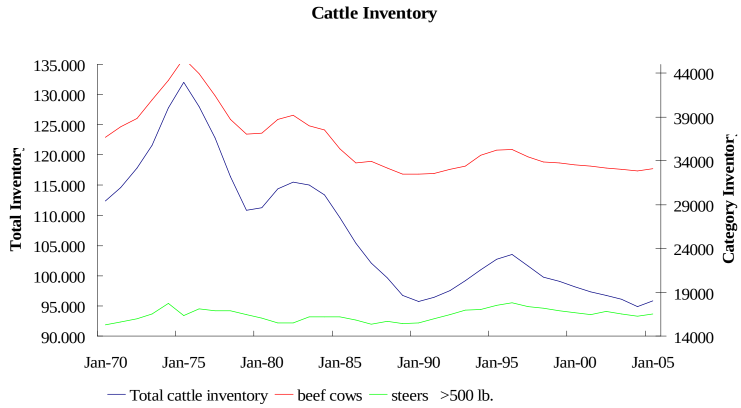


Figure 20: Cattle inventory in 1000 heads,
Source: USDA

Reports on grain production of the USDA on the 1st of August showed an expected decrease of 31% of the national grain production (the lowest level since 1970). In comparison with 1986 total production for corn was down 37% and that of soybean was down 23%. The shortfall in grains production did not lead to disastrous scarcities. First, there were sufficient stocks available from the previous harvest. Second, domestic demand shred as livestock producers liquidate their herds. Finally, major export countries of grains faced larger crops than other years. However the drought had a major effect on grain prices (Figure 19). We expect that livestock producers were heavily affected by the severe drought in the summer of 1988. The effect of the drought was less visible if we look at cattle inventory and placements figures. At the beginning of 1988 the cattle herd was already small (lowest cattle inventory level in history). In the preceding years, producers already began to liquidate their breeding cows (see Figure 20). The consequence was that demand for pastures was not that great. As a matter of fact only a small number of beef cows were slaughtered during the drought. Effects of the drought were felt the longest time by cow-calf operators. Those operators tried to expand their herds in the years following the drought. For this reason heifers were kept for breeding by operators. Herd expansion reduced the number of heifers available for feeding in 1989 and 1990. After 1990 total cattle inventory showed a rapid increase. Although the US experienced an extreme drought we do not observe large changes in cattle inventory, placements and marketing figures in the year of the event (see Figure 21).

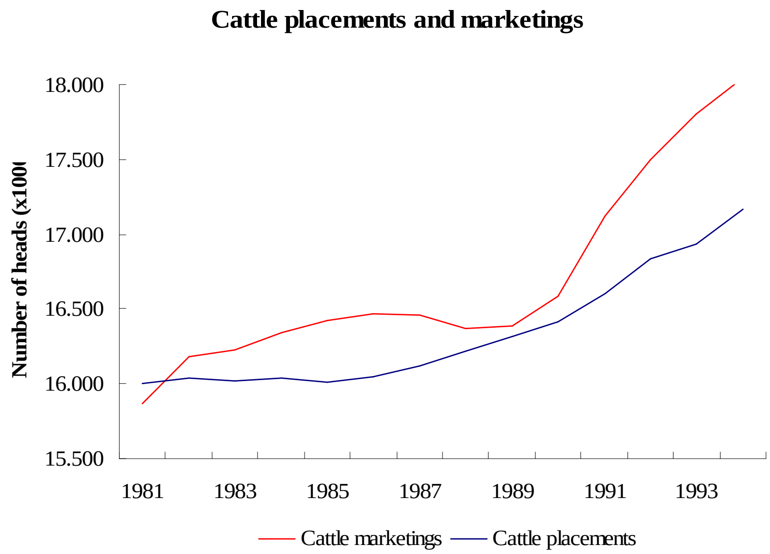


Figure 21: Cattle placemens and marketings, Source: USDA

However, two years after the drought, the same figures increased rapidly. In this case there exists a time lag between the moment a drought takes place and cattle inventory, placements and marketing figures change. Our figures suggest that a drought does not have a huge impact on cattle inventory and marketings in the short run. However, the same figures suggest that a drought results in huge changes in cattle inventories and marketings in the long run.

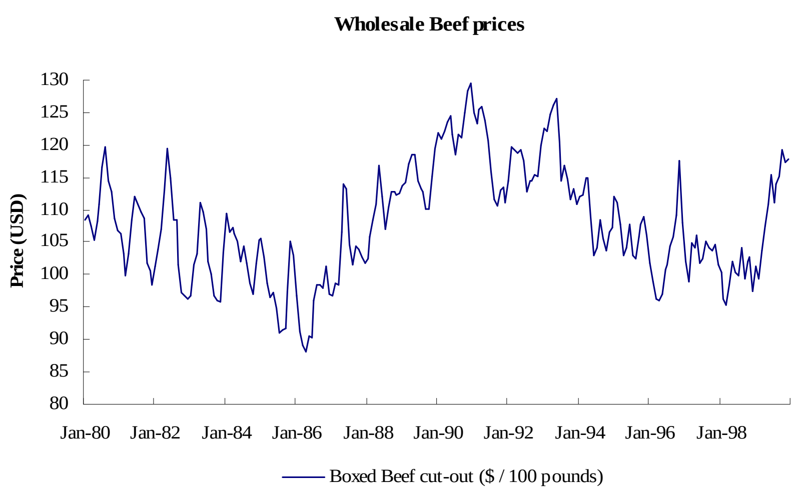


Figure 22: Wholesale beef prices, Source: USDA

Cattle feeders were affected more instantaneously by the drought. As higher feed (grain) prices increased the cost of feeding, cattle feeders dropped prices they were prepared to pay for feeder cattle. Because of high feeding costs, livestock producers bought cattle at heavier weights and fed them for fewer days. Furthermore cattle-operators were faced with higher feeding costs, which heavily pressured cattle profits. The combination of rebuilding the breeding herd and low profit margins due to high feeding costs, led to a lower number of cattle marketings (animals sold to slaughterhouses) in subsequent years (Figure 21). Apparently the effects for the cattle sector of the ’88 drought were more visible in the long run, than in the short run. Whether or not the drought directly affected consumer prices of beef is hard to say. What we can observe is that after 1988 wholesale beef prices continued to increase until 1991 (Figure 22).

Futures market and prices

The drought could stir up heavy inflation due to shortages on agricultural products. Cash prices of many agricultural products (particularly grains) skyrocketed following the drought. The severe drought had major effects on supply and prices of agricultural commodities.

In this section we take a closer look at the price behavior of futures contracts before, during and after the drought stroke the US. We shall have a look at four major futures contracts related to cattle: live cattle, feeder cattle, corn and soybean meal. For every category we elaborate on the factor time. Since price behavior can be measured at different time horizons (intraday, weekly, yearly) we consider the futures prices at different time aspects.

Live cattle futures

Take some time to have a good look at Figure 23. At first sight the two graphs appear to show random price behavior of two independent futures contracts. If we take a better look, we see extraordinary price-behavior of different futures contracts with the same underlying commodity. The graph represents the Live Cattle Aug 88 and Live Cattle Jun 89 contract. When both contracts are active, prices move in parallel until the first week of June 1988. The deferred futures contract decreases by almost 10% to the end of June. Contrary, the nearby futures contract moved upwards in the same period. Normally we would expect that futures prices are positively cointegrated. It seems that in this situation the relation-structure of prices of live cattle futures contract changed.

How is it possible that price relationships of futures contracts suddenly moved against each other? The price movement is a good example that investors should treat every futures contract independently. It is a perfect example of the first time effect as presented in Chapter 1: Prices of futures contracts with the same underlying asset but with different maturities (e.g. Live Cattle Aug 88 vs. Live Cattle Jun 89), can react differently to the same market event, at the same time. Reason for the discrepancy is that the contracts do not represent the same physical underlying commodity. Of course the underlying product is the same in name, we are both dealing with live cattle: fattened up cows and steers that are ready for slaughter. Nevertheless we should make an important distinction between the two contracts. A trader, who enters the nearby contract, obliges himself to buy or sell live cattle in August 1988. A trader, who enters the deferred contract, obliges himself to buy or sell live cattle in June 1989. The big difference is that both futures do not represent the same fattened animals at the same moment in time. Apparently there exists a difference in expected price of live cattle that will be delivered in the near future and live cattle that will be delivered in the far future. One of the reasons for the price differences to exist is the difference in expected supply and demand at the time of delivery.

The concept of cost of carry is useful to explain the relation between deferred- and nearby futures contracts and spot prices. The cost of carry is the storage cost of the underlying asset plus the cost of financing it minus the income received from it. In the case of consumption assets (such as live cattle), the futures price is greater than the spot price by an amount reflecting the cost of carry net of the convenience yield (Hull, J.C., 2006). Wherein the convenience yield is the measure of the benefits from ownership of an asset that are not obtained by the holder of a long futures contract on the asset. The cost of carry of live cattle futures contract are for example the cost of maintaining and delivering live cattle. A farmer who is selling live cattle with a futures contract should meet the contracts specifications, animals should be properly fed and delivered at the correct location. You can imagine that during the drought, the cost of carry for deferred live cattle futures is higher than nearby futures. Shortages on animal feed during the drought made it rather very expensive to feed live cattle during the whole summer, instead of delivering animals earlier.

Higher feeding costs and devastated grasslands can normally lead to higher liquidation levels of cattle (beef-cattle as well as dairy cattle). In contrast, the price decrease of nearby futures contracts in the summer of 1988 is not fed by an instantaneous raise in the supply of slaughter cattle. Slaughter figures stay constant during 1988. However major effects in the cattle sector become visible in the long run. The combination of rebuilding the breeding herd and low profit margins due to high feeding costs, led to lower cattle production in 1989 and 1990. This is in line with the deferred futures contract price, confirming the higher price of the deferred futures contract. In the long run, supply is under pressure since operators need time to rebuild their herds.

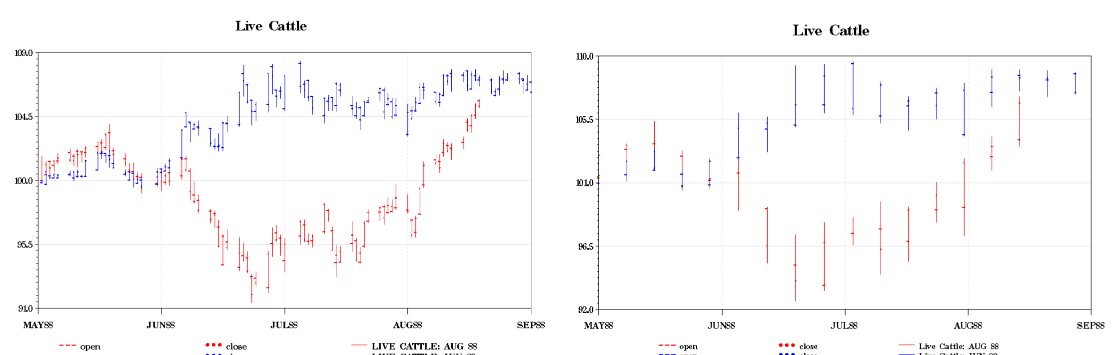


Figure 23: Live cattle futures contracts,
The left graph shows indexed prices based in daily data, right are indexed price based on weekly data.
Source: Transtrend B.V.

The divergence of prices of futures contracts took place during the summer months of 1988. Prices recover to “ordinary” parallel behavior after the summer months. Prices of live cattle futures contracts increased rapidly, after the drought of 1988. The severe drought of 1988 could have been an accelerator of the quick rise in cattle futures prices in 1989 (see Figure 24). In the same figure we see that the volatility of the Live Cattle Aug 88 contract price is high during the summer months. Ultimately the Live Cattle Aug 88 price returns to the same price levels as other active live cattle contracts.

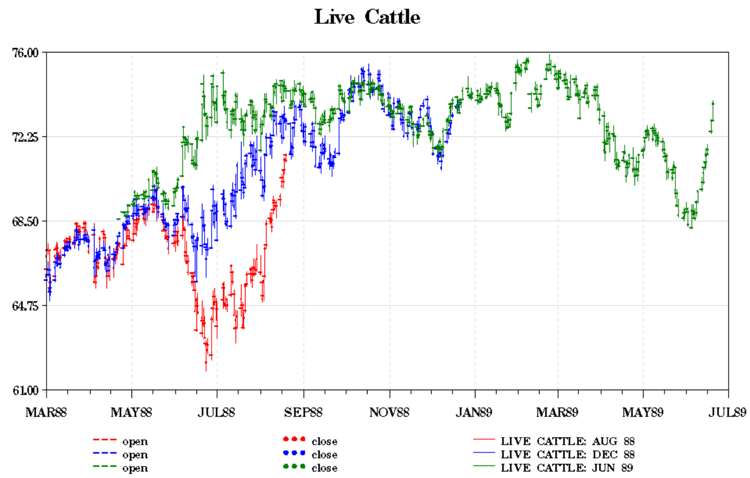


Figure 24: Prices of Live Cattle futures contracts, March ’88- July’89.
Source: Transtrend B.V.

Feeder cattle futures

The effect of the drought on prices of feeder cattle futures was not that extreme as it was on prices of live cattle futures contracts. The volatility of prices went up rapidly in the drought period. However prices of all active feeder cattle futures contracts continued to move together (see Figure 25). In other words, the direction of price movements of two contracts was equal. We see that nearby futures contracts, show a greater price decrease than deferred futures contracts. The figures suggest that nearby futures contracts are more heavily affected by an extreme event than deferred futures contracts.

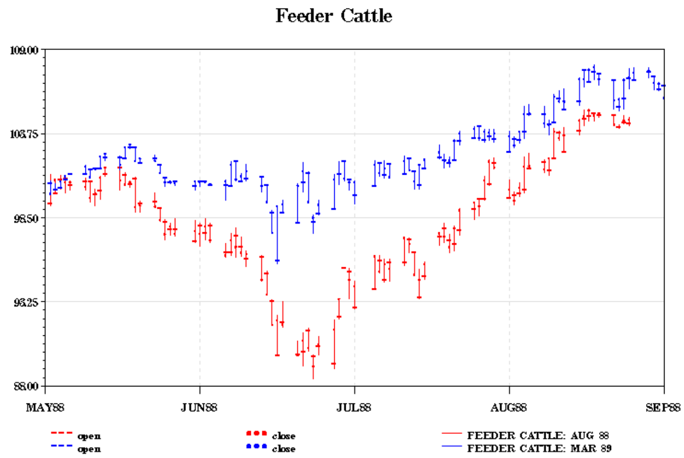


Figure 25: Prices of Feeder Cattle futures contracts, August ’88 and March ’89.
Source: Transtrend B.V.

In the long run we observed more volatility in futures contracts price behavior in times of the ’88 drought. Overall and at the end, prices of Live Cattle futures contracts moved up at the end of the summer of ’88. It seems that the drought had a negative effect on cattle supply which put prices of cattle futures contracts higher. An explanation can be that the drought had its effects on cattle supply. The effect was that prices of cattle futures at the end of the drought period increased to higher levels than before.

Corn and soybean meal futures

Drought does not only affect live cattle prices. Particularly grain producers feel the effects of a severe drought as the hot dry weather has a devastating effect on grain crops. The graphs in Figure 26 show price behavior of Corn futures in 1988. Prices of almost all corn futures doubled in June 1988 as expected corn yields plummeted. The expected scarcity of grains in the future put corn futures contracts prices higher.

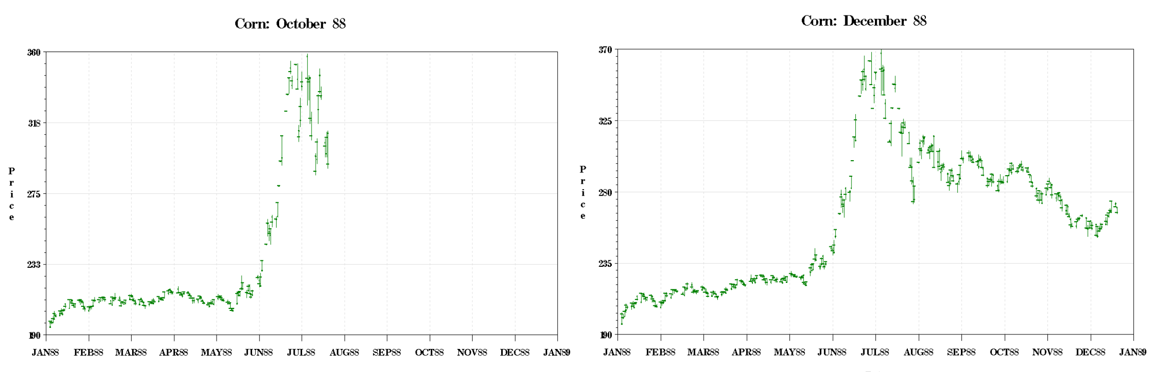


Figure 26: Prices of Corn Futures contracts, October ’88 and ‘December ’88.
Source: Transtrend B.V.

