An Explorative Study of Grain and Meat Price Relationships.

Andreas Tegle

NORWEGIAN UNIVERSITY OF LIFE SCIENCES
UMB SCHOOL OF ECONOMICS AND BUSINESS
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Foreword

This thesis concludes my master program in Economics (Samfunnsøkonomi) at UMB School of Economics and Business.

Working on this thesis has been both educational and challenging. I have learned a lot about commodity markets and how to analyze them. Hopefully, my work will be of use for others wanting to learn how agricultural commodity prices are related.

I would like thank my advisor Ole Gjølberg and Marie Steen for giving me good advices and feedback on the thesis. I would also like to thank my girlfriend, family and friends for supporting me while working on the thesis, but also for taking my mind of the thesis, in order to do something else.

Ås, 13.05.2013

Andreas Tegle

Abstract

Price relationships between hogs, cattle, broilers, corn, wheat and soybeans are studied for the period 2000-2012. Corn, wheat and soybeans are feed inputs to the three meat commodities. I wanted to find out how prices have been related, i.e. are price changes in feeds reflected in short term price changes in meat? If not, how long does it take for price changes in feeds to be reflected in meat prices?

To investigate the price relationships between the commodities Autoregressive Distributed Lag Models were used to explore lagged and contemporary effects going from one commodity to another. In addition, a Granger Causality test was carried out, using a Vector Autoregressive Model. A regression was also run to find the effect time has on meat/corn price ratios.

Positive contemporary connections were found between hog and cattle prices, corn and soybean prices, corn and wheat prices. A negative contemporary relationship was found between hogs and corn, which is in line with expectations. Six leads (Granger Causality) were found between the six commodity prices: Broiler lead hogs, wheat lead hogs, all commodities lead hogs, all commodities lead broiler, corn lead wheat and corn lead soybeans. Relatively few short term connections were found between grain and meat prices. Perhaps due to the use of production contracts, which limits the flexibility and the need to make adjustments to production when faced with changing feed costs.

Meat prices were found to react slowly to changes grain corn prices. Meat/corn price ratios have decreased considerably following the surge in grain prices starting in 2006. This has consequences for producers as many have been producing with losses. Some signs of increasing meat prices were however seen in 2010, signaling that there is a lower limit to meat/corn price ratios.

Key words: Agricultural markets, commodity analysis, short run, long run, VAR, Granger Causality, ADL, AR, dynamics, price relationships.

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1 Introduction

In the media, one often reads how grain prices are affecting meat prices. Typically, one makes the conclusion that prices are connected. One example is from USA Today, where an expert is predicting pork prices to fall the next few weeks and then rise in six months, following a period increasing grain prices (Keen 2012). As it is an expert talking, one assumes he is correct. In this thesis I want to find out what price relationships that really exist between grains and meats.

Over the past 10-20 years, a lot has changed in grain and meat markets, which may have had an effect on price relationships between the commodities. The meat industry has been through substantial changes the past two decades which have had an effect on how producers behave, which may affect how meat prices respond to changes in grain prices (Key & McBride 2007; Ward et al. 2000).

The grain prices included in this study are the prices of corn, wheat and soybeans. Soybeans are more often referred to as an oilseed, but I use the term grain as it is useful to have a term covering all the crops used. The meat prices included are the prices of lean hogs, live cattle and broiler.

One of the main reasons behind the increase in grain prices is the Renewable Fuel Standard (RFS) program imposed by the US Environmental Protection Agency (*Renewable Fuel Standard* 2005). The program required renewable fuel to be blended into transportation fuels. The program has pushed the demand of corn, used for ethanol production up and thereby pushed grain prices up. According to data from the United States Department of Agriculture (USDA) around 40% of the corn goes to feed (Capehart 2013). It used to be a lot more prior to the RFS program. Research has also showed that corn prices was 30% higher in the period 2006-2012 due to the ethanol mandate (Carter et al. 2012).

Grains and meats have an input-output relation, where grain is the input and meat is the output. Consequently, there has to be a connection between grain and meat prices. When grain prices are increasing, meat prices will have to follow, sooner or later. How long this takes, depends on the lifespan of animals, but more important is perhaps the flexibility of the industry and its ability to respond to increases in feed costs. It is reasonable to assume the flexibility of the industry is rather small. Once an investment in buildings and technology is made, one has to think long term, as the buildings and equipments are expensive and has few alternative uses. If however increasing feed costs leads to negative profits, meat prices will probably become more responsive as animals will be slaughtered and producers will go bankrupt if the grain/meat price ratios do not improve. Since 2006, meat prices have only had moderate increases while grain prices have reached record high levels. It makes one wonder when meat prices will pick up.

Traditionally, a meat producer respond to increasing feed costs by slaughtering the animal early, as the cost becomes larger than the benefit of keep feeding it. However, it has now become more complicated as production today often relies upon production contracts (Ward et al. 2000). The use of production contracts between packers/processors and producers' leads to better price risk management through the use of fixed price arrangements. For packers, production contracts leads to a more steady supply of animals. The increased integration in the industry has implications for short run price relationships between grains and meats. When meat producers face higher grain prices, they might not make adjustments to production because they are required by contract to deliver meat continuously and meat prices are not tied to the spot price, but to other price arrangements made with the packer.

The introduction above leads me to my research questions:

- Are there any stable connections between meat and grain prices?
- Are meat prices responding to changes in grain prices on a weekly basis or are there lags involved?
- Can observed prices ratios, be used to forecast subsequent price ratios or price changes?

My thesis is of particular interest for four groups: Producers, consumers, governments and speculators. Knowing how these markets are connected, makes it easier for grain and meat producers to hedge price risk and plan ahead. Meat producers will benefit from being able to recognize price patterns in order to make sound decisions on whether to slaughter animals or keep feeding them. If they learn how meat prices respond to grain prices they can use grain prices as an indicator of future meat prices. This is also why it is useful to investigate the dynamics between the commodities and not just individually.

The grain and meat price relationship matters for consumers as well. Consumers wants both low grain prices and low meat prices. The high grain prices effect on consumers in poor countries have been a topic for many years now (Townsend 2012). If meat prices were to pick up, this would be bad for consumers in rich countries as meat would be more expensive, but good for consumers in poor countries as the demand for meat would fall, which would decrease demand for grains used as feed.

Speculators in the commodity futures markets are interested in any market where money can be made. I believe there to be opportunities to make money by looking at price relationships between grain and meat markets. Speculators will be interested in looking at information in prices to make predictions on how prices will behave in the future. The long run price development for meat and grain prices are of particular interest for hedge funds. If prices deviate a lot from the long run mean, they will look at opportunities to sell the commodity priced high and buy the commodity which is priced low until relative prices return to normal. The meat/corn price ratio is important for evaluating whether corn or meat prices are priced too high.

Governments with large agricultural sectors are interested in learning how the markets are related. If a connection can be found between the markets, then an intervention in one market will have an effect on prices in other markets. For example, if the US government were to temporarily remove the ethanol mandate to put pressure off corn prices, this would have spillover effects on other agricultural prices. Learning how prices are connected is useful in order to design good policies.

An econometrical approach is used to find price relationships. Most of the econometrical analyses are using the log of returns. To start, autocorrelation plots and simple auto regressions are carried out. This gives the reader an understanding of the dynamics in each commodity. It is useful for the purpose of seeing if past prices can explain future prices of the same commodity. A regression is also carried out to see what affect time has on meat/corn ratio. It will show whether the ratio is trending upward or downward. The Autoregressive Distributed Lag (ADL) model; along with a Vector Auto Regressive

(VAR) model is used to find price relationships. The ADL model is using past values of the explained variable along with past and current values of other variables. Results of the ADL model yields information on dynamics between prices. If significant variables are found, then these can be used to explain current values of the explained variables. For instance, the findings can be used to determine how corn returns respond to an increase in hog returns. A VAR model is basically several ADL equations put together. The VAR model does not include current values like the ADL model did. The VAR model is run in order to undertake a Granger Causality (GC) test. GC tests if past values of one commodity price have a significant explanatory power on current price of another commodity. The test is used to give a simple interpretation of the results found in the VAR model.