Soybean meal futures prices moved in tandem with the Corn futures contracts. The extreme drought affected the expected soybean crop, which grows in the same area of the U.S. as corn. Apparently, the drought was expected to affect future soybean supply, which affected the price of an important soybean product, soybean meal. The price change appeared to be structural, as prices remained on high levels in 1989, since a lower amount of soybean (meal) on stock was available.

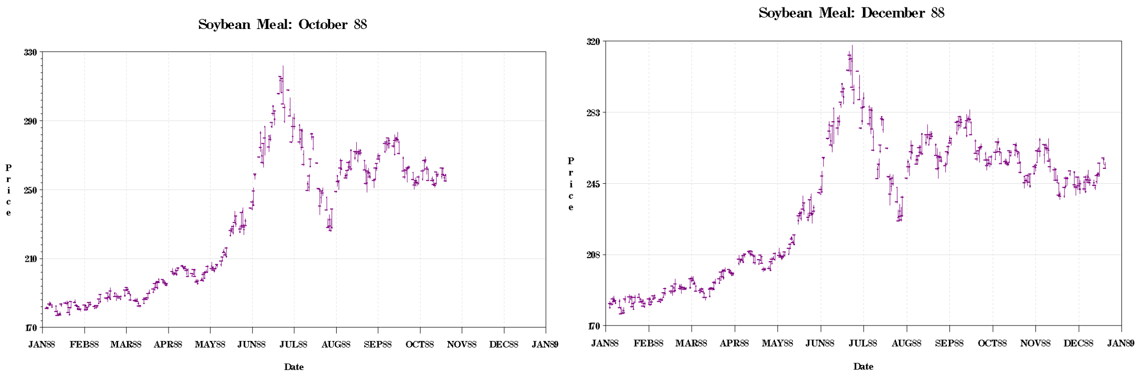


Figure 27: Prices of Soybean meal futures: October '88 and December '88
Source: Transtrend B.V.

Key points

In this section we took a closer look at the price behavior of cattle futures contracts around extreme market events. Key findings of the extreme event study are:

- Prices of live cattle futures contracts with different delivery dates behaved differently during the heavy drought conditions in the summer of '88 (June-July 1988).
- Nearby live cattle futures contracts decreased rapidly in price during the summer drought conditions. Deferred futures contracts showed a price increase in the same time period.
- Nearby live cattle futures contracts prices converged back, within two months, to price levels of deferred futures contracts.
- Price fluctuations (in percentages) of grain prices (cash and futures) where significantly higher than price reactions of cattle prices.
- Cash prices of cattle and cattle placements did not seem to be affected by the drought, in the short run.
- Cash prices of cattle and cattle placements seem to be more heavily affected by the drought, in the long run.

Implications for the cattle model

One of the goals of this chapter was to check whether the proposed relationships (over time) of our cattle model (Appendix B) hold for the cash as well as futures markets. In our approach we focus on a subset of factors which arguably dominates in the change of cattle supply. During the summer '88 drought, the most significant determinant change was the change of feed prices. We saw that during the drought cash and futures prices of feed ingredients rose significantly. It is obvious that other forces are active in the cattle supply chain however the change of the feed price arguably dominated. In Chapter 5 we estimated that the supply of steers is negatively related to feed price levels in the long run and short run. Data and figures of feed prices and cattle supply showed a negative relationship in the short run (not in the long run). The discrepant behavior of nearby and deferred futures prices of live cattle is in line with the expected live cattle price-supply response. In the short run, lower profit margins lead to a greater supply of animals, which results in lower cattle prices. In the long run, we can expect a decrease of supply, resulting in higher cattle prices (see Figure 27).

6.3 The discovery of BSE in the U.S.

The detection of BSE in a cow within the borders of the US had substantial economic impact. Before we describe this event, it is important to become familiar with BSE itself and the US cattle sector conditions at that time.

Bovine Spongiform Encephalopathy (BSE), also called Mad Cow Disease, is a neurological disease in cattle caused by proteins that create holes in the brain tissue of animals. The disease can be spread to other animals when animals eat feed with bone meal from another cow infected with BSE. Bone meal from BSE-infected cattle used as protein supplement in cattle feed is believed to cause the spread of BSE. Humans cannot contract BSE itself, but another related disease called Creutzfeld-Jakob disease. There is a really low risk for human health of BSE cases with animals. Humans can only be affected by eating the nervous tissue (like its brain or blood) of contaminated animals. Most of the meat consumed by humans is muscle tissue, which cannot contain BSE. Moreover, the risk to humans is extremely low, since cattle younger than 30 months cannot contract BSE. Actually most of the meat consumed in the US and Europe comes from animals that are younger than 30 months of age

Prior to the detection of BSE in the United States, there were several factors that influenced sector supply and consequently slaughter prices. First, the U.S. was in a cattle inventory-liquidation phase. The total number of cattle on feed declined from a peak in 1996 (103.5 million cattle animals in inventory) to a low in 2004 (95 million cattle animals in inventory). The decline led to an increasing trend of cattle prices in the same period.

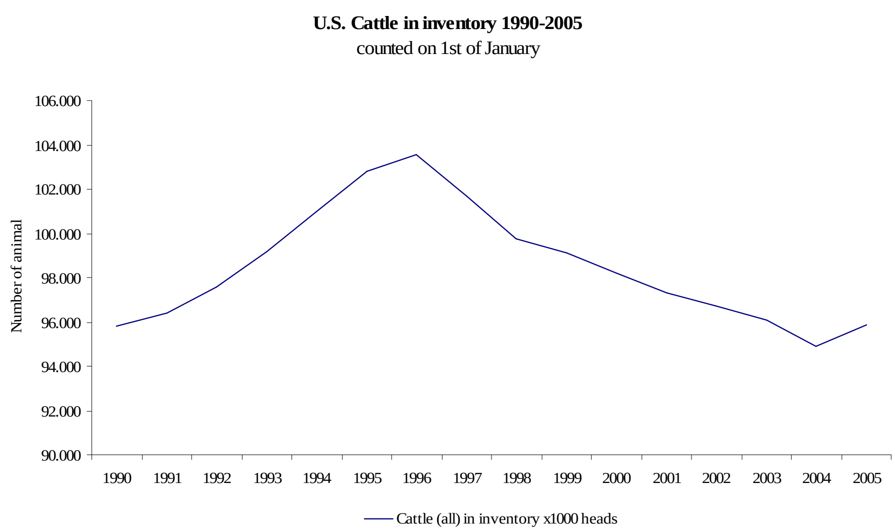


Figure 28: U.S. Cattle in Inventory as counted yearly on the 1st of January, Source: USDA

Second, Canada discovered its first BSE case on the 20th of May 2003. The incident led to a worldwide ban on large parts of Canadian cattle and beef products. To give an idea, the import of Canadian cattle accounted for 4% of total US beef supplies. Furthermore around 50% of all produced beef in Canada was exported. The impact on the Canadian beef sector was enormous. Cattle producers faced a rapid declining demand, leading to lower Canadian beef and cattle prices and a heavy increase in the number of animals in inventory. As a consequence the import ban led to lower supply, and raised cattle and beef prices. Worldwide bans on Canadian cattle increased the demand for US cattle, until the 23rd of December.

The first BSE cow detected in the U.S.

On December the 23rd the USDA announced that a dairy cow infected with BSE had been slaughtered. One of the first reactions of US' main beef trading partners was to ban the import of US beef and cattle. To give an impression of the impact: beef exports were expected to account for 10.4 percent of total US beef production in 2004. Mexico, Russia, Brazil, South Africa, Hong Kong, Japan, Singapore, Taiwan, Malaysia and South Korea are among the countries to ban the import of American beef. The European Union already banned U.S. beef because of concerns about the use of growth hormones. Canada restricted imports of cattle-related products from the U.S. to dairy products, cattle destined for immediate slaughter and boneless beef cuts from cattle under 30 months of age.

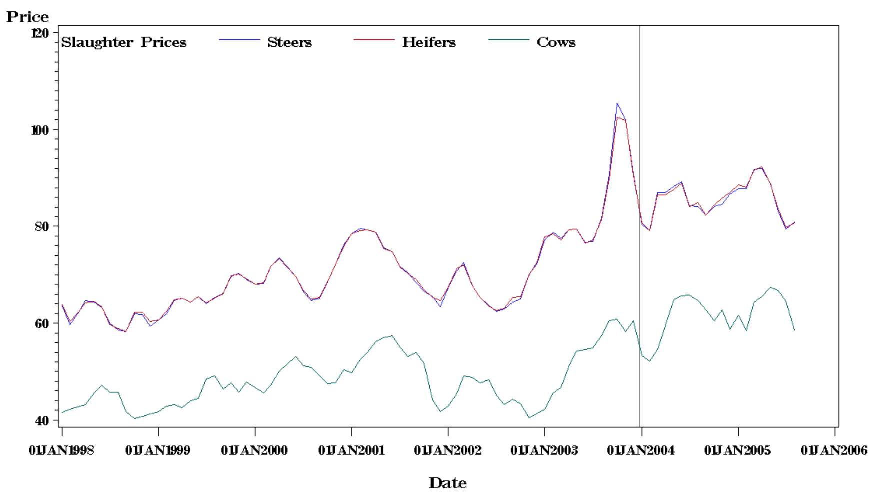


Figure 29: Monthly cattle slaughter prices
Source: USDA

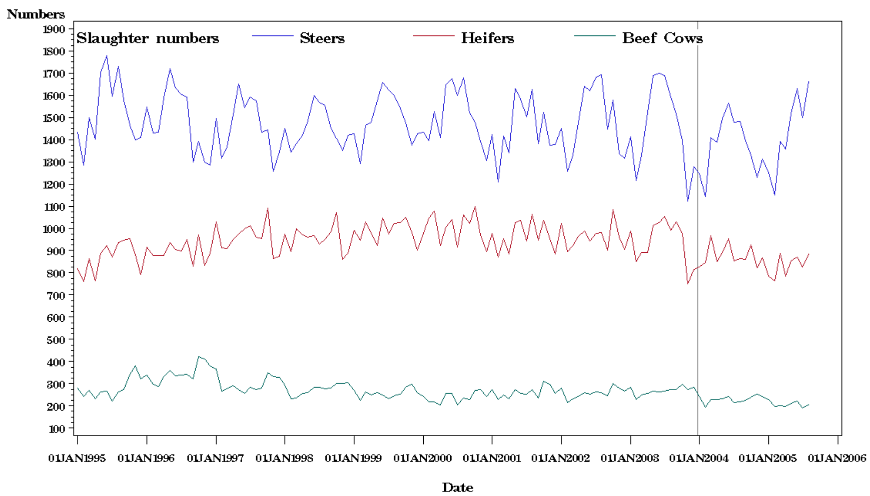
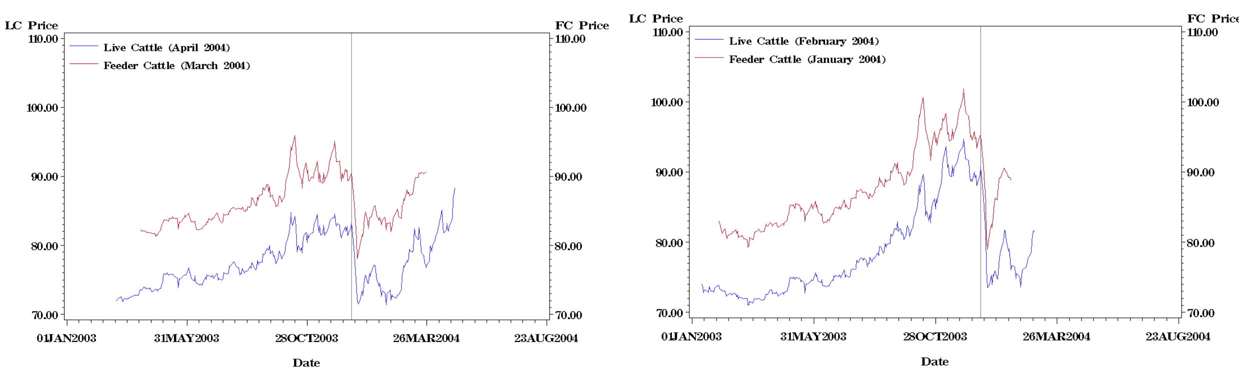


Figure 30: Monthly cattle slaughter numbers in thousands
Source: USDA

The announcement led to a decrease in slaughter prices of steers and heifers of more than 25 % in the same month (see Figure 29). Slaughter rates did not seem to be affected by the announcement in the first place (see Figure 30). Global bans on US cattle and beef had its effect on cash and futures prices of cattle, beef and its by-products. Nearby live cattle futures prices plummeted for five days in a row (see Figure 30)After the BSE announcement, all live cattle futures prices, moved limit down[3], up to four days in a row. In response of the plummeting prices in the first day, the CME raised the market limit from $ 1.50 to $ 5.00. During the next five trading days the nearby live cattle futures contract (Live Cattle Feb 04) plummeted from a price level of 90.68 on the 23rd of December to 73,53 on the 31st of December, a drop of almost 19%.

Figure 31: Live cattle futures prices around BSE event.
Source: Transtrend B.V.



Also feeder cattle futures contracts concurrently moved limit down. Feeder Cattle Jan 04 plummeted from a price of USD 95.23 on the 23rd of December to USD 78.93 on the 31st of January, down 17% (see Figure 31). Apparently futures markets anticipated on a sharp drop in cattle slaughter prices in the near future.

3 The market limit is the maximum advance or decline from the previous day's settlement permitted for a contract in one trading session by the rules of the exchange. If the price contract is said to move limit down, it declines in one day with the maximum allowed number of points.

If we take a closer look at prices of all futures contracts traded in the market, differences in price movements of contracts do occur. All futures contracts went limit down on the first and second day after the announcement of the BSE incident. On the third day, the nearby contracts of Feb 04 and Apr 04, plummeted again to a market limit. This is in contrast with futures contracts for Jun 04, Aug 04, Oct 04 and Dec 04, which did not fall until the market limit. Apparently prices of nearby cattle futures contracts (the upcoming four months) are more under pressure than prices of deferred cattle futures prices (Figure 32).

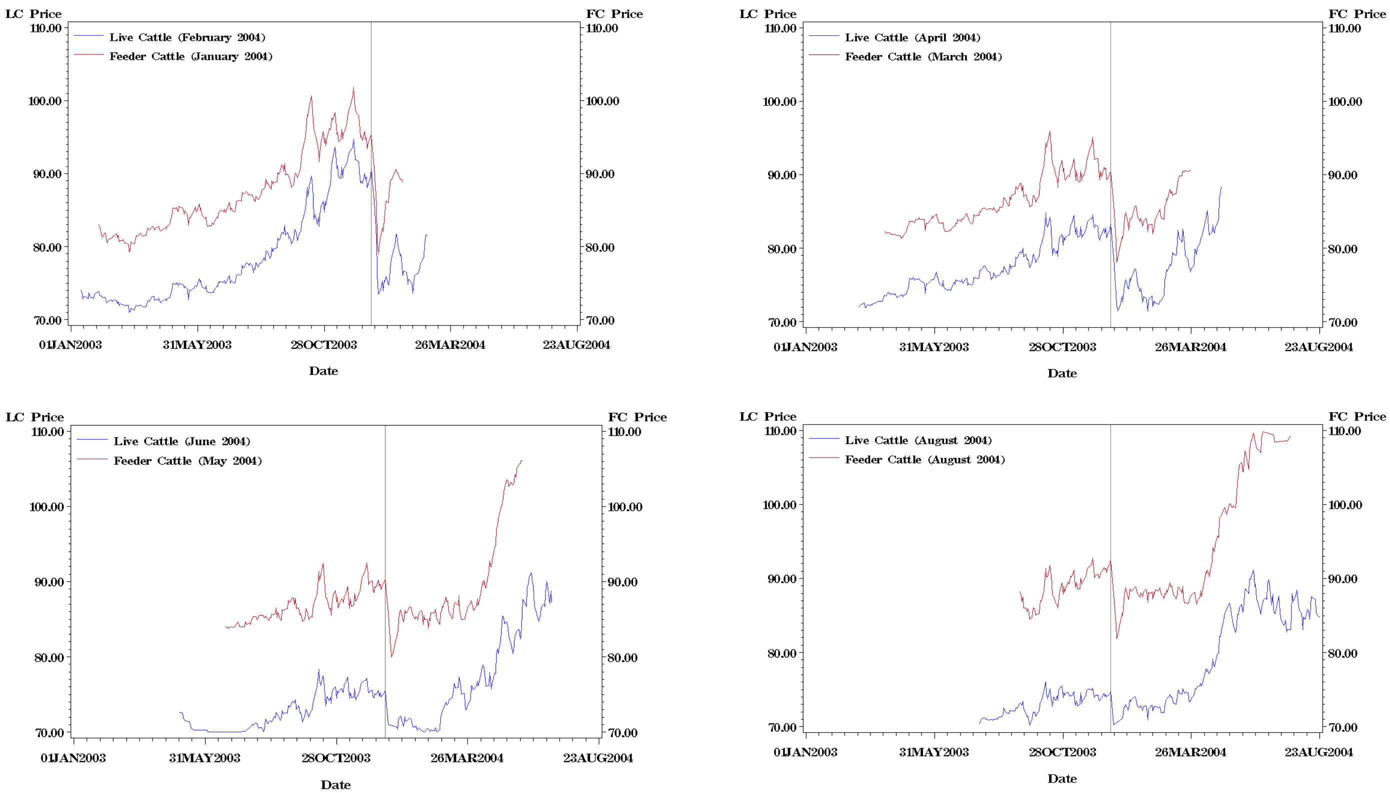


Figure 32: Live- and feeder cattle futures contract behavior around the BSE event.
Source Transtrend B.V.