2 Price Relationships for Grains and Meats. A Literature Review

The literature review will be focusing on establishing an overview of what price relationships exist. There has not been a lot of research directly related to meat and grain price relationships, which is why the most relevant articles will be given a thorough review. Emphasis will be given to Granger Causality tests as those are popular in detecting price relationships for agricultural commodities. Some other resources useful for understanding price relationships are also presented. Finally, an explanation of how this thesis complements previous research is given.

The paper most relevant for this research is that of Pozo and Schroeder (2012). They use price data for live cattle, feeder cattle, lean hogs, corn and soybeans in order two find price relationships through the use of a Granger Causality on a Structural VAR model. The price data used is the average of weekly futures prices and the period investigated is 1995-2012. Leads were found going from live cattle to hogs, hogs to soybeans and corn to soybeans. It was no surprise cattle were found to explain hogs. The commodities are closely related, and are substitutes in consumption. So when the price of cattle goes up, the price of hogs will follow. Hogs use soybeans as a source of protein and it is not unreasonable that hogs are in fact having an effect on soybean prices. Corn and soybeans compete for acreage and are complements in feed diets, so the finding makes sense.

Tejeda and Goodwin (2011) used daily spot prices for live cattle, feeder cattle, wheat, corn and sorghum Tejeda and Goodwin (2011). They split the data into pre and post the ethanol mandate (2005). In the pre ethanol period they found live cattle to lead soybeans. The finding is surprising as cattle are not huge consumers of soybeans and soybeans have many other uses than feed. The results from the vector models in this research were also used to do impulse response functions to see how a shock to one variable affects other variables. Most of the lags were found to be insignificant. Some signs of overshooting were found, meaning that a shock to one price caused a response in another variable, only for the response to return to zero after some days. Evidence of co-integration was found only for the post ethanol period. It indicates that something changed from the first period to the second period. What is interesting is that the findings in this article was quite different from that of (Pozo & Schroeder 2012). This could be because different periods was used, but also because this study used daily spot, while the other used weekly futures.

Ziemer and Collins (1984) conducted a GC test in order to detect relationships for livestock and crop prices. They found bi-directional leads for corn, wheat, beef and hogs. All of those were found to explain each other. What was striking about that research was that Granger Causality was found for close to all commodities. They used vehicle registration in the Granger Causality test to see if there is reason to suspect spurious findings. Vehicle registration was found significant for 5 out of 6 of the agricultural commodities. One must wonder whether the other findings were spurious as well.

Tejeda and Goodwin (2009) used correlation analyses to discover price relationships. They used weekly futures prices from 1998-2008. Prices were averaged. The commodity prices used were cattle, soybeans and corn. No significant correlation was found for corn and soybean with cattle prices. The authors argued that the reason no significant correlation was found was because meat producers modified the feeding ration when the price of corn or soybean increased and therefore changes to corn and soybean prices was not passed on to cattle prices[1].

This thesis can be looked as a complement to previous research, not as one that challenges it. Research on price relationships containing the six commodities used here has not been found elsewhere. It will also be interesting to see if results from the VAR model and Granger Causality test matches those of Pozo and Schroeder (2012) as those were using weekly data on some of the same commodities. Even though previous research has used various forms of VAR-models to elicit dynamics in these markets, it has not used it for these six commodities. In addition to the VAR model, an ADL model will be used. An ADL model has not been found used on grain and meat prices the latest years. In a research on the relationship between global food prices and the oil price an ADL model was used (Chen et al. 2010). The models used are well established tools for eliciting price relationships.

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[1] If there had been a cost to modifying feeding rations, then price increases in either corn or soybean would be passed on to cattle prices and a correlation would be found.

3 Theoretical Considerations and Basic Facts on Price Relationships between Meat and Grain Prices

In order to give sound reasoning for any findings that the thesis provides, it is important to understand how these markets are connected.

3.1 A microeconomic approach to grain and meat price dynamics

Below is a simple model of supply and demand I created for cattle[2]:

$$S^{cattle} = f\left(P^{corn}, P^{wheat}, P^{soybean}, P^{other\ inputs}, IF, TECH\right)$$

$$D^{cattle} = f\left(P^{hogs}, P^{broiler}, X\right)$$

Symbol	Explanation	Expected sign
$P^{corn}, P^{wheat}, P^{soybean}$	Price of corn, wheat and soybeans.	-
$P^{other\ inputs}$	Price of purchasing the livestock, labor, supplies, maintenance and capital cost.	-
IF	Institutional factors. Regulations set by the government which has an effect on the industry.	-
$TECH$	Technology. It is factors which help increase output without increasing input.	+
$P^{hogs}, P^{broiler}$	Price of hogs and broiler.	+
X	Other factors affecting demand such as income and trends.	+

[2] The demand and supply equations are loosely based upon information found on the web pages to Chicago Mercantile Exchange and United States Department of Agriculture (*CME Group ...* 2010; *Production Fact Sheet* 2007).

The supply of cattle rests mainly on the price of feed, here represented by corn, wheat and soybeans. When the price of feed goes up, supply shifts left and price increases. The second element in the supply equation is price of other inputs. Once those prices increase, the supply will shift left and the price of cattle increase. Institutional factors can also push prices both way, but more often it pushes supply left as regulations is considered to be negative for an industry. Technology is considered to be positive, pushing the supply right as it improves productivity. This further pushes the price of cattle down. The demand of cattle depends on the price of related meats. Increases in other meat prices will push demand for cattle up; pushing the price of cattle up as well. Increased income for the population or increased popularity of cattle will also help increase the demand and the price of cattle.

The topic of supply and demand is only complete after a discussion of the short run versus the long run. The difference between the short and long run for the price of cattle is graphed below.

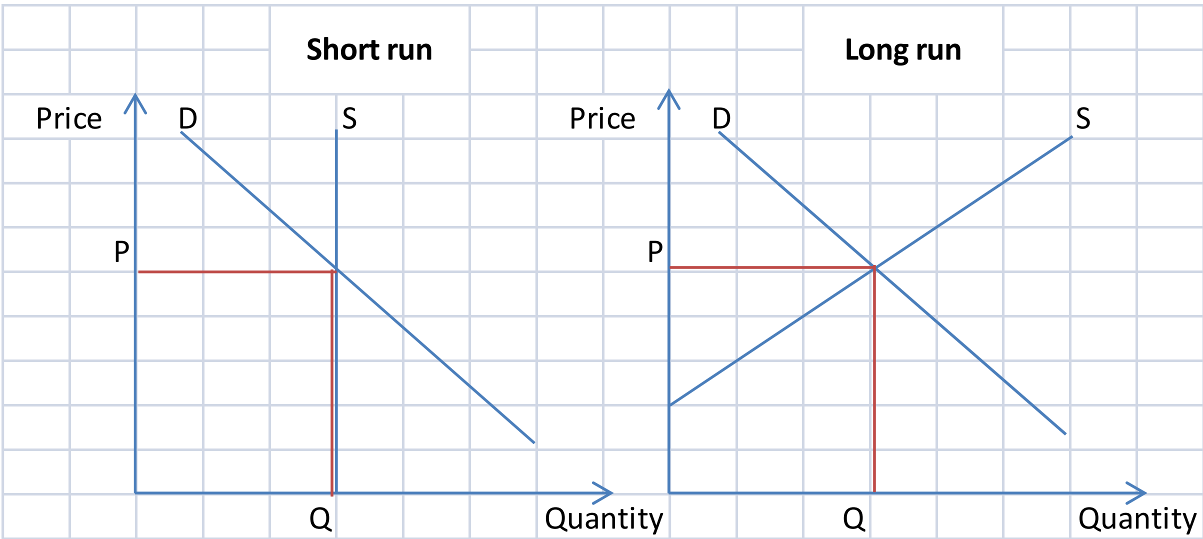

Figure 1 Demand and supply in the short and long run for cattle producers

This is a simplification of the real world, but is nevertheless useful for analyzing the price. In the short run supply is assumed fixed because producers have a given stock of animals which need to be fed to slaughter weight before production can be adjusted. It does not make economic sense for a meat producer to slaughter an animal just after birth. Consequently, the animal will need to be full grown before being sent to slaughter. As seen in the long run graph, the supply is elastic and is able to change in response to changes in feed costs. In the long run, meat producers will be able to change the stock of animals. The graphs for the short and long run also holds for the other commodities used in this research.

The analysis is a bit different for the case of hogs. Hogs have shown to have a negative price relationship with corn. What hog producers does is to walk hogs to markets early in the face of high feed costs, which increases supply (temporarily) and the sends the hog price down. Below is a graph I made, explaining the response in hog production following an increase in feed costs:

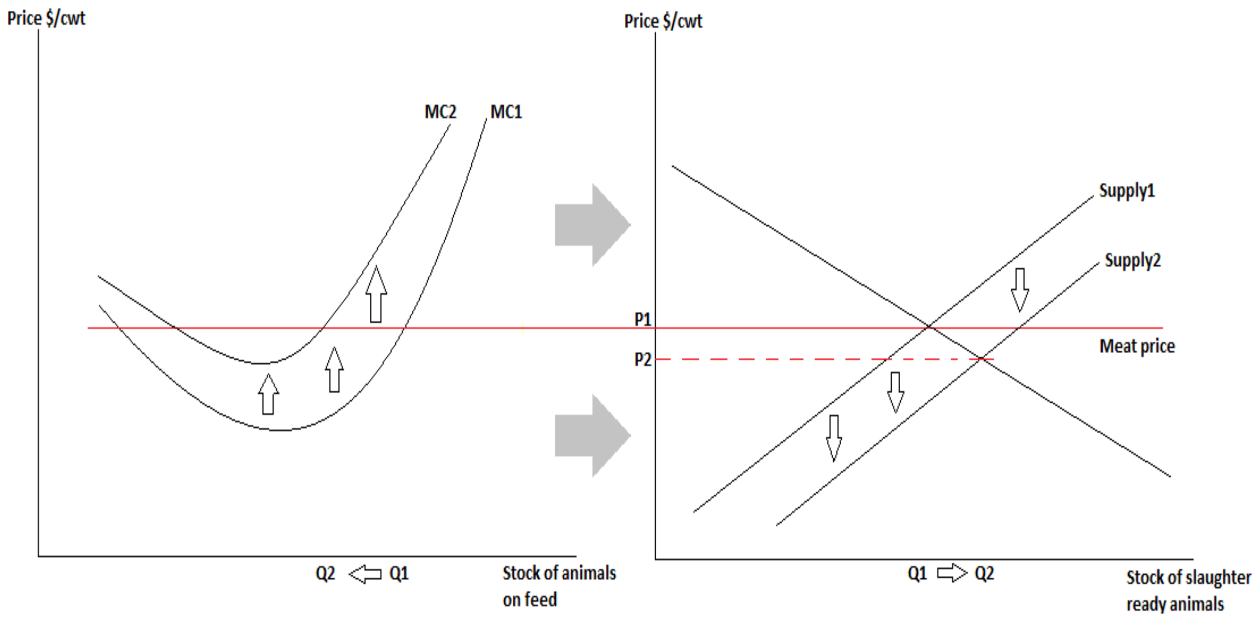

Figure 2 Response in hog supply and price, following an increase in feed costs.

Let us assume the price of corn increased. This increases costs for hog farmers and marginal cost shifts up from MC1 to MC2. Farmers react by slaughtering the hogs as they cannot afford to keep feeding them at those costs. This increases the supply of slaughtered hogs, moving supply from Supply1 to Supply2. As a consequence of the supply increase, the price of hogs decreases from P1 to P2.

With all this talk of short and long run it is necessary to provide an explanation for what time span the short run is compared to the long run. Short run is in this thesis set to be around one year. For the long run I am talking about two years and more. The supply will gradually switch from being inelastic to being elastic. Below is a representation the time it assumed that the supply is fixed for the commodities used. Supply gradually switches from being fixed to being elastic, but it is useful to have a reference point. The time it takes from planting to harvest for grains is also presented.

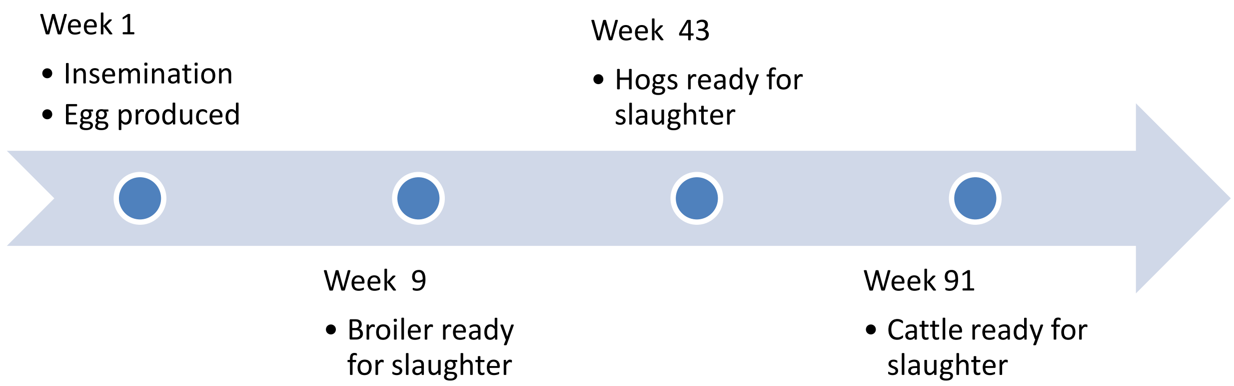

Figure 3 Timetable showing the time it takes from the decision to breed an animal until it is ready for slaughter (*CME Group ...* 2010; Dunsby et al. 2008 p. 133-150)

The timetable above does not hold for all producers. The time it takes from the decision to breed an animal and until it is ready for slaughter varies depending on wanted weight, feed price, weather and other considerations made by the producer. If a producer wishes to adjust the stock of animals it takes about as long time as in the time table above and this is also why it is presented. Producers make decisions of how many animals to produce in response to the price ratio of meat/feed. If the price ratio for hogs is high, producers will decide to inseminate more pigs and in turn receive more piglets. If all producers does this it creates an oversupply of slaughtered hogs and prices fall. For producers with obligations to packers it is likely to take a longer time to change as they have contracts requiring a steady delivery of meat.