The 2003 U.S. BSE case significantly decreased live cattle futures prices beyond an immediate price drop following the confirmation. The impact was different for different futures contracts. The effects were stronger and more persistent on the nearby futures. The effects were not permanent; in approximately five months for the nearby futures reached pre-event price levels. Most of the other North American BSE events did not had a significant effect on live cattle futures prices and volatility. The 2003 US BSE case was an exception, the impact was stronger for nearby maturities than for more distant maturities (Jin *et al.*, 2008)

The BSE incident did not only affect cattle prices. In addition corn- and soybean meal prices were affected by the event. As described earlier, corn and soybean meal are important ingredients of cattle feed. Corn contains a high level of starch. Soybean meal is high on proteins. Together they are important ingredients of animal feed, to reduce the time to fatten cattle. An important substitute of soybean meal is a rest-product of beef production: bone meal. If made from contaminated animals, it can be a risk factor for BSE, when healthy animals consume the bone meal. You can imagine that feed-producers try to find substitutes, like soybean meal, in case bone meal is banned. The ban on Canadian cattle not only led to an increase in U.S. cattle and beef prices. Moreover U.S. feed prices inclined rapidly, due to a higher demand for U.S. beef.

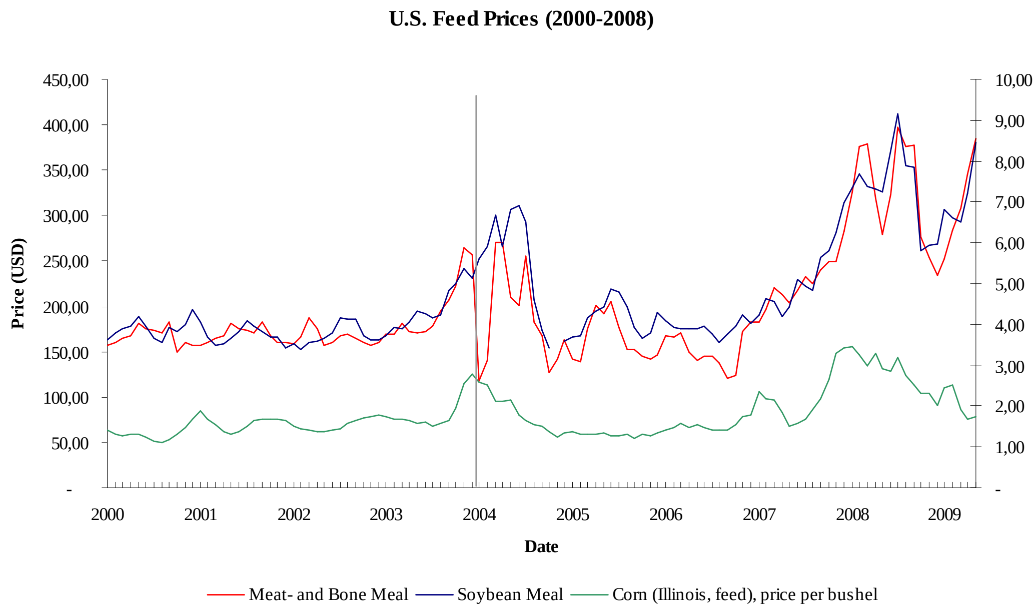


Figure 33: Prices of cattle feed ingredients
Source: USDA

The U.S. BSE incident on 23rd of December led to a remarkable price reaction of cattle feed ingredients. See Graph Figure 33 for the cash price reactions, the vertical line indicates the moment of detection of the first BSE-animal detected inside the borders of the USA. Logically the prices of meat- and bone meal (MBM) and soybean meal are highly correlated (See Figure 33). Both products are high on protein level and as such interchangeable. Conversely the correlation structure of MBM and soybean meal suddenly changed on the first US BSE incident. The ban on cattle and beef products, including MBM, led to a sharp decline in demand of MBM. Main result: cash prices of MBM plummeted (-54%) in January 2004. Conversely, soybean meal prices increased. Soybean meal apparently was a perfect substitute for MBM for cattle feeders. Strangely, after 3 months cash prices of MBM were already at their old levels. Moreover corn price declined sharply in the year following the BSE announcement.

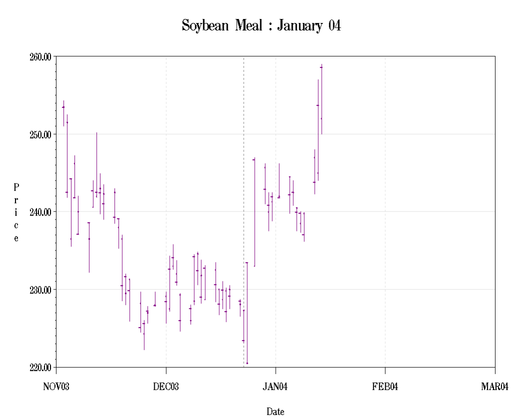


Figure 34: Soybean meal Jan 04,
Source: Transtrend B.V.

Futures markets and prices

We take a closer look at feed prices, by elaborating on the price reactions of futures prices of soybean meal and corn. After the BSE announcement on the 23rd of December, price of nearby Soybean meal contracts (Figure 35) dropped until a price level of 227.3 at the opening, where after they skyrocketed on the same day to a level of 223.4. On the 24th of December the contract again drops in price at opening. A couple of hours after opening, the Japanese government were the first to introduce a trading ban on US beef and cattle. The ban was followed by Mexico, Brazil, Russia, Ukraine, and a number of Asian counties from Singapore to South Korea. After the main international trading partners, announced their bans on US cattle and beef, the contract prices sky rocketed, reaching its day limit move on 233.40.

An international ban on all cattle and beef products led apparently to an increase in futures prices of corn and soybean meal. Not only did the price of soybean meal and corn futures prices rise on the short run (Figure 35). The BSE incident in the United States seem to be more structural, reflected by a price increase of corn and soybean futures prices in the subsequent months of the BSE announcement (Figure 36).

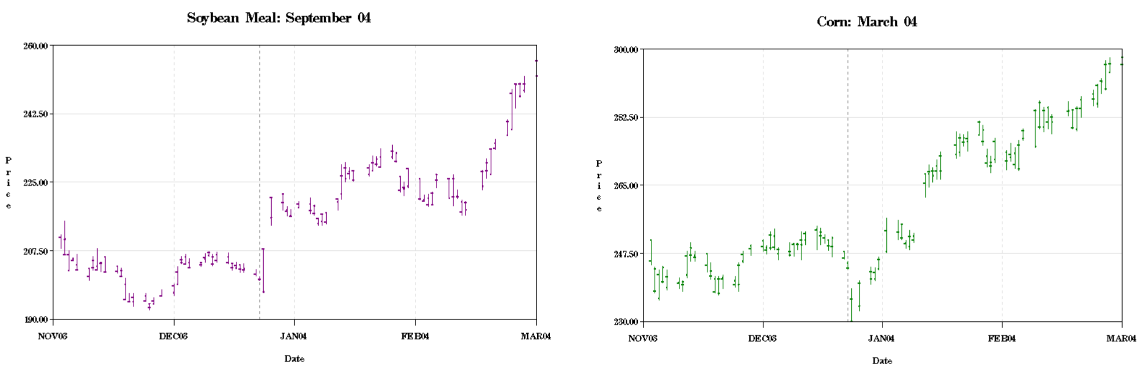


Figure 35: Soybean Meal Sep 04 and Corn Mar 04.
Source Transtrend B.V.

We believe that the main reason for the price behavior is twofold:

1) Meat- and Bone meal can be easily substituted by soybean meal for its use of soybean meal. Soybean meal as well as MBM are exported all over the world for the production of cattle feed. When import bans restrict the supply of cattle products, such as MBM, the market will use its substitutes, leading to higher demand on soybean meal.
2) Bans on U.S. beef- and cattle resulted in lower supply of American cattle. In case, worldwide demand for beef and cattle stays at the same levels, other economies worldwide need to increase their supply. In parallel this leads to increasing demand (and as such increasing prices) of cattle feed.

Long run time effects

We see that prices of deferred live cattle and feeder cattle contracts, returned to the pre-BSE price level one month after the BSE announcement (see Figure 36). Even more remarkable, was the strong incline in cattle futures prices in the long run: After 6 months, all cattle futures contracts set new record-high price levels. Apparently, the pressure on cattle prices at the end of December 2003 was followed by a rapid increase in cattle prices six months later. Prices of deferred corn and soybean contracts showed a rapid increase until five months after the announcement (see Figure 36). From that point in time the deferred futures contracts rapidly decreased. Apparently, we observe not only extreme futures price reactions in the short run. Price effects are more remarkable in the long run.

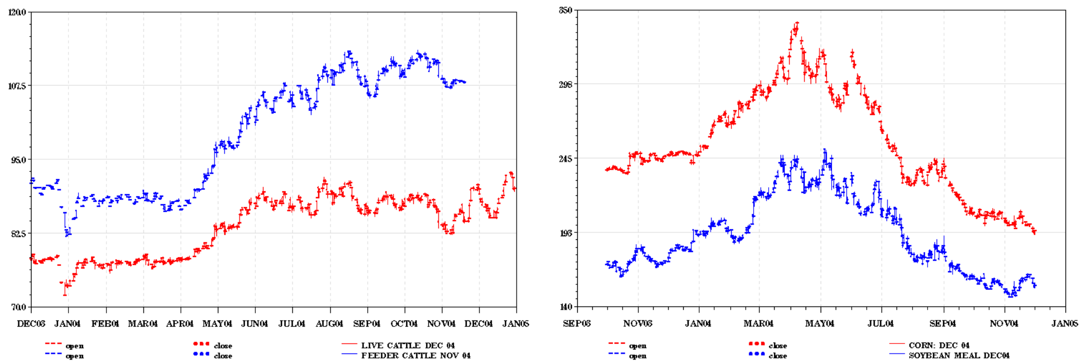


Figure 36: Live Cattle Dec 04, Feeder Cattle Nov 04, Corn Dec 04 and Soybean Meal Dec 04
Source: Transtrend B.V.

You may question what the impact of BSE is on demand. According to a study of Kuchler and Tegene (2006) in name of the USDA, was the impact on domestic demand considerably small. After an initial disease outbreak, people returned to their usual eating habits. The study examines consumers' retail purchases of beef and beef products after the BSE incident. They found that deviations from purchase patterns were limited to no more than 2 weeks for all beef products in the U.S.

Conclusions:

- The announcement of BSE in the US on the 23rd of December 2003 had a major effect on prices of live cattle, feeder cattle, soybean meal and corn futures contracts.
- In the short run (in the first month), prices of live cattle and feeder cattle futures contracts declined heavily. However, after one month prices returned to pre-event price levels.
- In the long run (after 6 months), prices of live cattle and feeder cattle futures contracts increased to new historic high levels.
- Cash prices of steers and heifers were significantly negatively affected in the month of the BSE announcement. Prices of beef-cows were did not show heavy fluctuations.
- Cash prices of U.S. feed prices were instantaneously heavily affected at the day of the BSE announcement.

- Prices of corn and soybean meal futures contracts were heavily affected by the BSE announcement. On the announcement day itself, corn and soybean meal contracts opened lower, but prices recovered during the same day and were set higher.
- Up to 5 months after the BSE event prices of corn and soybean meal futures contracts were considerably higher then pre-announcement levels.
- In the long run (over 5 months after the BSE event), prices of corn and soybean meal futures contracts were lower than pre-announcement levels.

Implications for the cattle model

In this section we focused on a subset of factors which arguably dominates the change of cattle supply. The detection of BSE in the United States had a major effect on slaughter prices of steers and heifers. Also feed ingredients respond heavily on the days after the announcement. Cash prices and futures prices of cattle products and futures plummeted immediately after the announcement. In our supply relationships we hypothesized that slaughter prices do affect the (future) animal slaughter supply of animals. In Chapter 5 we found evidence of a short run negative price – supply relationship of all animal categories. In the long run, cattle prices are negatively related to slaughter supply of all animals. In this chapter we considered the supply relationship in the cash and futures markets after the announcement of the detection of BSE. Surprisingly we did not encounter large deviations of cattle supply, which makes it hard to draw conclusions on the supply relationship of cattle. We do encounter strong changes in slaughter prices and feed ingredient prices. We also encounter a time lag of 6 months between a rapid increase and decrease in the futures as well as cash prices of cattle. The length of the time lag corresponds with the time it takes to feed live cattle before it is send to slaughter.

6.4 Conclusions and summary

Goal of this chapter was to check whether relationships (over time) of our proposed cattle model (Appendix B) hold. We performed two case studies for two extreme market events in the cattle sector. We claimed that during extreme events a specific subset of factors arguably dominates. The dominant factors expressed as variables were observed more easily than in most "average" situations. Changes of variables do not come to surface since they are labeled as white noise or random behavior. We chronologically described the effects of the drought of '88 and the discovery of BSE in the US in 2003.

During the drought of 1988 we see that cash and futures prices of cattle feed ingredients rose significantly. It is obvious that other forces are active in the cattle supply chain, however the change of the feed price arguably dominated. Data and figures of feed prices and cattle supply showed a negative relationship in the short run (not in the long run). The dissimilar behavior of nearby and deferred futures prices of live cattle is in line with the expected live cattle price-supply response. In the short run, lower profit margins led to a greater supply of animals, which results in lower cattle prices. In the long run, we can expect supply to decrease, resulting in higher cattle prices

The detection of BSE in the United States had a major effect on slaughter prices of steers and heifers. Prices of feed ingredients responded significantly on the days after the announcement. Cash prices and futures prices of cattle products plummeted immediately after the announcement. Surprisingly we did not encounter large deviations in cattle supply, which makes it hard to draw conclusions on the supply relationship of cattle. We did not encounter significant changes in slaughter prices and feed ingredient prices. Furthermore, the price behavior of cattle futures suggests that lagged price reactions might occur, which is in line with the third time effect as mentioned in Section 1.4: Price changes of a futures contract (e.g. Live Cattle Oct 04), caused by one and the same market event, can lead to different price reactions, at different periods in time.

Besides checking the proposed cattle supply model, we gave the reader a good understanding how cattle futures prices behave. The case studies exhibited some real-life examples of the proposed time effects of futures contracts as mentioned earlier.

7. Conclusions and Recommendations

The main objective of our work was to assess, describe and where possible model the price behavior of cattle and cattle related futures contracts. The general conclusions and implications that emerge from our research are segregated from three perspectives: cattle futures contract properties, fundamental cattle relationships and extreme events.

Cattle futures contract properties

We assessed the cattle futures market from a fundamental and biological perspective, wherein we discovered and explained three time effects. The first time effect is an instantaneous price discrepancy. The price-behavior of a futures contract caused by one and the same market event, can lead to different price reactions, at different periods in time. The second time effect is the fundamental price discrepancy. Prices of futures contracts on different underlying assets in different stages of life behave differently at identical market events at the same time. The third effect describes a price discrepancy in different moments in time. Price-behavior of a futures contract caused by one and the same market event, can lead to different price reactions, at different periods in time. The three time effects strengthen our idea to focus on the fundamental characteristics and relationships that affect cattle supply. We realized that there is only one way to uncover the price behavior of cattle futures and cattle futures relationships: by revealing the biological sequence and fundamental details of cattle and cattle operations. Our findings alert practitioners to be cautious for three different time effects which influence prices of live cattle and feeder cattle futures. Moreover practitioners should be cautious in doing time-series analysis of futures contracts and treat every futures contract independently and individually.

Fundamental cattle relationships

Based on fundamental and biological details of beef-cattle we described the biological sequence of cattle and how cattle in different stages of their lives interrelate. We explained the underlying fundamentals and dynamics of cattle breeding, feeding and ultimately slaughtering. We showed that cattle production is a flow operation: output of one operation is input for the next one. The unexpected price behavior of cattle products is ascribed to the biological time lag and the “dual purpose” of cattle in its production process. Cattle are simultaneously used as consumption good, for beef production, and as a capital good, to replace future beef production. Four different stages in cattle production are distinguished and presented in a flow diagram. The cattle flow diagram forms the first main result of our research. Ultimately, the beef-cattle flow diagram forms the basis in specifying (economic) relations in cattle supply and cattle price behavior. We recommend practitioners to use the cattle flow diagram at the development of trading strategies of live cattle and feeder cattle futures.