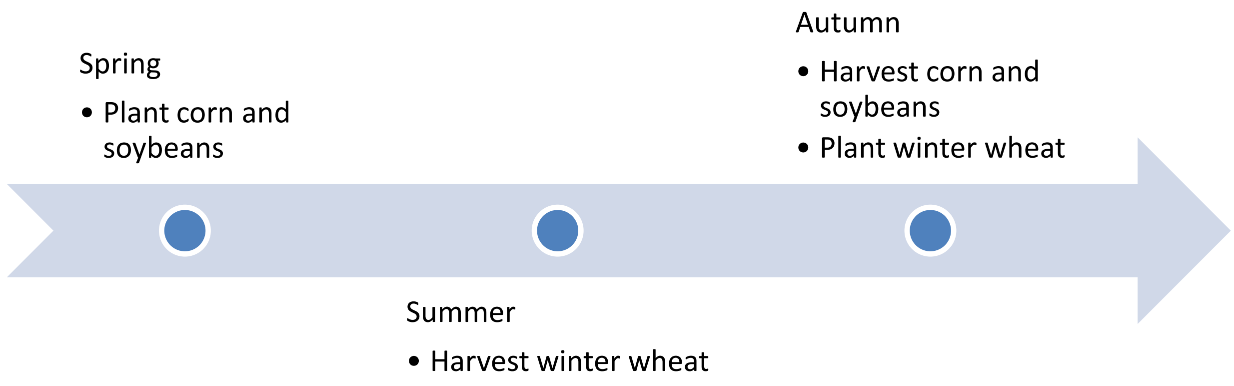

Figure 4 Timetable showing planting and harvesting seasons for corn, wheat and soybeans (National Agricultural Statistics Service 2010).

The time table above is based on data from the US as it is the producer with the most influence on prices. A new supply of grains only comes only once a year and is fixed until next year's supply comes. Worldwide, the supply is continuous as planting and harvesting seasons differ depending on how far north or south it is grown. In the northern hemisphere planting is done in the spring and harvest is in the autumn, while it in the southern hemisphere is opposite. Most grains are however grown in the northern hemisphere, with large producing countries such as Russia, Canada, USA and eastern European countries. The decision to plant a new crop is made 6-12 months before harvest. This has implications for prices as supply decisions are made on the basis of current prices.

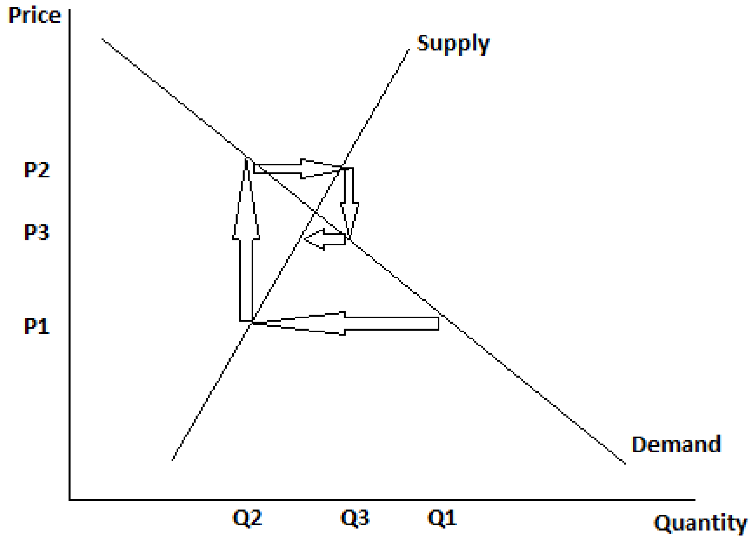

Figure 5 The cobweb model (Ezekiel 1938). Used as an illustration for agricultural commodities with lagged supply.

Assume the above model represent the wheat market. What happens is that there is a shock to supply so that quantity is equal to Q1. Farmers then decide to plant less wheat because of the low price (P1). When the harvest season comes, quantity is at Q2. This pushes the price upward to P2. The high price then causes farmers to increase production. This procedure goes on until the shock is phased out and the market returns to equilibrium.

A cobweb model is well suited for illustrating a long run price-quantity relationship for agricultural commodities. Agricultural commodities are different from many other commodities in the way that supply is fixed in the short run. The cobweb approach can be used to evaluate meat price-quantity relationships as well. When corn prices increase, hog producers will decide to decrease production. After some months the quantity of hogs will be significantly smaller, which will push hog prices up. Higher hog prices then cause production to pick up. Of course, farmers are not so short sighted that they cannot predict prices to decrease if all farmers increase supply. Still, farmers to tend to behave similarly, which causes these price fluctuations. For hogs, these price-quantity relationships are particularly strong. The price cycles in hogs are commonly referred to as the hog cycle. Every 4-6 year hog prices tend to peak because of variation in hog quantities (Dunsby et al. 2008 p. 137).

3.2 Facts on feed use and costs

The point of this section is to get a grasp of the relative importance of each grain as well as the combined importance of grains. The information is useful when discussing the results in chapter 6.

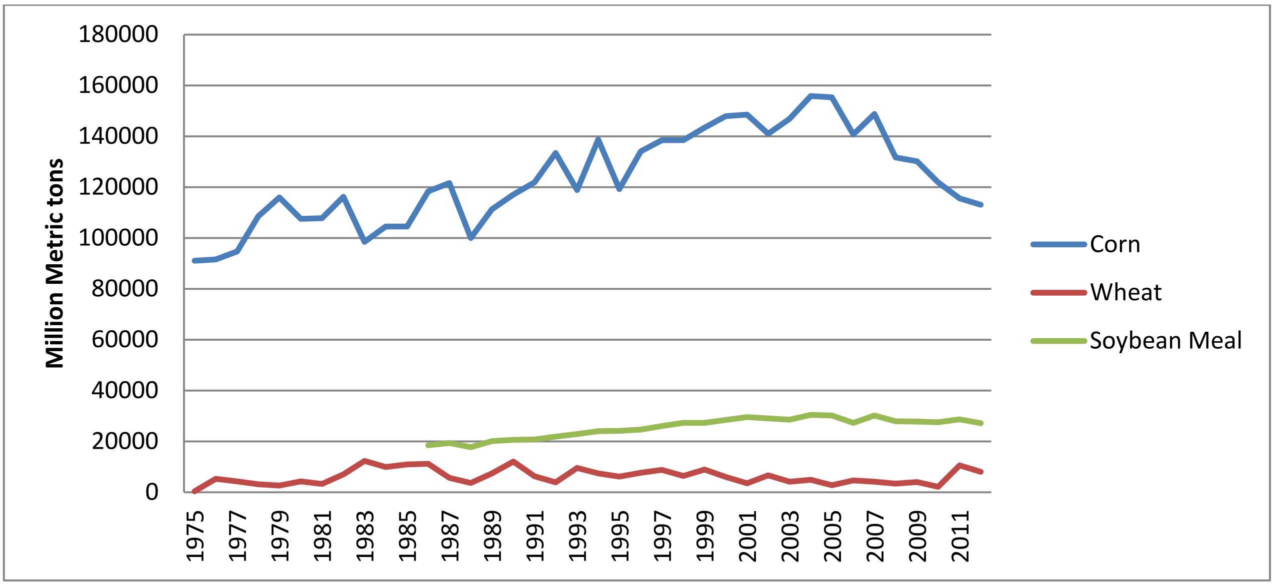

Figure 6 Feed and residual use in the United States (*Feed Grains Database* 2013).

Residual use is grains that are unaccounted for. It is gone and USDA does not know where it went (Vocke 2013). Often though, this is used for feed. We can see that corn is by far the most important grain for feed use, followed by soybeans and wheat. Raw soybeans can also be used as feed, but it is not included as feed data from the USDA was not found for raw soybeans. Other grains such as barley, sorghum and oats are also used for feed but they are not part of this study and are therefore not included. What we see is a decrease in the use of corn since 2005, which is when the RFS program was implemented. Some of the corn lost to ethanol is returned as dried distiller grains which is used as feed for cattle (Anderson et al. 2008).

Some animals are better than others at converting feed into weight gain. Feed conversion rates are used to measure how effective a feed diet is in converting the feed into weight gains. Feed conversion rates are important for determining the cost of a specific diet.

Table 1 Feed conversion: Grains required per gram of animal weight gain (Currie 2007).

	Hog	Cattle	Broiler
Feed conversion	3.1	8.3	2
Feed conversion relative to broiler	155 %	415 %	

Broilers have the highest feed conversion, followed by hogs and cattle. A relatively low number indicate little feed is needed for the animal to gain weight, while a large number requires large amounts of feed for the animal to gain weight. Feed conversion is an important measure to see if a diet is working properly. If feed conversion improves so does the income/cost ratio given that the price of the diet does not change.

Assume all an animal eat corn. One bushel equals 56 pounds. In the below table we see how price increases in corn affects feed costs for broiler, hogs and cattle.

Table 2 How corn price affects feed costs. $ per bushel: Corn price per bushel. $ per pound: Corn price per pound. Broiler, Hogs, Cattle: Feed cost per pound of meat produced

$ per bushel	$ per pound =($ per bushel/56)	Broiler =($ per pound×2)	Hogs =($ per pound×3.1)	Cattle =($ per pound×8.3)
5	0.09	0.18	0.28	0.74
6	0.11	0.21	0.33	0.89
7	0.13	0.25	0.39	1.04
8	0.14	0.29	0.44	1.19

The first thing we see in the table above is that it is cheaper to feed broiler, than it is to feed hogs and cattle. The second thing to take form this is that animals with higher feed conversion rates are hit harder by increases in feed costs. When the price of corn increases from $5-$6, costs for cattle producers increase by 15 cents per pound of meat, while costs for broiler producers only increase by 3 cents.

It is not that simple to evaluate how feed prices affect costs for meat producers. Cattle for example, make use of pasturing for feed and it is a cheaper way to gain weight than using corn is. This also explains how cattle production can be profitable. If all cattle ate were corn, the cost of feeding the cattle could at times be higher than the price of the cattle. Hogs and cattle also consume milk when it is born. Animals are being fed a range of feed grains, along with nutrient supplements. This complicates the analysis of how feed conversion rates is affecting costs.

Table 3 Feed expenses relative to farm expense (*Production Fact Sheet* 2007).

	Hog farms	Cattle farms	Broiler farms
Farm expense $billion	15.5	54.8	29.4
Feed expense $billion	6.8	11.5	17.1
Ratio Feed/Farm	44 %	21 %	58 %

This table is interesting because it says something about the importance of feed for different producers. Farms with relatively higher feed costs will have more troubles once feed prices increase, and production will be more responsive to changes in feed prices. More responsive production should also lead to meat prices being more responsive to grain prices. Feed costs account for as much as 58% of total broiler farm costs. Hog farms have a feed/farm ratio of 44%, followed by cattle farms at 21%. Other costs include purchase of livestock/chickens, labor, supplies, repairs, maintenance and interest rate costs. Except from purchase of livestock/chicken, the other categories are small in comparison (*Production Fact Sheet* 2007).

4 Stylized Facts on Grain and Meat Prices, 2000-2012

This section gives an overview of price movements and basic price relationships. At first the price data used is presented. Next there is a section on grain prices and one section on meat prices. At last, I will cover price relationships by looking at how grain prices have moved compared to meat prices. A table summarizing what is learned is found at the end of the chapter.

4.1 Choice of data

The price data used in this research is listed in the table below:

Table 4 Data type, source and pricing unit

Commodity	Type of data	Source	Pricing unit used
Corn	Futures	Chicago Board of Trade	$ per bushel
Wheat	Futures	Chicago Board of Trade	$ per bushel
Soybean	Futures	Chicago Board of Trade	$ per bushel
Lean Hogs	Futures	Chicago Mercantile Exchange	Cents per pound
Live Cattle	Futures	Chicago Mercantile Exchange	Cents per pound
Broiler	Spot	USDA	Cents per pound

The broiler prices are spot, since there is no futures market for broilers. Prices are quoted on Fridays each week and the period investigated is 2000-2012(2. Nov), which totals a number of 670 observations for each commodity. Weekly data was chosen because it was easy to gather and there are plenty of observations which increase the significance of test statistics. Higher data frequency such as daily data increases the noise. The futures prices are using the front contract, which is being rolled over once the current contract is expiring.

Corn, wheat and soybeans were chosen to include in this thesis because of its close relation to the meat market, but also because they are all large crops in terms of production volume. Hogs, cattle and broiler were chose because they are the three dominating meat products on the market.

4.2 Basic facts on prices

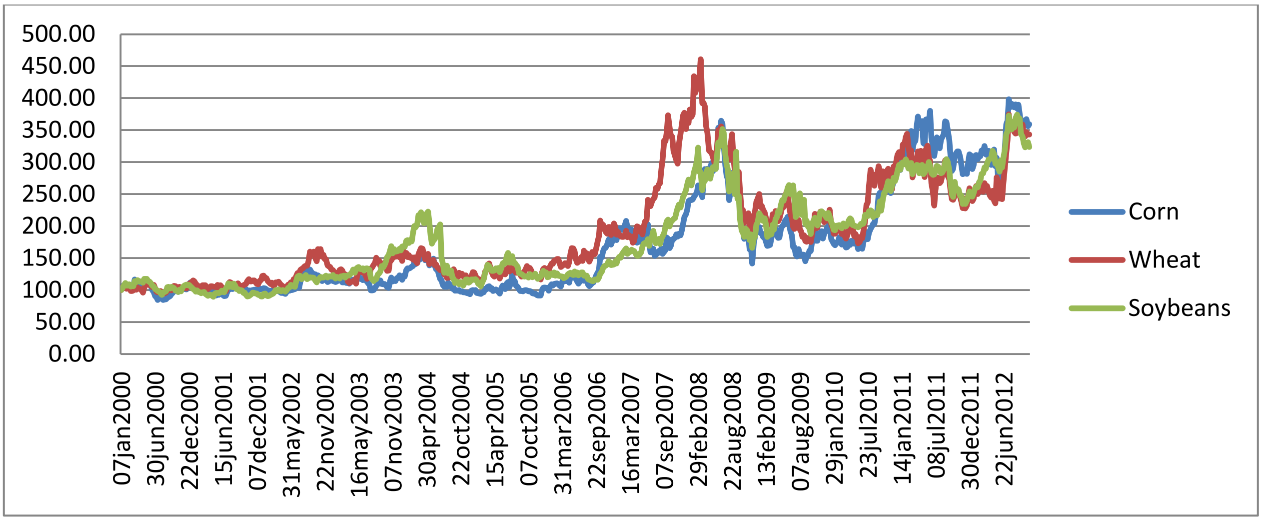

Figure 7 Indices for grain prices 2000-2012. Jan 2000 = 100

Grain prices quite clearly move together in the long run. The grains are substitutes in production so one expects the grains to move together. There have been some price bumps over the 12 year period. Adverse weather has contributed to many of the price bumps and it is an important factor in determining supply from year to year.

Since the start of 2006 grain prices have been soaring. Several factors have been pointed to as reasons for price increases since 2005 (Trostle 2010):

- Slow growth in production relative to consumption
- Demand for bio fuels
- Declining value of U.S. dollar
- Policies adopted to by importers and exporters to reduce home food price inflation

Production has not kept pace with consumption. This has reduced grain stocks and helped push grain price up. Demand from developing economies such as China has helped push the demand for grains up.

Production of bio fuel has increased rapidly since 2005, when the RFS was introduced. Acreage which were used to produce corn for feed use, is now used to produce corn for ethanol. The increased demand for corn have pushed prices of all grains up. Today, around 40% of the corn crop is used for ethanol production. According to data from USDA, alcohol for fuel use accounted for 43% of total corn use as of 2012, while it in 2000, accounted for 8% of the corn crop (*US domestic ...* 2012).