Fluctuations in the supply of cattle categories arise from a number of measurable influences. We found evidence that there exist three important determinants of cattle supply: the price of corn, the price of cattle sold to the cattle buyer, and the number of animals available for replacement. By statistical analysis we select which lagged determinants are most relevant for specifying cattle supply. We developed a supply equation for every cattle category (steers, heifers, breeding cows and calves). First, we specified which variables provide the best explanation of cattle supply fluctuations. Secondly, we created supply equations for every cattle category. We examined, for each cattle category, which (lagged) variables provide significant explanation of cattle supply. Using U.S. price, supply and inventory data of cattle and corn in 1975-2005 we performed a stepwise regression procedure, on a set of supply equations for steers-, heifers-, cows- and calves-slaughter. The result is a set of supply equations which only include the variables that are most relevant for specifying cattle supply.

We find evidence of a short-run negative supply relationship for all animal cattle categories. This means that an increase in the price of slaughter animals would result in a decrease in the supply of slaughtered animals. When the price of slaughter cattle rises, producers are willing to retain animals to produce animals in the future, instead of slaughtering them instantaneously. We find that the short run negative supply relationship affects the total life cycle of cattle. Surprisingly also steers show a short-run negative supply relationship. We find mixed results for the dependency of corn to cattle supply. In line with our expectations corn is omitted from the calves supply equation (since calves are less dependent on feed prices, as calves are feed by their mothers and mainly fed by summer grass). Finally, we found evidence that the replacement inventory is positively related to the supply of cattle, for all animal categories. In the long run a positive supply response is less evident for all cattle categories. Our findings should alert practitioners to be cautious for the use of fundamental cattle price and supply data.

Extreme events

Finally, we link cash markets with futures market by performing two case studies. We perform two studies in which we qualitatively asses different extreme events in the cattle sector. We claim that during an extreme event a specific subset of factors arguably dominates. The dominant factors expressed as variables can then be easily measured. For example in most "average" situation, changes of variables do not come to surface since they are recognized as white noise or random behavior. The effect of an extreme event can be measured more efficiently. We described the effects of the drought of 1988 chronologically and the discovery of BSE in the US in 2003. Besides checking the proposed cattle supply model, the case studies exhibited some real-life examples of the proposed time effects of futures contracts. The findings of the case studies alert practitioners to be cautious for three time effects to be (simultaneously) active in the market.

Applications and recommendation for investment strategies

We provide some recommendations for the development of investment strategies. In the world of finance, correlation is a statistical measure how two securities move in relation to each other. We believe that it is necessary to recognize that different markets can be differently correlated under different circumstances. It is not unusual that under some circumstances two markets have the opposite correlation structure than normal. This understanding is of importance in the investors risk perception. As such, it is important to understand how to deal with changing correlations in changing markets. An example makes things clear. Assume the following conditions hold:

- There are 2 factors (A and B)
- There are 2 markets (M and N)
- Factor A is (almost) always active, for example the weather
- Factor B is sporadically active, for example a drought or disease
- Market M is positively influenced by factor A, as well as factor B
- Market N is positively influenced by factor A, and negatively by factor B

The question for an investor might be which positions he should take in both markets. He can decide to take a long position in market M and a short position in market N. We believe that an investors should get exposure to a particular factor, and not only to a specific market. In this case the best decision would be to take a long position in market M as well as market N. With this market combination you are only exposed to factor A and you totally reduced the risk to factor B, in case it occurs. The result from a risk management perspective is that you are less (not) sensitive for changing correlations between markets.

Recommendations for future research

In our research we focused on uncovering fundamental relationships in supply and demand in cattle commodities. We believe that our research results can be used by practitioners as a starting point for the development of commodity trading strategies. From the perspective of a researcher, risk manager or investor we think that it is crucial to understand the fundamental aspects and relationships of commodity price-, supply- and demand behavior. As a recommendation for future research we suggest to focus on the applications of the time effects and the discovered supply- demand- relationships in cattle commodity trading strategies. In the first place, our results can be used to discover whether a combination of different outright products (e.g. single live cattle futures contracts) can give exposure to different risks. A direction for future research is to discover which combinations of cattle and cattle related futures contracts can give exposure to some risk that is not discoverable in the outright product itself. It might be possible to capture certain type of risk in agricultural products by making combinations of outright future contracts. A combination of products in this sense can give a valuable addition to a portfolio as an investor is diversifying to different kinds of fundamental risks of that commodity (not only the price- risk of the outright future contract itself). As second, we recommend researchers to put not too much efforts in trying to predict market- or price behavior. More worthwhile for investors and risk managers is to find out which fundamental risks are encapsulated in certain financial products (e.g. a futures contract) and how it is possible to get more (less) exposure to different kind of risks encapsulated in the outright product itself or by making combinations of outright products. Finally, we recommend that commodity price research by itself should not only emphasize on short-term price analysis. For example by performing time-series analysis and econometric methods for analyzing financial market and price movements. We recommend that researchers together with practitioners (e.g. traders of those financial products) keep in mind the theory and (biological) fundamentals underlying a commodity price model.

References

Aadland, D., Bailey, D.V., 2001, *“Short-Run Supply Responses in the U.S. Beef-Cattle Industry"*, American Journal of Agricultural Economics, Vol. 83, pp. 826-39

Alexander, C.A., 2005, Market Models, A guide to financial data analysis, *John Wiley & Sons*, West Sussex, England

Beal, D.J., 2005, *“SAS Code to Select the Best Multiple Linear Regression Model for Multivariate Data Using Information Criteria”*, Proceedings of the 13th Annual Conference of the SouthEast SAS Users Group

Brooks, R.J., 1972, *“A Decision Theory Approach to Optimal Regression Designs”*, Biometrika, Vol. 59, pp. 563-571

Chicago Board of Trade, 2006, The Chicago Board of Trade Handbook of Futures & Options, *McGrawHill*, NewYork

Cook, E.R., Seager, R., Cane, M.A., Stahle D.W., 2007, *“North American drought: Reconstructions, causes, and consequences”*, Earth Science Reviews, Vol. 81, pp. 93-134

Draper, N.R., Smith, H., 1998, Applied regression analysis, 3rd edition, *John Wiley & Sons Inc.*, New York

Güvenen, O., W.C. Labys, and J.B. Lesourd, 1991, International Commodity Market Models,*Chapman and Hall*, London

Hylleberg, S., 1992, Modelling Seasonality, *Oxford University Press*, New York

Hull, J.C., 2006, Options, Futures and Other Derivatives, 6th edition, *Pearson Prentice Hall*, New Jersey

Jarvis, L.S., 1974, *“Cattle as capital goods and Ranchers as portfolio managers: An application to the Argentine Cattle sector”*, The Journal of Political Economy, Vol. 82, pp.489-520

Jin, H.J., Power, G.J., Elbakidze L., 2008, “*The Impact of North American BSE Events on Live Cattle Futures Prices”*, American Journal of Agricultural Economics, Vol. 90, pp. 1279-1286

Kenyon, D., Bainbridge, B., Ernst, R., 1991, *"Impact of cash settlement on feeder cattle basis"*, Western Journal of Agricultural Economics, Vol. 16, pp. 93-105

Kuchler, F., Tegene A., 2006, *"Did BSE announcements reduce beef purchases?"*, Economic Research Report No. 34, Economic Research Service of the USDA, Washington, D.C.

Labys, W.J., Pollak, P.G., 1984, Commodity Models for Forecasting and Policy Analysis, *Croom Helm*, London

Lord, M.J., 1991, Imperfect competition and international commodity trade: Theory, Dynamics and policy modeling, *Clarendon Press*, Oxford, U.K.

Palmer, W.C., 1965, *"Meteorological drought"*, Research Paper No. 45, Office of Climatology, U.S. Weather Bureau, Washington, D.C.

Peel, D. Meyer, S., 2002, "*Cattle price seasonality"*, Managing for today's cattle market and beyond, Research Paper The University of Arizona

Smith, A., 2005, *"Partially overlapping time series: A new model for volatility dynamics in commodity futures"*, Journal of Applied Econometrics, Vol. 20, pp. 405-422

Sen, A., Srivastava, M., 1990, Regression Analysis, theory, methods, and applications, *Springer-Verlag*, NewYork

Websites

http://www.agcensus.usda.gov, USDA, the Census of Agriculture 2007, released on 4th of February 2009

http://www.ers.usda.gov/briefing/cattle/Background.htm, USDA, Economic Research Service, 21st of September 2009

http://www.agmanager.info/farmmgt/income/enterprise/2007, studies conducted at Kansas State University, Department of Agricultural Economics, 21st of September 2009

Appendix A Short run futures price behavior

A1 Introduction

We aim to give a clear understanding how futures prices behave concurrently. In Chapter 1 we described that for agricultural commodities more than one contract is actively traded every moment in time. Every futures contract should be treated individually since the underlying commodity of the contract is delivered at a different moment in time. The aim of this chapter is to give the reader a better understanding of the price behavior of agricultural futures contracts. In this chapter we assess the price behavior of futures contracts in the short-run (at the same moment in time). We question whether related prices of futures contracts show common movements at the same moment in time. We elaborate on time effect 1: prices of futures contracts with the same underlying asset but with different delivery months (e.g. live cattle future October 2009 vs. live cattle future December 2009), can react differently to the same news event, at the same time. We compare causal relations in price movements of futures contracts in the short run (on the same day).

A2 Research method

To examine price behavior of futures contracts we create a 3-step research method. Of great importance is that every future contract itself is treated independently. For example, we treat Live Cattle Jul 09 separately and in parallel with Live Cattle Aug 09. In addition to Live Cattle futures contracts, we aim to assess the cattle related commodities contracts feeder cattle, corn and soybean meal.

Research Steps:

1) Stage identification

A live cattle futures contract starts trading 18 months prior to the moment of physical delivery of the underlying. Prior to analyzing different contracts, we classify stages in the contract, since prices might react differently, in different phases during the life of a contract. Later on, it helps us to give a good comparison basis to compare contracts in the same stages of its life's. We create our own indicators to recognize different stages.

2) Identification of significant price movements

We can examine price behavior by evaluating every price-movement at every moment in time. Another way is to only focus on special market events, for example when extreme price movements show up. By focusing on extreme cases (significant price movements) we try to filter for "noise" or "random behavior" of a contract. To identify significant price movements, we first create our own criteria of such a price-movement.

3) Assessment of contracts using the stages of life

Step 1 resulted in predefined stages of futures contracts and Step 2 identifies a significant price movement. In this last step we identify whether prices of different futures contracts move together.

We show whether common movements in prices of related commodities tend to appear. We trace which futures contracts (with a different delivery month) appear to show similar co-movements with other futures contracts (with another delivery month). We measure the existence of causal relations between the price-behavior of different futures contracts at the same moment in time.

A3 Stage Identification

Our notion exists that futures contracts tend to behave differently in different stages of their life. Let us make things clear with an example. When a new futures contract becomes active, none or only a few participant will enter the contract.

Figure 37 shows three indicators of a live cattle futures contract: price, volume and open interest. Volume indicates the number of contracts traded during one day. Open Interest is the number of open contracts of a given future or option contract. An open contract can be a long or short contract that has not been exercised, closed out, or allowed to expire. In the first months a contract is active, most futures contracts have low volume and low open interest. Apparently only a small number of market participants are into the market. You can imagine that a contract behaves differently in the first stage of life of a contract. During this first period, which is characterized by low liquidity, prices are set by only a few market participants.

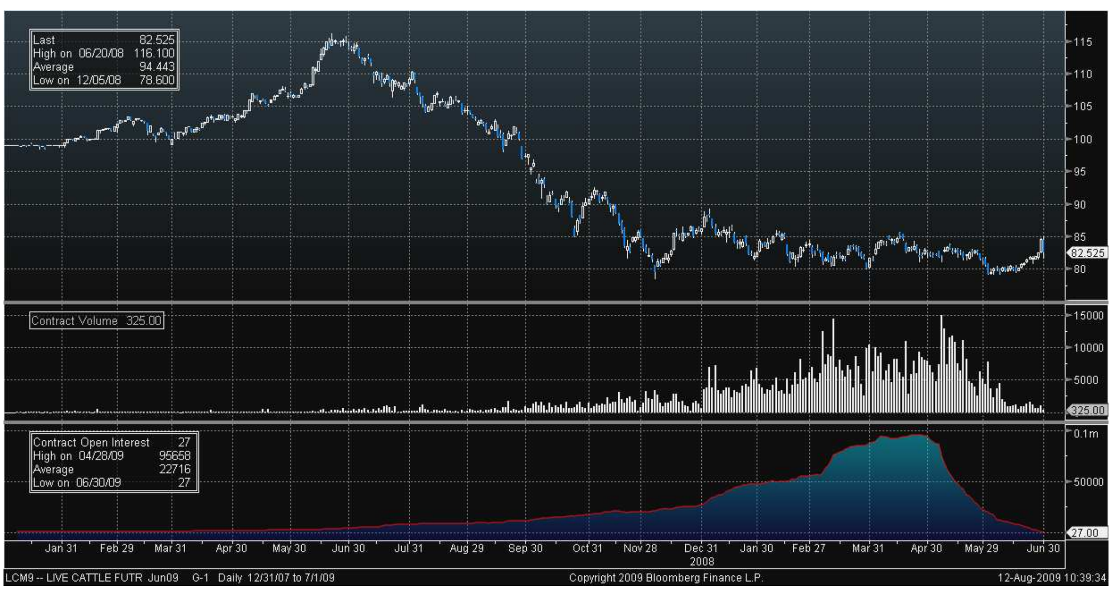


Figure 37:Prices, volume and open interest during full life time of Live Cattle June 09
Source: Bloomberg

Liquidity Indicator

Based on long term- and large changes in volume in combination with changes in open interest (and number of trades) we determine in which periods a contract is "actively traded". We create the indicator to measure whether the contract is actively traded and observe whether settlements appear as an overall market-equilibrium or prices appear out of one-time trades.

Two variables that are of particular interest to measure the liquidity of a futures contract are volume and open interest. Volume is the number of futures contracts traded during a specified period of time, usually one trading session. One buy and one sell equals a volume of one. Open interest is the total number of futures contracts outstanding in the market. In other words it represent the number of contracts that have not yet been offset or fulfilled by delivery. It is an indicator of the depth or liquidity of a futures market, which influences the ability to buy or sell at or near a given price. In our liquidity indicator we label every day whether a futures contract is "active" or "inactive". We consider a contract to be "active" when the contract is traded actively and of which price movements are established by a substantial number of market participants. We consider a contract to be actively traded when a contract is traded for a longer period of time, with continuous high volumes and with a substantial and increasing level of open interest. We consider a contract to be "inactive" when it is not traded regularly and prices are set by the exchange itself or by a small number of market participants. We select the following criteria for a futures contract to be labeled as "actively traded".

Indicator / Label	Characteristic
Volume	1. We measure at time t, the maximum daily volume (Vol_{max}) of all contracts with the same underlying commodity that are traded in the market. 2. We calculate the average trading volume of a contract during its last 10 trading days = $AvgVol_t$ 3. We choose an average-volume-threshold level : $\tau_{vol} = 10\%$
Open Interest	1. We measure, at time t, the open interest (with t in days). 2. We choose a threshold level for open interest : $\varphi_{oi} = 500$
Label = InActive **Label = Active**	A contract has the label ***"InActive"*** in beginning A contract can receive the label **"Active"** when: $AvgVol_t > \tau_{vol} \cdot Vol_{max}$ **AND** $OI_t > \varphi_{oi}$ $AvgVol_t > 0{,}10 \cdot Vol_{max}$ **AND** $OI_t > 500$

A4 Significant Price Movements

To identify significant price movements we use a “limit-move” as a criteria for a movement to be labeled as “significant”. For every futures contract traded, the exchange sets a largest amount of change that the price of a commodity futures contract is allowed to undergo. During that trading day, it is not possible to trade a futures contract at a price either above or below the futures contract price after a limit move. The limit price is set by the exchange on which the futures contract trades. Limits are set in place to limit the risk (volatility) in futures price movements. Limit moves can be either up or down and limits are changed over time by the exchange.

For example assume that a Live Cattle futures contract is selling for $0,80 per pound, and has a limit of $0,03 per pound. This means that the contract is not allowed to move $.03 per pound above or below the previous day's settlement price. If a cattle decease drastically reduces the supply of cattle, the futures price will rise to the $3 cents limit level ($ 83 cents), not higher. We label every price movement that is signaled as a limit-move as significant. We measure two different limit-moves: limit-up and limit-down.

A5 Assessment of futures contracts

First we created a fair comparison basis with the liquidity criterion. After that we set a definition for a significant price movement. Now it is time to assess whether common price movements of related commodities futures contracts tend to appear. We only assess those futures contracts that are in the same, liquid stage of life and are actively traded. We focus on intra-market price movements, wherein we assess co-movements of futures contracts with the *same* underlying commodity although with a *different* delivery months.

Intra-market co-movement

Live Cattle Apr 08 is selling for $90 cents per pound at the 3rd of January. We signal a significant price increase at the 4th of January in the mentioned contract. At the same date the Live Cattle June 08 and Live Cattle Oct 08 show a significant price increase. The other actively traded contracts, Live Cattle Aug 08 and Live Cattle Dec 08, did not make a limit move that day. Apparently there are three contracts which show co-movements. We trace which futures contracts show common movements at significant price movements at the same moment in time. The focus lies on co-movement of the *different* delivery months.

With the use of this analysis we trace which futures contracts show common movements at significant price movements at the same moment in time. The focus lies on price-relations of the different delivery months and a different underlying commodity.

Measurement and analysis

We use the daily futures contracts price data of Live Cattle, from 1965 until April 2009. First we calculate at every trading day, using the mentioned liquidity criterion, whether a contract is “active”. Subsequently we calculate for every “active” contract, at every trading day, whether a significant price change appeared.

The exchange changed its limit-move criterion several times, during 1965-2009. We make sure to use the appropriate price-limit in that period. We also keep track whether a movement is limit-up (in case of a positive price change) or limit-down (in case of a negative price change). Finally, we calculate in which fraction of times each contract month moves significantly, under the condition that the February contract shows an extreme price movement. Of course we perform the calculation for all contract months and for several different underlying commodities.

Results

The following graphs show statistics of the behavior of live cattle futures in the period 1960-2009. Since the reader might find it difficult to interpret the graph, we give some information how to interpret the graphs. The y-axis shows the fraction of active contracts which move concurrently with another contract. (the conditional contract) The bars represent the conditional contract months of live cattle contracts. The x-axis refers to the contract which moves in comparison with the conditional month (represented by the bar). An example makes everything clear. Consider the most left bar. The graph indicates that the conditional contract month is labeled as February, the fraction of contracts that move up is 47% and the contract that moves signals 2 months. In other words, in 47% of the times that a Live Cattle February contract shows a significant price movement up, the April contract shows a significant price increase. Consider the December bar at 4 months: conditional on a significant price increase of a December Live Cattle futures contract, the April futures contracts moves up concurrently. We perform the same analysis for live cattle, feeder cattle and corn futures in the period 1965 – 2009.

The graphs show that cattle futures are heavily influenced by the nearby contract months. This is in contrast with corn futures. Corn futures are far most affected by the December futures contract. The December futures contract seems to heavily influence other cattle series. The main reason is that this contract applies to the first new crop month.

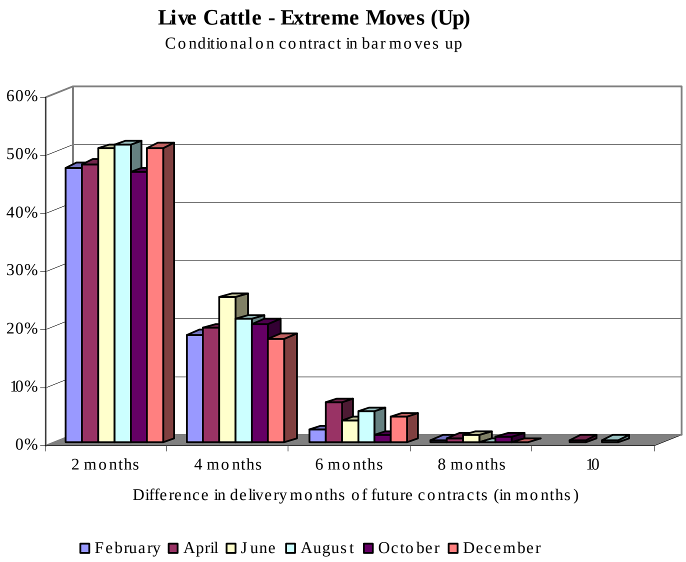


Figure 38: Live Cattle futures behavior 1960-2009
Source: Transtrend

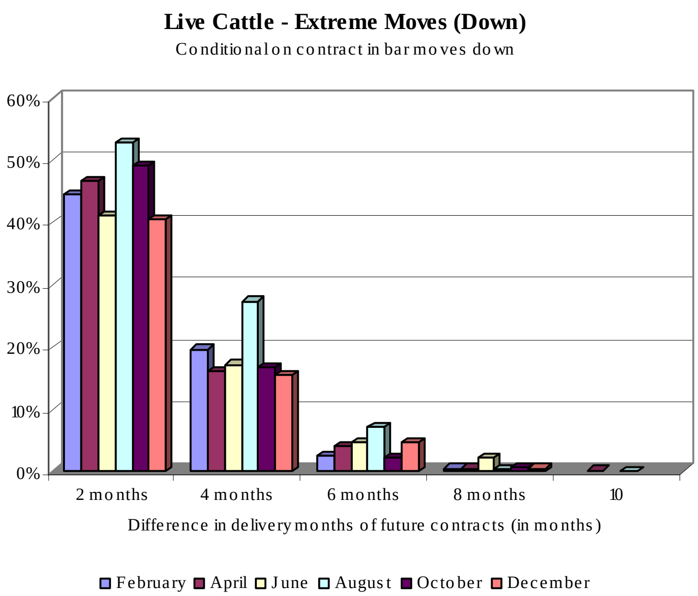
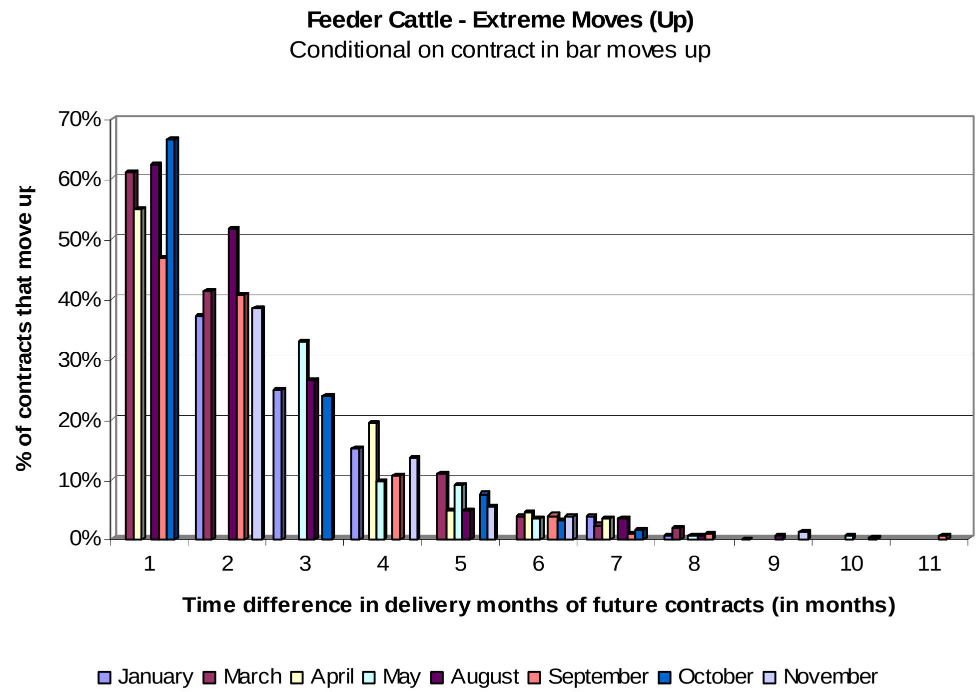
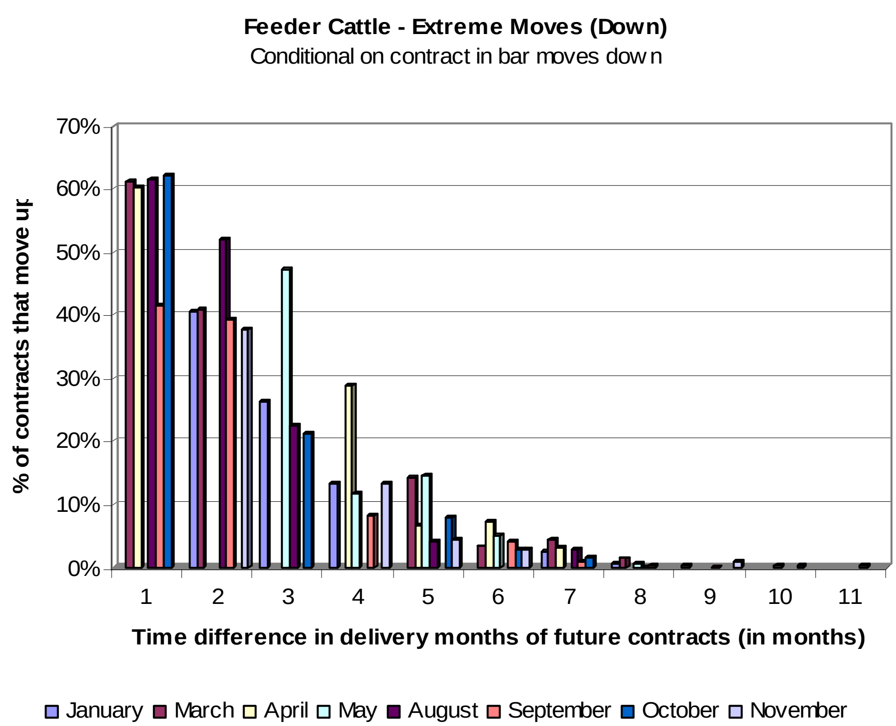


Figure 39: Live Cattle futures behavior 1960-2009
Source: Transtrend


Feeder Cattle - Extreme Moves (Up)
Conditional on contract in bar moves up
70%
60%
50%
40%
30%
20%
10%
0%
% of contracts that move up
1
2
3
4
5
6
7
8
9
10
11
Time difference in delivery months of future contracts (in months)
January March April May August September October November


Feeder Cattle - Extreme Moves (Down)
Conditional on contract in bar moves down
70%
60%
50%
40%
30%
20%
10%
0%
% of contracts that move up
1
2
3
4
5
6
7
8
9
10
11
Time difference in delivery months of future contracts (in months)
January March April May August September October November

Appendix B Fundamental cattle flow diagram

Figure 40: Flow diagram of beef cattle production in the U.S.

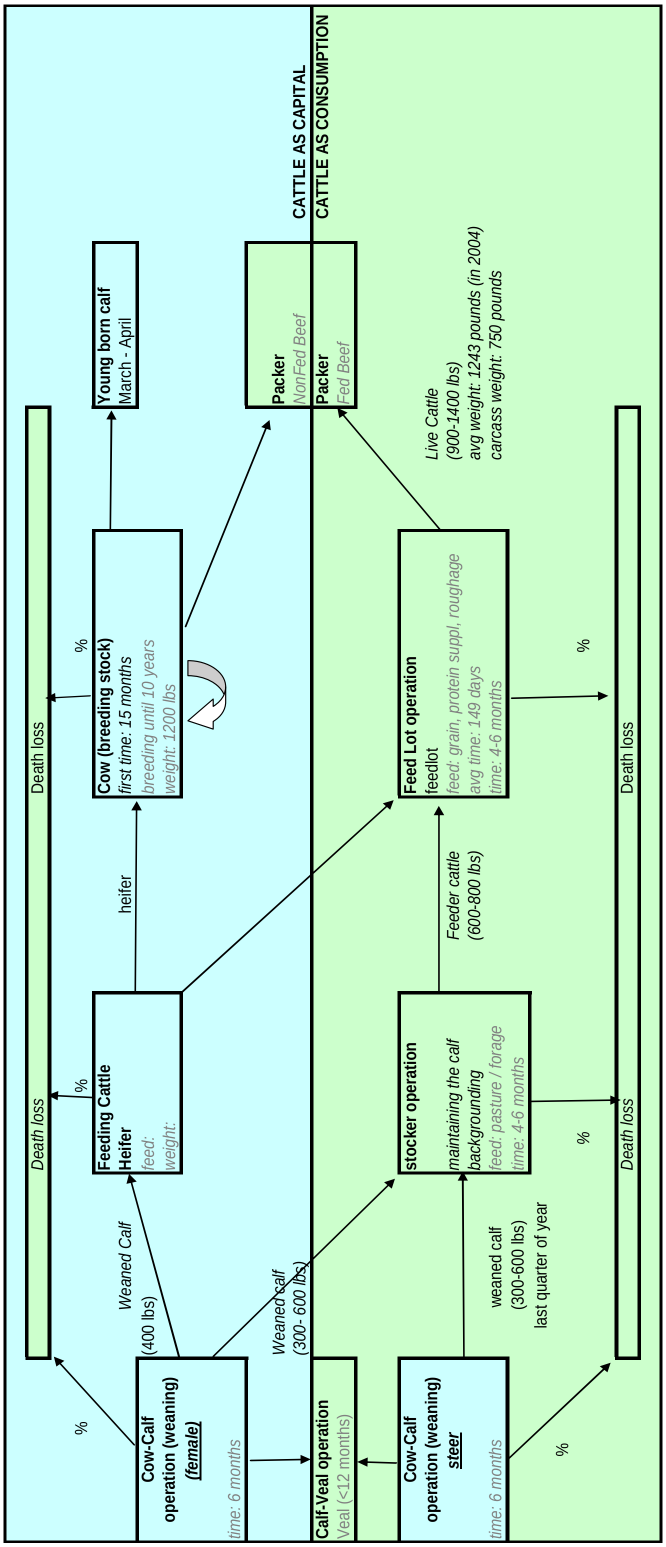
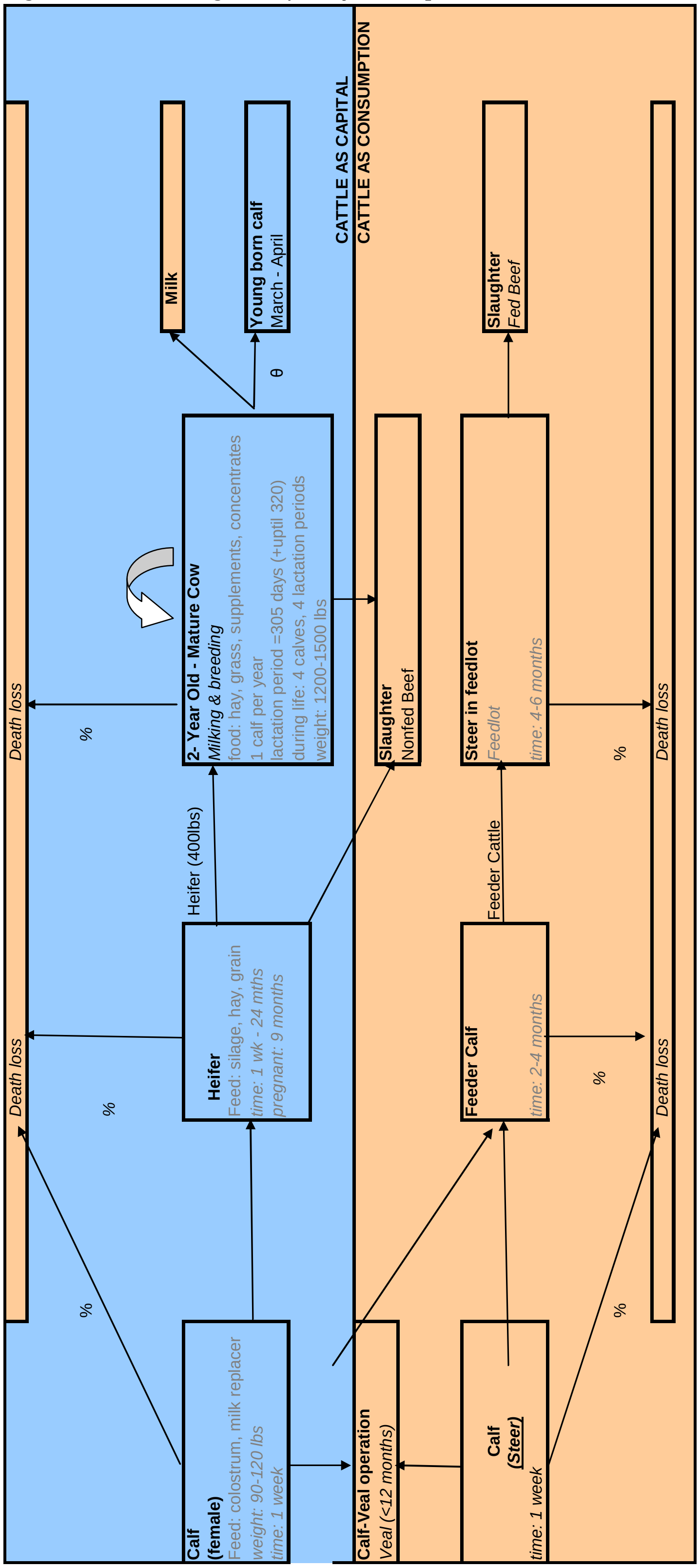


Figure 41: Flow diagram of dairy cattle production in the U.S.