The dollar has gotten relatively weaker since 2000. A weaker dollar causes commodities quoted in US dollar to increase. The grain prices used here are all quoted in US dollars.

The last bullet point is also important. In 2010 the Russian government imposed a ban on wheat exports. This created bottlenecks and limited the supply of wheat to the world market. Countries importing from Russia had to look elsewhere, which in turn pushed prices up. Export restrictions create fear of shortages, which causes countries to stock up on grains and push prices further up.

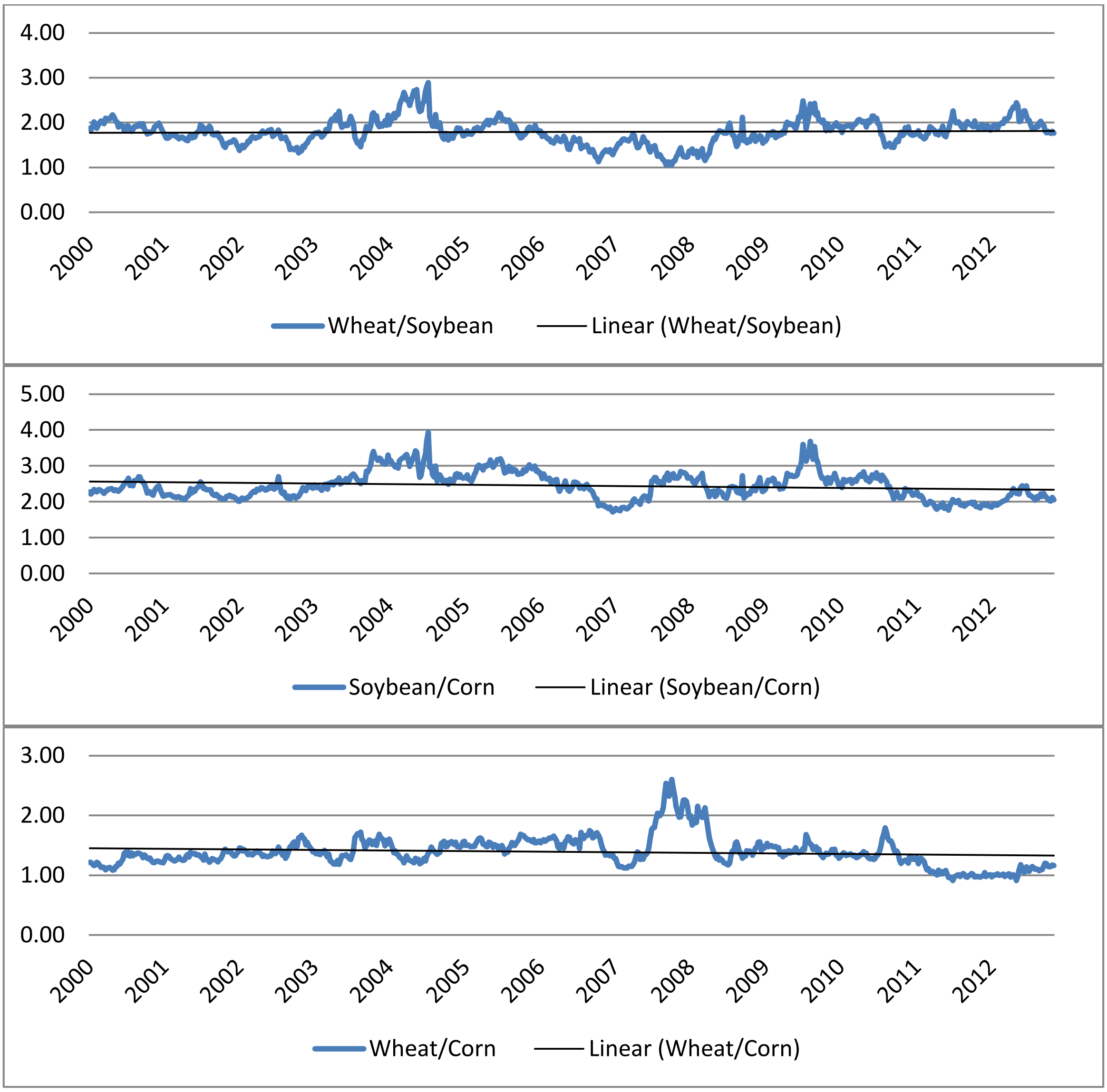

Figure 8 Grain price ratios, 2000-2012.

Relative prices are of greater interest than absolute prices. What is interesting here is to see if there are any trends in price ratios. A trend indicates that prices are moving away from each other. There does not seem to be any clear trends here. In periods prices are deviating from the long term mean, but returns after some time. The deviations have at times been large as seen in 2004 for soybean prices. That year, the soybean crop was terrible due to poor weather conditions. Long term deviations in price are not expected. If one grain consistently yield higher profits than the other grains, farmers will switch to that grain and rive relative prices back to the long run mean.

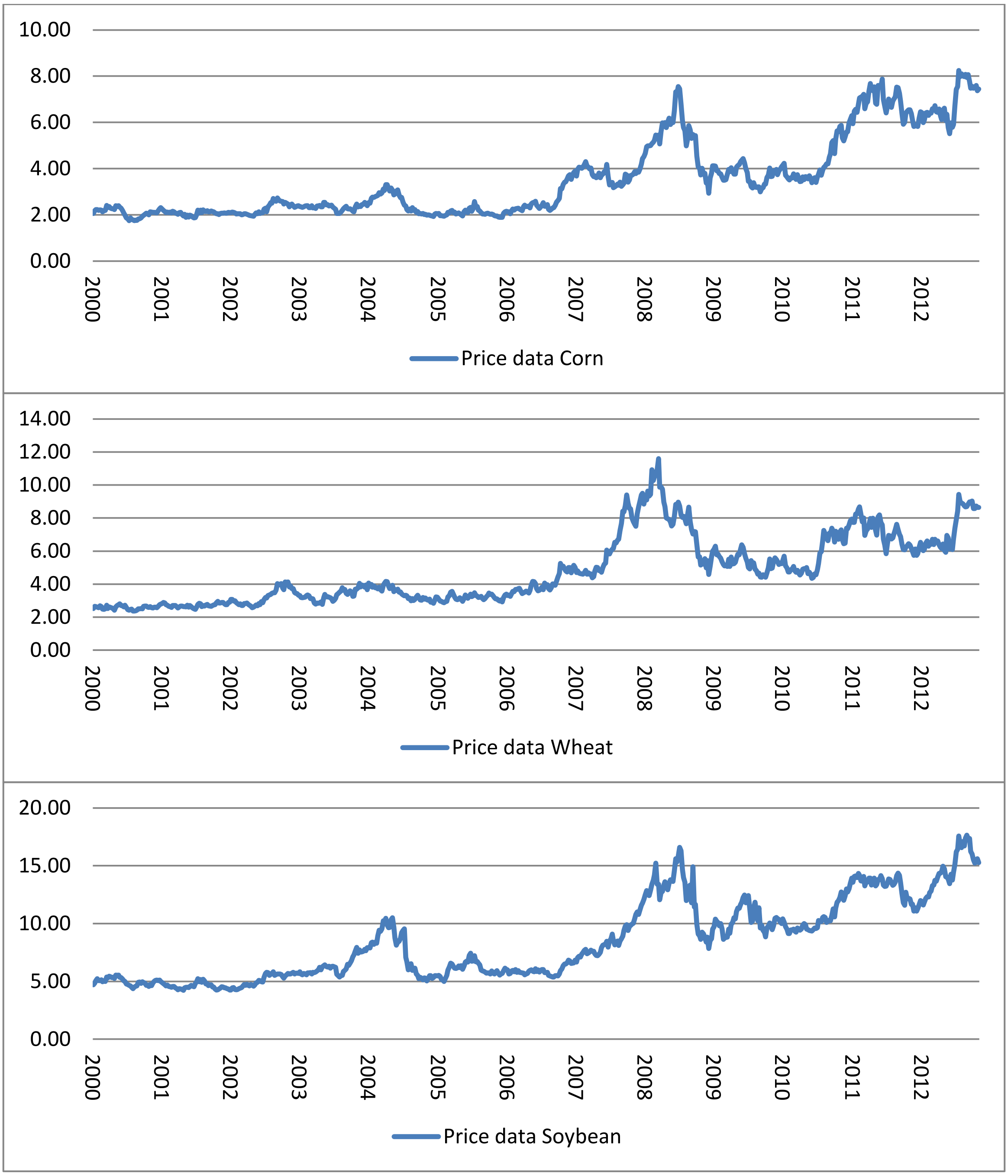

Figure 9 Grain prices. Dollars per bushel. 2000-2012.