Appendix C Backward elimination - Multiple Regression – Step 1

Results after performing the first step of the backward elimination to our multiple regression equations are presented in tabular formula on the next two pages. We present the results per animal category at three different time scales (quarterly, semi-annually and annually). As an example the results in the upper left corner represent the results of performing a regression estimation on equation (1A) of Chapter 4:

1a)
$$SStr_t = \alpha_0 + \sum_{i=0}^{i=4} \alpha_{1,3i} PSStr_{t-3i} + \sum_{i=0}^{i=4} \alpha_{2,3i} PCrn_{t-3i}$$

Which is the same as:

$$SStr_t = \alpha_0 + \alpha_{1,0}PSStr_{t-0} + \alpha_{1,3}PSStr_{t-3} + \alpha_{1,6}PSStr_{t-6} + \alpha_{1,9}PSStr_{t-9} + \alpha_{1,12}PSStr_{t-12} + \alpha_{2,0}PCrn_{t-0} + \alpha_{2,3}PCrn_{t-3} + \alpha_{2,6}PCrn_{t-6} + \alpha_{2,9}PCrn_{t-9} + \alpha_{2,12}PCrn_{t-12}$$

Via OLS procedure performed in SAS on historical cattle data we estimate the unknown parameters (α_0, $\alpha_{1,0}$,…, $\alpha_{1,12}$, $\alpha_{2,0}$,…, $\alpha_{2,12}$).

Table 3: OLS Regression Results-Summary

OLS Regression Results - Summary

STEERS - Quarterly

Parameter $\alpha_{variable,time\ lag}$	Param	T-stat
$\alpha_{0,0}$	3,564,545	27.78
$\alpha_{1,0}$	15,374-	3.34-
$\alpha_{1,3}$	2,696-	0.50-
$\alpha_{1,6}$	12,185	2.31
$\alpha_{1,9}$	3,072	0.57
$\alpha_{1,12}$	4,011	0.88
$\alpha_{2,0}$	89,452-	1.14-
$\alpha_{2,3}$	148,570	1.32
$\alpha_{2,6}$	91,802-	0.80-
$\alpha_{2,9}$	101,413-	0.89-
$\alpha_{2,12}$	20,997-	0.27-
Sample size (n)	138	
Adjusted -R^2	0.15	

STEERS - Semi-Annual

Parameter $\alpha_{variable,time\ lag}$	Param	T-stat
$\alpha_{0,0}$	4,136,965	1.56
$\alpha_{1,0}$	8,483-	0.77-
$\alpha_{1,6}$	16,537-	1.36-
$\alpha_{1,12}$	8,211	0.67
$\alpha_{1,18}$	29,127	2.74
$\alpha_{2,0}$	50,024-	0.37-
$\alpha_{2,6}$	225,029-	1.47-
$\alpha_{2,12}$	146,222-	0.97-
$\alpha_{2,18}$	257,862-	1.83-
$\alpha_{3,0}$	103	0.77
$\alpha_{3,6}$	45-	0.34-
$\alpha_{3,12}$	53	0.40
$\alpha_{3,18}$	93	0.64
Sample size (n)	63	
Adjusted -R^2	0.21	

STEERS - Annual

Parameter $\alpha_{variable,time\ lag}$	Param	T-stat
$\alpha_{0,0}$	763,116-	0.25-
$\alpha_{1,0}$	11,867-	0.61-
$\alpha_{1,12}$	8	0.00
$\alpha_{1,24}$	26,963	1.34
$\alpha_{2,0}$	310,039-	1.02-
$\alpha_{2,12}$	506,799-	1.67-
$\alpha_{2,24}$	208,574-	0.81-
$\alpha_{3,0}$	169	0.77
$\alpha_{3,12}$	442	1.51
$\alpha_{3,24}$	319	1.36
Sample size (n)	32	
Adjusted -R^2	0.50	

HEIFERS - Quarterly

Parameter $\beta_{variable,time\ lag}$	Param	T-stat
$\beta_{0,0}$	1,248,679.19	10.28
$\beta_{1,0}$	2,918.42-	0.63-
$\beta_{1,3}$	1,762.29-	0.34-
$\beta_{1,6}$	10,468.48	2.03
$\beta_{1,9}$	3,183.38	0.61
$\beta_{1,12}$	1,542.96	0.34
$\beta_{2,0}$	169,237.46-	2.19-
$\beta_{2,3}$	74,123.48	0.67
$\beta_{2,6}$	26,890.89-	0.24-
$\beta_{2,9}$	26,363.62-	0.23-
$\beta_{2,12}$	83,228.84	1.08
Sample size (n)	138	
Adjusted -R^2	0.28	

HEIFERS - Semi-Annual

Parameter $\beta_{variable,time\ lag}$	Param	T-stat
$\beta_{0,0}$	794,039-	1.70-
$\beta_{1,0}$	4,181-	0.61-
$\beta_{1,6}$	13,312	1.82
$\beta_{1,12}$	10,522-	1.41-
$\beta_{1,18}$	7,841	1.41
$\beta\alpha_{2,0}$	143,608-	1.81-
$\beta_{2,6}$	5,812-	0.07-
$\beta_{2,12}$	184,209-	2.17-
$\beta_{2,18}$	88,603	1.17
$\beta_{3,0}$	170	1.56
$\beta_{3,6}$	247	2.02
$\beta_{3,12}$	142	1.26
$\beta_{3,18}$	2-	0.02-
Sample size (n)	63	
Adjusted -R^2	0.79	

HEIFERS - Annual

Parameter $\beta_{variable,time\ lag}$	Param	T-stat
$\beta_{0,0}$	1,263,872	1.77
$\beta_{1,0}$	13,764	0.91
$\beta_{1,12}$	5,353-	0.32-
$\beta_{1,24}$	7,580-	0.56-
$\beta_{2,0}$	359,442-	1.90-
$\beta_{2,12}$	129,339-	0.72-
$\beta_{2,24}$	351,203	2.06
$\beta_{3,0}$	78-	0.35-
$\beta_{3,12}$	672	2.27
$\beta_{3,24}$	123	0.51
Sample size (n)	32	
Adjusted -R^2	0.86	

COWS-Quarterly

Parameter $\gamma_{variable,time\ lag}$	Param	T-stat
$\gamma_{0,0}$	914,487	14.37
$\gamma_{1,0}$	1,209-	0.46-
$\gamma_{1,3}$	4,162-	1.29-
$\gamma_{1,6}$	4,183	1.33
$\gamma_{1,9}$	3,300	1.05
$\gamma_{1,12}$	10,931-	4.25-
$\gamma_{2,0}$	14,554	0.36
$\gamma_{2,3}$	29,507-	0.51-
$\gamma_{2,6}$	92,695	1.55
$\gamma_{2,9}$	2,639-	0.04-
$\gamma_{2,12}$	75,402	1.87
Sample size (n)	138	
Adjusted -R^2	0.48	

COWS - Semi-Annual

Parameter $\gamma_{variable,time\ lag}$	Param	T-stat
$\gamma_{0,0}$	750,969	1.35
$\gamma_{1,0}$	2,333	0.53
$\gamma_{1,6}$	7,849-	1.51-
$\gamma_{1,12}$	5,089-	0.95-
$\gamma_{1,18}$	4,189	0.93
$\gamma_{2,0}$	58,409-	1.09-
$\gamma_{2,6}$	61,285	1.02
$\gamma_{2,12}$	22,258	0.37
$\gamma_{2,18}$	67,271-	1.23-
$\gamma_{3,0}$	160-	4.98-
$\gamma_{3,6}$	135	3.35
$\gamma_{3,12}$	69	1.73
$\gamma_{3,18}$	69	1.73
Sample size (n)	63	
Adjusted -R^2	0.78	

COWS - Annual

Parameter $\gamma_{variable,time\ lag}$	Param	T-stat
$\gamma_{0,0}$	115,794	0.08
$\gamma_{1,0}$	4,983	0.56
$\gamma_{1,12}$	19,959-	1.95-
$\gamma_{1,24}$	14,546	1.41
$\gamma_{2,0}$	134,299-	0.96-
$\gamma_{2,12}$	270,941	1.92
$\gamma_{2,24}$	120,835-	0.93-
$\gamma_{3,0}$	193-	2.85-
$\gamma_{3,12}$	225	2.06
$\gamma_{3,24}$	64	0.95
Sample size (n)	32	
Adjusted -R^2	0.79	

CALVES - Quarterly

Parameter $\mu_{variable,time\ lag}$	Param	T-stat
$\mu_{0,0}$	270,187.98	15.02
$\mu_{1,0}$	520.58-	1.86-
$\mu_{1,3}$	657.66-	1.87-
$\mu_{1,6}$	469.06-	1.33-
$\mu_{1,9}$	94.54	0.27
$\mu_{1,12}$	570.56-	2.21-
$\mu_{2,0}$	2,770.84	0.40
$\mu_{2,3}$	2,071.10-	0.21-
$\mu_{2,6}$	5,869.96	0.60
$\mu_{2,9}$	4,275.14	0.44
$\mu_{2,12}$	6,173.54-	0.86-
Sample size (n)	138	
Adjusted -R^2	0.79	

CALVES - Semi-Annual

Parameter $\mu_{variable,time\ lag}$	Param	T-stat
$\mu_{0,0}$	257,136	3.60
$\mu_{1,0}$	2,091-	4.59-
$\mu_{1,6}$	906-	1.54-
$\mu_{1,12}$	1,065	2.00
$\mu_{1,18}$	38-	0.07-
$\mu_{2,0}$	13,962-	1.31-
$\mu_{2,6}$	4,728	0.42
$\mu_{2,12}$	9,986-	0.91-
$\mu_{2,18}$	5,172-	0.54-
$\mu_{3,0}$	8-	1.56-
$\mu_{3,6}$	10-	1.75-
$\mu_{3,12}$	11	1.89
$\mu_{3,18}$	13	2.12
Sample size (n)	63	
Adjusted -R^2	0.92	

CALVES - Annual

Parameter $\mu_{variable,time\ lag}$	Param	T-stat
$\mu_{0,0}$	601,695	4.76
$\mu_{1,0}$	4,219-	5.26-
$\mu_{1,12}$	331	0.37
$\mu_{1,24}$	3-	0.00-
$\mu_{2,0}$	40,638-	2.49-
$\mu_{2,12}$	1,310-	0.07-
$\mu_{2,24}$	22,928-	1.55-
$\mu_{3,0}$	22-	2.05-
$\mu_{3,12}$	11	0.57
$\mu_{3,24}$	21	1.82
Sample size (n)	32	
Adjusted -R^2	0.96	

Table 4: OLS Regression results, Delta – Supply equations

OLS Delta Regression Results - Summary

STEERS - Quarterly

Parameter $\alpha_{\text{variable,time lag}}$	*Param*	*T-stat*
$\Delta\alpha_{1,0}$	0.39-	6.14-
$\Delta\alpha_{1,3}$	0.14-	2.20-
$\Delta\alpha_{1,6}$	0.06	0.88
$\Delta\alpha_{1,9}$	0.05	0.77
$\Delta\alpha_{1,12}$	0.09-	1.42-
$\Delta\alpha_{2,0}$	0.03	0.76
$\Delta\alpha_{2,3}$	0.07	1.69
$\Delta\alpha_{2,6}$	0.03-	0.69-
$\Delta\alpha_{2,9}$	0.09-	1.96-
$\Delta\alpha_{2,12}$	0.04	0.85
Sample size (n)	138	
Adjusted -R^2	0.31	

STEERS - Semi-Annual

Parameter $\alpha_{\text{variable,time lag}}$	*Param*	*T-stat*
$\Delta\alpha_{1,0}$	0.16-	3.77-
$\Delta\alpha_{1,6}$	0.20-	4.45-
$\Delta\alpha_{1,12}$	0.03-	0.72-
$\Delta\alpha_{1,18}$	0.06	1.42
$\Delta\alpha_{2,0}$	0.06	2.59
$\Delta\alpha_{2,6}$	0.04-	1.59-
$\Delta\alpha_{2,12}$	0.03-	1.17-
$\Delta\alpha_{2,18}$	0.07-	2.98-
$\Delta\alpha_{3,0}$	0.49	3.25
$\Delta\alpha_{3,6}$	0.20-	1.18-
$\Delta\alpha_{3,12}$	0.31-	1.84-
$\Delta\alpha_{3,18}$	0.15	0.96
Sample size (n)	62	
Adjusted -R^2	0.63	

STEERS - Annual

Parameter $\alpha_{\text{variable,time lag}}$	*Param*	*T-stat*
$\Delta\alpha_{1,0}$	0.17-	1.95-
$\Delta\alpha_{1,12}$	0.05-	0.56-
$\Delta\alpha_{1,24}$	0.07-	0.82-
$\Delta\alpha_{2,0}$	0.00	0.03
$\Delta\alpha_{2,12}$	0.00	0.06
$\Delta\alpha_{2,24}$	0.01-	0.17-
$\Delta\alpha_{3,0}$	0.05-	0.20-
$\Delta\alpha_{3,12}$	0.30	1.00
$\Delta\alpha_{3,24}$	0.35-	1.19-
Sample size (n)	32	
Adjusted -R^2	0.12	

HEIFERS - Quarterly

Parameter $\beta_{\text{variable,time lag}}$	*Param*	*T-stat*
$\Delta\beta_{1,0}$	0.29-	4.26-
$\Delta\beta_{1,3}$	0.05-	0.72-
$\Delta\beta_{1,6}$	0.22	3.16
$\Delta\beta_{1,9}$	0.01	0.13
$\Delta\beta_{1,12}$	0.18-	2.62-
$\Delta\beta_{2,0}$	0.09-	1.82-
$\Delta\beta_{2,3}$	0.08	1.78
$\Delta\beta_{2,6}$	0.02-	0.49-
$\Delta\beta_{2,9}$	0.00-	0.06-
$\Delta\beta_{2,12}$	0.06-	1.25-
Sample size (n)	138	
Adjusted -R^2	0.36	

HEIFERS - Semi-Annual

Parameter $\beta_{\text{variable,time lag}}$	*Param*	*T-stat*
$\Delta\beta_{1,0}$	0.27-	2.91-
$\Delta\beta_{1,6}$	0.19	1.92
$\Delta\beta_{1,12}$	0.19-	1.91-
$\Delta\beta_{1,18}$	0.14	1.71
$\Delta\beta\alpha_{2,0}$	0.03-	0.63-
$\Delta\beta_{2,6}$	0.05	1.09
$\Delta\beta_{2,12}$	0.11-	2.21-
$\Delta\beta_{2,18}$	0.15	3.29
$\Delta\beta_{3,0}$	0.26	1.20
$\Delta\beta_{3,6}$	0.36	1.53
$\Delta\beta_{3,12}$	0.08	0.34
$\Delta\beta_{3,18}$	0.23-	0.95-
Sample size (n)	62	
Adjusted -R^2	0.52	

HEIFERS - Annual

Parameter $\beta_{\text{variable,time lag}}$	*Param*	*T-stat*
$\Delta\beta_{1,0}$	0.05-	0.47-
$\Delta\beta_{1,12}$	0.11-	1.06-
$\Delta\beta_{1,24}$	0.13-	1.50-
$\Delta\beta_{2,0}$	0.02-	0.60-
$\Delta\beta_{2,12}$	0.00-	0.11-
$\Delta\beta_{2,24}$	0.12	2.77
$\Delta\beta_{3,0}$	0.18	0.82
$\Delta\beta_{3,12}$	0.59	2.71
$\Delta\beta_{3,24}$	0.12-	0.54-
Sample size (n)	32	
Adjusted -R^2	0.86	

COWS-Quarterly

Parameter $\gamma_{\text{variable,time lag}}$	*Param*	*T-stat*
$\Delta\gamma_{1,0}$	0.34-	4.28-
$\Delta\gamma_{1,3}$	0.27-	3.73-
$\Delta\gamma_{1,6}$	0.07	0.98
$\Delta\gamma_{1,9}$	0.09	1.33
$\Delta\gamma_{1,12}$	0.39-	5.00-
$\Delta\gamma_{2,0}$	0.06	0.97
$\Delta\gamma_{2,3}$	0.07-	1.06-
$\Delta\gamma_{2,6}$	0.06	0.90
$\Delta\gamma_{2,9}$	0.11	1.67
$\Delta\gamma_{2,12}$	0.04-	0.59-
Sample size (n)	138	
Adjusted -R^2	0.46	