Corn prices have increased from around $2 to $8, and reached an all time high in 2012. Wheat prices rose from around $2.5 to $9, and had an all time high just below $12 in 2008. Soybeans went from $5 to $15 and reached an all time high in 2012. At times corn was prices higher than wheat, but this was quite seldom.

Table 5 Means and Standard Deviation, log returns 2000-2012, annualized

	Return	Standard deviation
Corn	0.0441	0.14
Wheat	0.0425	0.14
Soybeans	0.0405	0.13

Corn, wheat and soybeans have similar returns and standard deviations. This exemplifies how closely related these markets are. And it is also a testimony for market efficiency. When returns in one grain deviate from another, the market brings returns back to equal levels. Investing in the commodities would yield about the same return and risk.

In this next section, I will be focusing on meat prices, in the same way I did for grain prices.

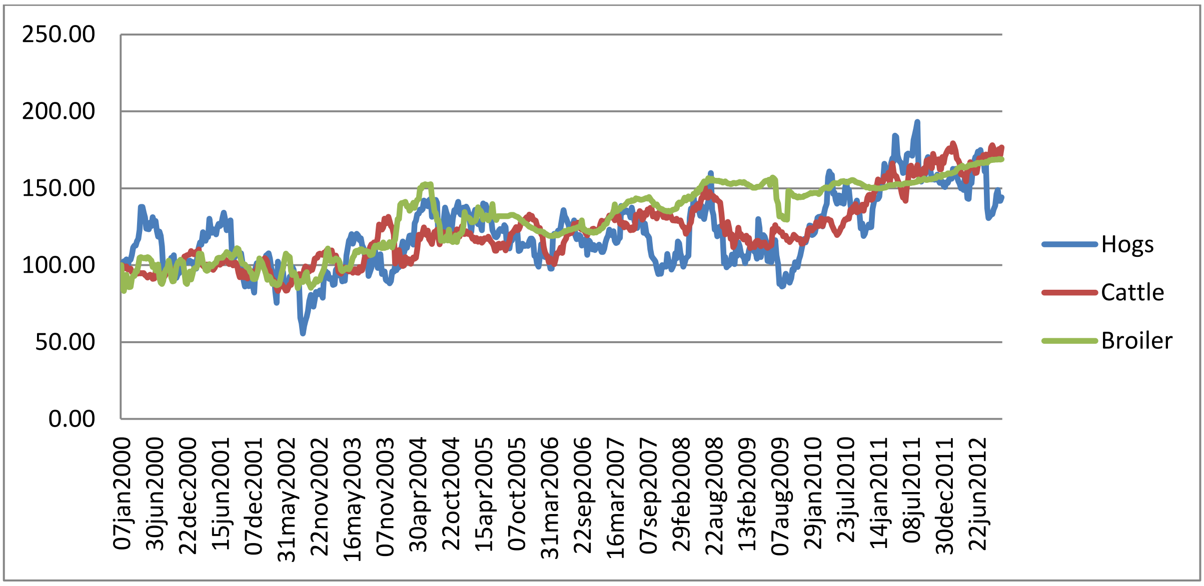

Figure 10 Indices for meat prices 2000-2012. Jan 2000 = 100

These indices look uninteresting in comparison to that of grain prices. Prices have had moderate increases, with some variation around the mean. We can see a price bump in 2003 and again in 2010 for all meat prices. The same price bump was seen for grains in 2010.

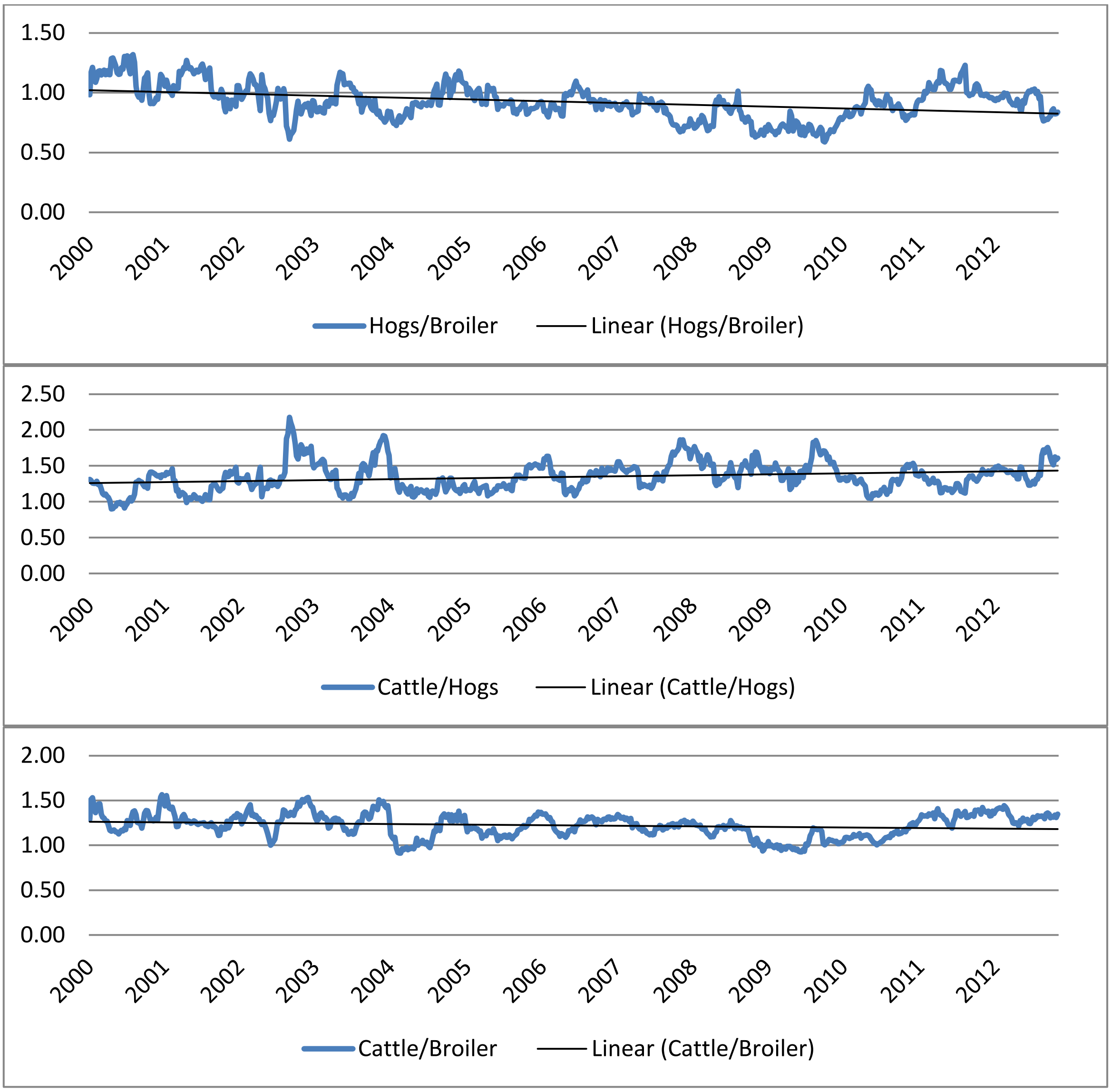

Figure 11 Meat rice ratios. 2000-2012.