COWS - Semi-Annual

Parameter $\gamma_{\text{variable,time lag}}$	*Param*	*T-stat*
$\Delta\gamma_{1,0}$	0.07-	0.80-
$\Delta\gamma_{1,6}$	0.08-	1.03-
$\Delta\gamma_{1,12}$	0.27-	3.31-
$\Delta\gamma_{1,18}$	0.01-	0.12-
$\Delta\gamma_{2,0}$	0.01	0.12
$\Delta\gamma_{2,6}$	0.09	1.41
$\Delta\gamma_{2,12}$	0.05	0.85
$\Delta\gamma_{2,18}$	0.01-	0.14-
$\Delta\gamma_{3,0}$	1.12-	1.71-
$\Delta\gamma_{3,6}$	1.40	2.27
$\Delta\gamma_{3,12}$	0.49	0.75
$\Delta\gamma_{3,18}$	0.24	0.37
Sample size (n)	62	
Adjusted -R^2	0.59	

COWS - Annual

Parameter $\gamma_{\text{variable,time lag}}$	*Param*	*T-stat*
$\Delta\gamma_{1,0}$	0.10	1.40
$\Delta\gamma_{1,12}$	0.26-	3.70-
$\Delta\gamma_{1,24}$	0.15	1.82
$\Delta\gamma_{2,0}$	0.10-	1.47-
$\Delta\gamma_{2,12}$	0.18	2.94
$\Delta\gamma_{2,24}$	0.07-	1.05-
$\Delta\gamma_{3,0}$	0.03-	0.05-
$\Delta\gamma_{3,12}$	0.21	0.30
$\Delta\gamma_{3,24}$	2.07	2.76
Sample size (n)	32	
Adjusted -R^2	0.95	

CALVES - Quarterly

Parameter $\mu_{\text{variable,time lag}}$	*Param*	*T-stat*
$\Delta\mu_{1,0}$	0.26-	2.63-
$\Delta\mu_{1,3}$	0.46-	5.02-
$\Delta\mu_{1,6}$	0.06-	0.70-
$\Delta\mu_{1,9}$	0.05	0.59
$\Delta\mu_{1,12}$	0.08	0.91
$\Delta\mu_{2,0}$	0.02	0.30
$\Delta\mu_{2,3}$	0.01-	0.17-
$\Delta\mu_{2,6}$	0.06	0.85
$\Delta\mu_{2,9}$	0.08	1.20
$\Delta\mu_{2,12}$	0.13-	1.82-
Sample size (n)	138	
Adjusted -R^2	0.31	

CALVES - Semi-Annual

Parameter $\mu_{\text{variable,time lag}}$	*Param*	*T-stat*
$\Delta\mu_{1,0}$	0.35-	3.46-
$\Delta\mu_{1,6}$	0.49-	4.37-
$\Delta\mu_{1,12}$	0.12-	0.82-
$\Delta\mu_{1,18}$	0.16-	1.30-
$\Delta\mu_{2,0}$	0.04	0.67
$\Delta\mu_{2,6}$	0.17	2.83
$\Delta\mu_{2,12}$	0.03-	0.39-
$\Delta\mu_{2,18}$	0.03-	0.49-
$\Delta\mu_{3,0}$	0.06-	0.14-
$\Delta\mu_{3,6}$	0.12-	0.28-
$\Delta\mu_{3,12}$	0.11-	0.19-
$\Delta\mu_{3,18}$	0.05	0.11
Sample size (n)	62	
Adjusted -R^2	0.66	

CALVES - Annual

Parameter $\mu_{\text{variable,time lag}}$	*Param*	*T-stat*
$\Delta\mu_{1,0}$	0.55-	5.21-
$\Delta\mu_{1,12}$	0.02-	0.12-
$\Delta\mu_{1,24}$	0.06-	0.37-
$\Delta\mu_{2,0}$	0.17-	2.20-
$\Delta\mu_{2,12}$	0.04	0.50
$\Delta\mu_{2,24}$	0.08-	1.32-
$\Delta\mu_{3,0}$	1.17-	2.13-
$\Delta\mu_{3,12}$	1.08	1.39
$\Delta\mu_{3,24}$	0.52	0.87
Sample size (n)	32	
Adjusted -R^2	0.85	

Appendix D Summary Results after backward elimination – Step 2

The next pages show the results of the OLS estimation procedure after backward elimination. As example the table in the upper-left corner of Table 5 gives the same estimation results, after rounding, of the parameters of the steers quarterly supply equation as presented on page 52, including its t-statistics, number of observations and the R-squared:

$$SStr_t = 3521 - 14.3 \cdot PSStr_t + 15.2 \cdot PSStr_{t-6} - 130.3 \cdot PCrn_{t-9}$$

Table 5: Regression results -after backward elimination

OLS Regression Results - Summary - After backward elimination

STEERS - Quarterly

Parameter $\alpha_{variable,time\ lag}$	Param	T-stat
$\alpha_{0,0}$	3,521,110	30.29
$\alpha_{1,0}$	14,278-	4.28-
$\alpha_{1,6}$	15,155	4.65
$\alpha_{2,9}$	130,338-	3.46-
Sample size (n)	*138*	
Adjusted -R^2	*0.17*	

STEERS - Semi-Annual

Parameter $\alpha_{variable,time\ lag}$	Param	T-stat
$\alpha_{0,0}$	4,146,759	3.83
$\alpha_{1,18}$	14,254	2.54
$\alpha_{2,6}$	331,696-	2.89-
$\alpha_{3,12}$	142	2.60
Sample size (n)	*63*	
Adjusted -R^2	*0.18*	

STEERS - Annual

Parameter $\alpha_{variable,time\ lag}$	Param	T-stat
$\alpha_{0,0}$	1,682,455	0.65
$\alpha_{3,12}$	692	4.37
Sample size (n)	*32*	
Adjusted -R^2	*0.38*	

HEIFERS - Quarterly

Parameter $\beta_{variable,time\ lag}$	Param	T-stat
$\beta_{0,0}$	1,269,286	11.76
$\beta_{1,6}$	11,135	7.78
$\beta_{2,0}$	93,121-	2.46-
Sample size (n)	*138*	
Adjusted -R^2	*0.31*	

HEIFERS - Semi-Annual

Parameter $\beta_{variable,time\ lag}$	Param	T-stat
$\beta_{0,0}$	985,245-	2.29-
$\beta_{1,6}$	73,158	2.77
$\beta_{2,0}$	204-	3.18-
$\beta_{3,0}$	290.70	9.48
$\beta_{3,6}$	268.15	8.77
Sample size (n)	*63*	
Adjusted -R^2	*0.78*	

HEIFERS - Annual

Parameter $\beta_{variable,time\ lag}$	Param	T-stat
$\beta_{0,0}$	1,876,896	3.05
$\beta_{2,0}$	450,424-	2.91-
$\beta_{3,0}$	73,514,939	13.50
Sample size (n)	*32*	
Adjusted -R^2	*0.87*	

COWS-Quarterly

Parameter $\gamma_{variable,time\ lag}$	Param	T-stat
$\gamma_{0,0}$	902,887	16.26
$\gamma_{1,12}$	87,750-	9.69-
$\gamma_{2,6}$	88,645	3.26
$\gamma_{2,12}$	65,237.00	2.48
Sample size (n)	*138*	
Adjusted -R^2	*0.48*	

COWS - Semi-Annual

Parameter $\gamma_{variable,time\ lag}$	Param	T-stat
$\gamma_{0,0}$	845,113	1.60
$\gamma_{1,6}$	10,594-	2.83-
$\gamma_{3,6}$	39.33	3.57
Sample size (n)	*63*	
Adjusted -R^2	*0.56*	

COWS - Annual

Parameter $\gamma_{variable,time\ lag}$	Param	T-stat
$\gamma_{0,0}$	1,460,910-	2.28-
$\gamma_{2,12}$	384,450	3.04
$\gamma_{3,24}$	115	6.86
Sample size (n)	*32*	
Adjusted -R^2	*0.65*	

CALVES - Quarterly

Parameter $\mu_{variable,time\ lag}$	Param	T-stat
$\mu_{0,0}$	270,082	26.45
$\mu_{1,3}$	1,361-	7.73-
$\mu_{1,12}$	631-	4.09-
Sample size (n)	*138*	
Adjusted -R^2	*0.79*	

CALVES - Semi-Annual

Parameter $\mu_{variable,time\ lag}$	Param	T-stat
$\mu_{0,0}$	446,116	9.51
$\mu_{1,0}$	1,165-	2.13-
$\mu_{1,6}$	2,494-	5.33-
$\mu_{3,18}$	2.26	3.30
Sample size (n)	*63*	
Adjusted -R^2	*0.85*	

CALVES - Annual

Parameter $\mu_{variable,time\ lag}$	Param	T-stat
$\mu_{0,0}$	502,707	3.55
$\mu_{1,0}$	4,703-	3.79-
$\mu_{3,24}$	11.76	5.14
Sample size (n)	*32*	
Adjusted -R^2	*0.80*	

Table 6: Correlation matrix for models after backward elimination

Correlation Matrix - After regression results											
STEERS											
QUARTERLY				***SEMI-ANNUAL***					***ANNUAL***		
	$\alpha_{1,0}$	$\alpha_{1,6}$	$\alpha_{2,9}$		$\alpha_{1,18}$	$\alpha_{2,6}$	$\alpha_{3,12}$			$\alpha_{3,12}$	
$\alpha_{1,0}$	1.00			$\alpha_{1,18}$	1.00				$\alpha_{3,12}$	1.00	
$\alpha_{1,6}$	0.89	1.00		$\alpha_{2,6}$	0.01	1.00					
$\alpha_{2,9}$	0.23	0.25	1.00	$\alpha_{3,12}$	0.60-	0.24	1.00				
HEIFERS											
QUARTERLY				***SEMI-ANNUAL***					***ANNUAL***		
	$\beta_{1,6}$	$\beta_{2,0}$			$\beta_{1,6}$	$\beta_{2,0}$	$\beta_{3,0}$	$\beta_{3,6}$		$\beta_{2,0}$	$\beta_{3,0}$
$\beta_{1,6}$	1.00			$\beta_{1,6}$	1.00				$\beta_{2,0}$	1.00	
$\beta_{2,0}$	0.26	1.00		$\beta_{2,0}$	0.07-	1.00			$\beta_{3,0}$	0.35	1.00
				$\beta_{3,0}$	0.06	0.19-	1.00				
				$\beta_{3,6}$	0.21	0.11-	0.00-	1.00			
COWS											
QUARTERLY				***SEMI-ANNUAL***					***ANNUAL***		
	$\gamma_{1,12}$	$\gamma_{2,6}$	$\gamma_{2,12}$		$\gamma_{1,6}$	$\gamma_{3,6}$				$\gamma_{2,12}$	$\gamma_{3,24}$
$\gamma_{1,12}$	1.00			$\gamma_{1,6}$	1.00				$\gamma_{2,12}$	1.00	
$\gamma_{2,6}$	0.17	1.00		$\gamma_{3,6}$	0.74-	1.00			$\gamma_{3,24}$	0.04	1.00
$\gamma_{2,12}$	0.15	0.72	1.00								
CALVES											
QUARTERLY				***SEMI-ANNUAL***					***ANNUAL***		
					$\mu_{1,0}$	$\mu_{1,6}$	$\mu_{3,18}$			$\mu_{1,0}$	$\mu_{3,24}$
	$\mu_{1,3}$	$\mu_{1,12}$									
				$\mu_{1,0}$	1.00				$\mu_{1,0}$	1.00	
$\mu_{1,3}$	1.00			$\mu_{1,6}$	0.79	1.00			$\mu_{3,24}$	0.43-	1.00
$\mu_{1,12}$	0.75	1.00		$\mu_{3,18}$	0.53-	0.46-	1.00				

Table 7: Regression results, supply change equation, after backward elimination

OLS Delta Regression Results - Summary - After backward elimination

STEERS - Quarterly

Parameter $\alpha_{variable,time\ lag}$	*Param*	*T-stat*
$\Delta\alpha_{1,0}$	0.40-	6.83-
Sample size (n)	138	
Adjusted -R^2	0.25	

STEERS - Semi-Annual

Parameter $\alpha_{variable,time\ lag}$	*Param*	*T-stat*
$\Delta\alpha_{1,0}$	0.16-	4.06-
$\Delta\alpha_{1,6}$	0.17-	4.26-
$\Delta\alpha_{2,0}$	0.07	2.89
$\Delta\alpha_{3,0}$	0.22	6.02
Sample size (n)	62	
Adjusted -R^2	0.56	

STEERS - Annual

Parameter $\alpha_{variable,time\ lag}$	*Param*	*T-stat*
$\Delta\alpha_{1,0}$	0.19-	2.81-
Sample size (n)	32	
Adjusted -R^2	0.18	

HEIFERS - Quarterly

Parameter $\beta_{variable,time\ lag}$	*Param*	*T-stat*
$\Delta\beta_{1,0}$	0.28-	4.32-
$\Delta\beta_{1,6}$	0.26	4.26
$\Delta\beta_{1,12}$	0.20-	3.24-
Sample size (n)	138	
Adjusted -R^2	0.34	

HEIFERS - Semi-Annual

Parameter $\beta_{variable,time\ lag}$	*Param*	*T-stat*
$\Delta\beta_{1,0}$	0.38-	4.50-
$\Delta\beta_{1,12}$	0.23-	2.76-
$\Delta\beta_{2,18}$	0.19	3.84
$\Delta\beta_{3,0}$	0.19	3.44
Sample size (n)	62	
Adjusted -R^2	0.43	

HEIFERS - Annual

Parameter $\beta_{variable,time\ lag}$	*Param*	*T-stat*
$\Delta\beta_{2,24}$	0.14	4.11
$\Delta\beta_{3,12}$	0.68	3.93
Sample size (n)	32	
Adjusted -R^2	0.49	

COWS-Quarterly

Parameter $\gamma_{variable,time\ lag}$	*Param*	*T-stat*
$\Delta\gamma_{1,0}$	0.36-	4.50-
$\Delta\gamma_{1,3}$	0.29-	4.32-
$\Delta\gamma_{1,12}$	0.39-	4.98-
Sample size (n)	138	
Adjusted -R^2	0.42	

COWS - Semi-Annual

Parameter $\gamma_{variable,time\ lag}$	*Param*	*T-stat*
$\Delta\gamma_{1,12}$	0.31-	4.60-
$\Delta\gamma_{3,6}$	1.74	3.96
Sample size (n)	62	
Adjusted -R^2	0.57	

COWS - Annual

Parameter $\gamma_{variable,time\ lag}$	*Param*	*T-stat*
$\Delta\gamma_{1,12}$	0.31-	5.21-
$\Delta\gamma_{2,12}$	0.24	4.75
$\Delta\gamma_{2,24}$	1.05	2.59
Sample size (n)	32	
Adjusted -R^2	0.69	

CALVES - Quarterly

Parameter $\mu_{variable,time\ lag}$	*Param*	*T-stat*
$\Delta\mu_{1,3}$	0.50-	6.44-
Sample size (n)	138	
Adjusted -R^2	0.35	

CALVES - Semi-Annual

Parameter $\mu_{variable,time\ lag}$	*Param*	*T-stat*
$\Delta\mu_{1,0}$	0.33-	4.05-
$\Delta\mu_{1,6}$	0.46-	6.02-
$\Delta\mu_{2,6}$	0.15	2.80
$\Delta\mu_{3,0}$	0.09-	4.03-
Sample size (n)	62	
Adjusted -R^2	0.70	

CALVES - Annual

Parameter $\mu_{variable,time\ lag}$	*Param*	*T-stat*
$\Delta\mu_{1,0}$	0.63-	6.49-
$\Delta\mu_{1,12}$	0.41-	4.20-
Sample size (n)	32	
Adjusted -R^2	0.78	

Table 8: Correlation matrix, delta-model, after backward elimination

Correlation Matrix - After regression results, for Delta Model

STEERS DELTA

QUARTERLY

	$\Delta\alpha_{1,0}$
$\Delta\alpha_{1,0}$	1.00

SEMI-ANNUAL

	$\Delta\alpha_{1,0}$	$\alpha 1$	$\Delta\alpha_{2,0}$	$\Delta\alpha_{3,0}$
$\Delta\alpha_{1,0}$	1.00			
$\Delta\alpha_{1,6}$	0.28-	1.00		
$\Delta\alpha_{2,0}$	0.01-	0.05-	1.00	
$\Delta\alpha_{3,0}$	0.25	0.33-	0.12-	1.00

ANNUAL

	$\Delta\alpha_{1,0}$
$\Delta\alpha_{1,0}$	1.00

HEIFERS DELTA

QUARTERLY

	$\Delta\beta_{1,0}$	$\Delta\beta_{1,6}$	$\Delta\beta_{1,12}$
$\Delta\beta_{1,0}$	1.00		
$\Delta\beta_{1,6}$	0.17-	1.00	
$\Delta\beta_{1,12}$	0.33	0.18-	1.00

SEMI-ANNUAL

	$\Delta\beta_{1,0}$	$\Delta\beta_{1,12}$	$\Delta\beta_{2,18}$	$\Delta\beta_{3,0}$
$\Delta\beta_{1,0}$	1.00			
$\Delta\beta_{1,12}$	0.16	1.00		
$\Delta\beta_{2,18}$	0.01-	0.00	1.00	
$\Delta\beta_{3,0}$	0.32	0.28	0.11	1.00

ANNUAL

	$\Delta\beta_{2,24}$	$\Delta\beta_{3,12}$
$\Delta\beta_{2,24}$	1.00	
$\Delta\beta_{3,12}$	0.05-	1.00

COWS DELTA

QUARTERLY

	$\Delta\gamma_{1,0}$	$\Delta\gamma_{1,3}$	$\Delta\gamma_{1,12}$
$\Delta\gamma_{1,0}$	1.00		
$\Delta\gamma_{1,3}$	0.16-	1.00	
$\Delta\gamma_{1,12}$	0.50	0.10-	1.00

SEMI-ANNUAL

	$\Delta\gamma_{1,12}$	$\Delta\gamma_{3,6}$
$\Delta\gamma_{1,12}$	1.00	
$\Delta\gamma_{3,6}$	0.55-	1.00

ANNUAL

	$\Delta\gamma_{1,12}$	$\Delta\gamma_{2,12}$	$\Delta\gamma_{2,24}$
$\Delta\gamma_{1,12}$	1.00		
$\Delta\gamma_{2,12}$	0.03-	1.00	
$\Delta\gamma_{2,24}$	0.34-	0.00-	1.00

CALVES DELTA

QUARTERLY

	$\Delta\mu_{1,3}$
$\Delta\mu_{1,3}$	1.00

SEMI-ANNUAL

	$\Delta\mu_{1,0}$	$\Delta\mu_{1,6}$	$\Delta\mu_{2,6}$	$\Delta\mu_{3,0}$
$\Delta\mu_{1,0}$	1.00			
$\Delta\mu_{1,6}$	0.06-	1.00		
$\Delta\mu_{2,6}$	0.14-	0.10	1.00	
$\Delta\mu_{3,0}$	0.31-	0.17	0.36	1.00

ANNUAL

	$\Delta\mu_{1,0}$	$\Delta\mu_{1,12}$
$\Delta\mu_{1,0}$	1.00	
$\Delta\mu_{1,12}$	0.03-	1.00

Appendix E OLS Assumptions

We have to make sure that our estimation results are valid by checking whether all assumptions (as proposed by Brooks (1972)) that are made for the ordinary least squares estimator are satisfied. Some assumptions hold in general, others are checked one by one for all regression equations.

Assumption 1: Model is linear in parameters
The input of our Ordinary Least Squares estimation is a linear equation and the model is therefore linear in parameters.

Assumption 2: The data are a random sample of the data generating process
We use all data available during the given time-slot. Selection biases are avoided since all data-observations in the given time-slot were available and used in our empirical analysis. You can argue whether the chosen time-interval 1970-1995 is randomly chosen, however since it is such a long time interval we assume that this will not give much bias.

Assumption 3: The errors are statistically independent from one another
We presented the correlation matrices after the backward elimination procedures. In three times, some high correlation coefficients are measured. We should be aware that using these estimation models can lead to over specification problems.

Assumption 4: The independent variables are not too strongly collinear
The correlation matrices of our models after backward elimination (Table 6 and Table 8) exhibit low correlations for most regression parameters. Most correlation figures are not that high that it gives problems with multi-collinearity, as a practical rule of thumb we say that a correlation larger than 0.9 or smaller than -0.9 is suspicious. At the regression model on absolute data-values for cows on yearly aggregated data, we find a correlation of 0.94, which is troublesome. We neglect the results of those model estimates which show significantly high correlations.

Assumption 5: The expected value of the residuals is zero
By using an intercept in every regression equation, the expected value of the residuals is nearly perfect to zero in every regression equation.

Assumption 6: The residuals have constant variance (homoscedasticity)
This assumption requires that the standard deviation and variance of the error terms (μ) are constant for all variables. If this assumption does not hold, the estimated coefficient is open to question. To ensure that we have no, or small, heteroskedasticity in the data, the Whites heteroskedasticity test is used. This method

tests whether the error terms are identically distributed with the same variance. If the OLS technique is used while heteroskedasticity is present in the dataset, it is possible that the standard errors are wrong and the conclusion drawn from the test is not satisfactory. The White test can be performed using SAS and gives the values for the Whites Test statistic. The test is based on the residuals of the fitted model. The null hypothesis for this test maintains that the errors are homoscedastic and independent of the regressors and that several technical assumptions about the model specification are valid. For details, see theorem 2 and assumptions 1–7 of White (1980). When the model is correctly specified and the errors are independent of the regressors, the rejection of this null hypothesis is evidence of heteroscedasticity. We compare the calculated $\chi 2$ with the critical $\chi 2$. If the calculated value is greater than the critical value we can reject the null and we conclude that their might be heteroscedasticity. Test results, presented in the next table, suggest that almost in all cases the null hypotheses are accepted. In the most right column indicates the probability that the test statistic is greater than the critical value following a $\chi 2$ distribution. Values lower then 0.05 indicate that we can reject the null-hypothesis. In other words heteroscedasticty in most regression equations, except two, do not have to be considered and do not lead to misspecifying errors.

White Test statistics - Absolute regression equations

		Degr.of freedom	***χ2***	***Pr > χ2***
Steers	*Quarter*	9	21.38	0.01
	Semi-annual	20	20.22	0.44
	Annual	2	6.57	0.04
Heifers	*Quarter*	5	7.49	0.19
	Semi-annual	20	16.00	0.72
	Annual	5	4.83	0.44
Beef-cows	*Quarter*	9	22.14	0.01
	Semi-annual	9	11.77	0.23
	Annual	5	5.12	0.40
Calves	*Quarter*	9	12.95	0.17
	Semi-annual	5	4.95	0.42
	Annual	9	5.30	0.81

White Test statistics - Relative regression equation				
		Degr.of freedom	***$\chi2$***	***Pr > $\chi2$***
Steers	*Quarter*	2	2.94	0.23
	Semi-annual	14	15.97	0.32
	Annual	2	0.67	0.72
Heifers	*Quarter*	9	11.91	0.22
	Semi-annual	20	20.48	0.42
	Annual	5	6.19	0.29
Beef-cows	*Quarter*	9	12.95	0.17
	Semi-annual	5	4.95	0.42
	Annual	9	5.30	0.81
Calves	*Quarter*	2	4.90	0.09
	Semi-annual	14	8.17	0.88
	Annual	5	3.52	0.62

Assumption 7: The residuals are normally distributed

We test for normality of the residuals by conducting a Jarque-Bera test[4]. The next tables gives the Jarques_Bera test results for every regression equation. We present the Jarque-Bera test statistic, the critical value following a asymptotic chi-square distribution. If the residuals are normally distributed, the histogram should be bell-shaped and the Jarque Bera statistic should not be significant. We can conclude that most residuals are normally distributed. In these cases we show the residual normal probability plot to exhibit what problems exist. We see that the residuals are not normally distributed since the distribution of the

4 Here we following the definition and calculations of the Jarque-Bera test as expressed on http://en.wikipedia.org/wiki / Jarque–Bera test: In statistics, the Jarque-Bera test is a goodness-of-fit measure of departure from normality, based on the sample kurtosis and skewness. The test is named after Carlos M. Jarque and Anil K. Bera. The test statistic JB is defined as $JB = \frac{n}{6} \cdot (S^2 + \frac{(K-3)^2}{4})$ where n is the number of observations (or degrees of freedom in general); S is the sample skewness, K is the sample kurtosis. The statistic JB has an asymptotic chi-square distribution with two degrees of freedom and can be used to test the null hypothesis that the data are from a normal distribution. The null hypothesis is a joint hypothesis of the skewness being zero and the excess kurtosis being 0, since samples from a normal distribution have an expected skewness of 0 and an expected excess kurtosis of 0 (which is the same as a kurtosis of 3). As the definition of JB shows, any deviation from this increases the JB statistic. The histograms tells us that the residuals are either highly skewed or represented.

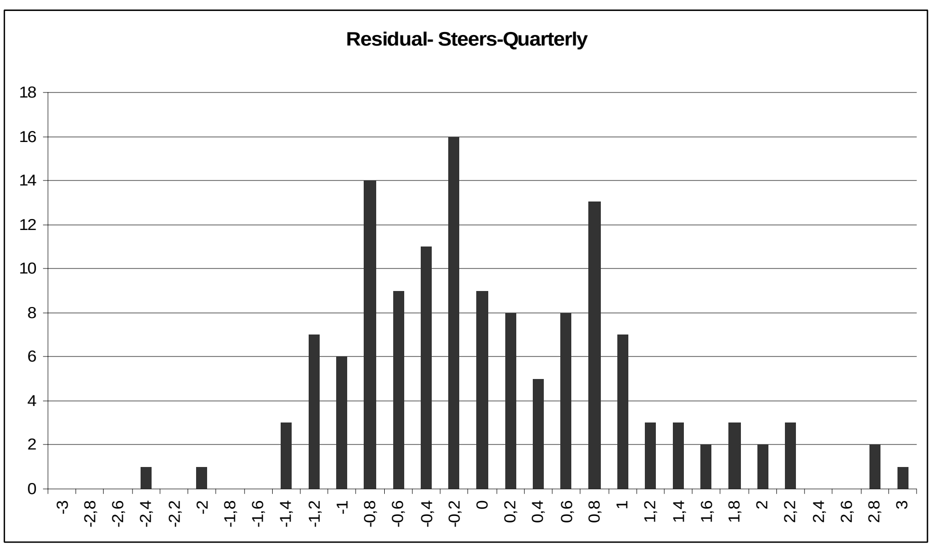
residuals are either highly skewed or some outliers lead to problems. The last figures include some residual representations of those models that are highly skewed.

Table 9: Jarque Bera Test Statistics, Absolute structural model

Jarque Bera Statistic - Summary - After backward elimination					
STEERS - Quarterly		**STEERS - Semi-Annual**		**STEERS - Annual**	
JB-Statistic	7,28	JB-Statistic	3,38	JB-Statistic	1,86
Critical Value	5,99	Critical Value	5,99	Critical Value	5,99
P-Value	0,03	P-Value	0,18	P-Value	0,39
Normality	**FALSE**	Normality	TRUE	Normality	TRUE
HEIFERS - Quarterly		**HEIFERS - Semi-Annual**		**HEIFERS - Annual**	
JB-Statistic	5,75	JB-Statistic	0,60	JB-Statistic	0,72
Critical Value	5,99	Critical Value	5,99	Critical Value	5,99
P-Value	0,06	P-Value	0,74	P-Value	0,70
Normality	TRUE	Normality	TRUE	Normality	TRUE
COWS-Quarterly		**COWS - Semi-Annual**		**COWS - Annual**	
JB-Statistic	95,46	JB-Statistic	32,58	JB-Statistic	0,47
Critical Value	5,99	Critical Value	5,99	Critical Value	5,99
P-Value	0,00	P-Value	0,00	P-Value	0,79
Normality	**FALSE**	Normality	**FALSE**	Normality	TRUE
CALVES - Quarterly		**CALVES - Semi-Annual**		**CALVES - Annual**	
JB-Statistic	1,06	JB-Statistic	0,37	JB-Statistic	1,11
Critical Value	5,99	Critical Value	5,99	Critical Value	5,99
P-Value	0,59	P-Value	0,83	P-Value	0,57
Normality	TRUE	Normality	TRUE	Normality	TRUE

Table 10: Jarque Bera Test Statistics, Absolute structural model

Jarque Bera Statistic (delta equations)- Summary - After backward elimination					
STEERS - Quarterly		**STEERS - Semi-Annual**		**STEERS - Annual**	
JB-Statistic	1,50	JB-Statistic	5,15	JB-Statistic	0,49
Critical Value	5,99	Critical Value	5,99	Critical Value	5,99
P-Value	0,47	P-Value	0,08	P-Value	0,78
Normality	TRUE	Normality	TRUE	Normality	TRUE
HEIFERS - Quarterly		**HEIFERS - Semi-Annual**		**HEIFERS - Annual**	
JB-Statistic	2,10	JB-Statistic	2,58	JB-Statistic	1,90
Critical Value	5,99	Critical Value	5,99	Critical Value	5,99
P-Value	0,35	P-Value	0,28	P-Value	0,39
Normality	TRUE	Normality	TRUE	Normality	TRUE
COWS-Quarterly		**COWS - Semi-Annual**		**COWS - Annual**	
JB-Statistic	1,46	JB-Statistic	1,27	JB-Statistic	1,43
Critical Value	5,99	Critical Value	5,99	Critical Value	5,99
P-Value	0,48	P-Value	0,53	P-Value	0,49
Normality	TRUE	Normality	TRUE	Normality	TRUE
CALVES - Quarterly		**CALVES - Semi-Annual**		**CALVES - Annual**	
JB-Statistic	1,53	JB-Statistic	0,44	JB-Statistic	0,97
Critical Value	5,99	Critical Value	5,99	Critical Value	5,99
P-Value	0,47	P-Value	0,80	P-Value	0,62
Normality	TRUE	Normality	TRUE	Normality	TRUE



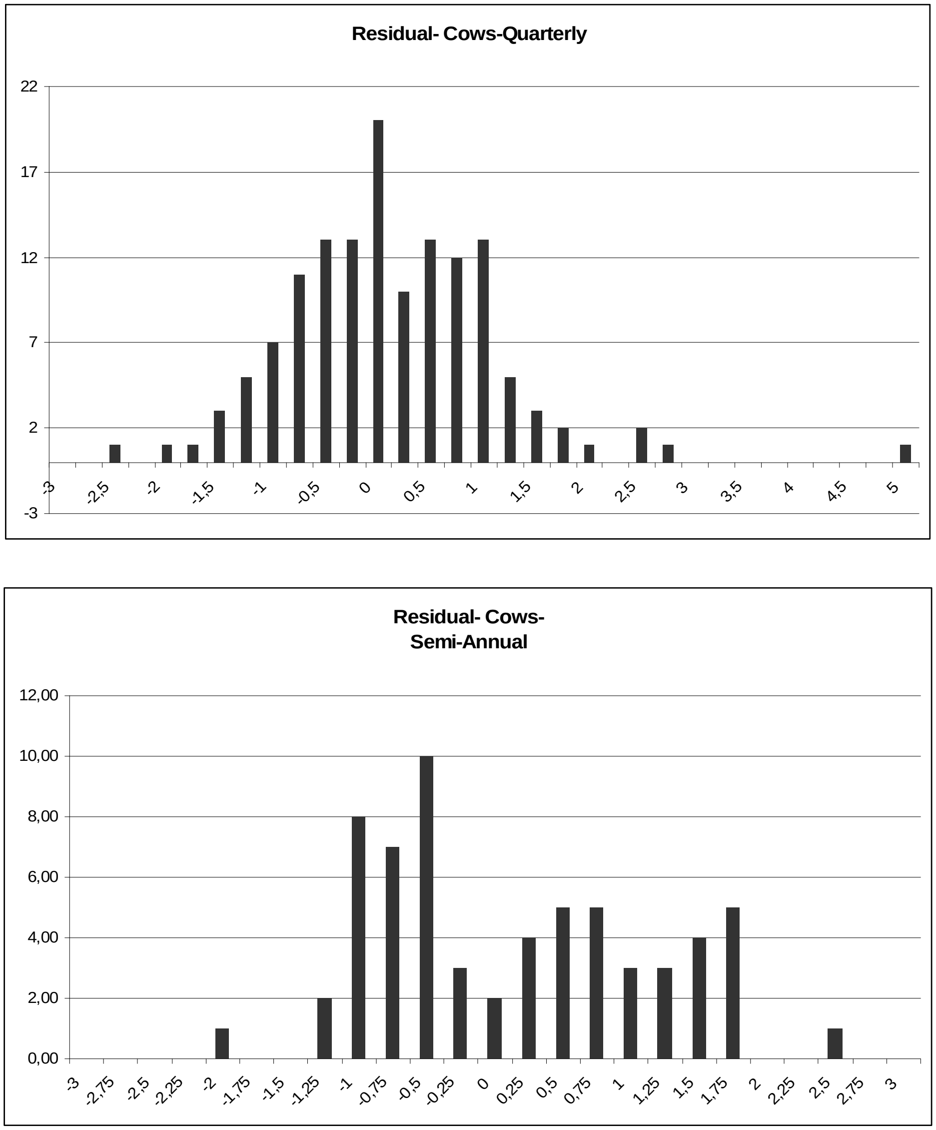


Figure 42: Residuals Cows quarterly and semi annual models