The Hogs/Broiler price ratio is trending downwards with broiler prices increasing more than hog prices. Looking at the Cattle/Hogs price ratio it seems as cattle have been increasing relative to hogs as well. In general though, the prices seem to follow each other quite closely.

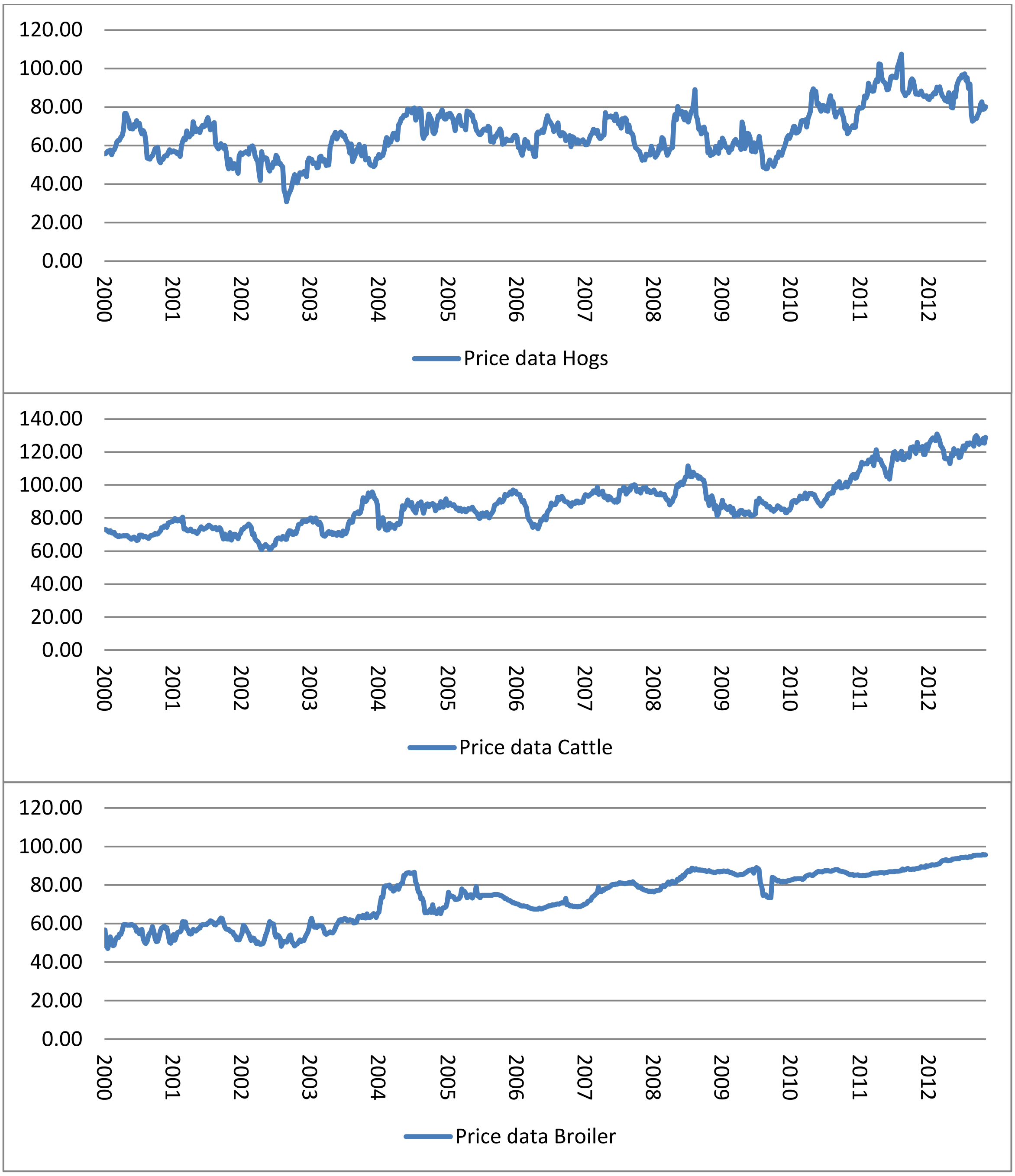

Figure 12 Meat prices. Cents per pound. 2000-2012.

The hog price has been moving from around 60 to 80 cents. The cattle price has been moving from 70 to 110 cents. Broiler has gone from 50 to 90 cents.

Table 6 Means and Standard Deviation for log returns, 2000-2012, annualized.

	Return	Standard deviation
Hogs	0.0124	0.16
Cattle	0.0194	0.07
Broiler	0.0178	0.07

Hogs have the highest standard deviation and the lowest returns. All three meats are poor investments as returns are at levels below what is expected for a riskless asset.

In the following section I will look at grain and meat prices combined. The section is a bit different from those above, because emphasis is now on price relationships between grain and meat prices.

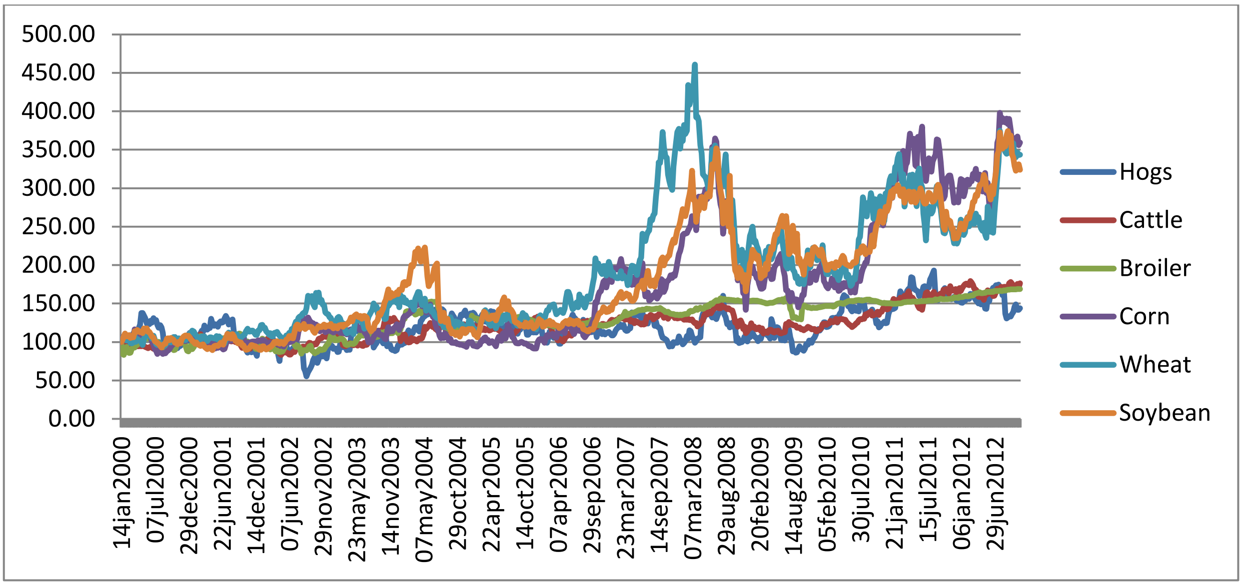

Figure 13 Indices for meat and grain prices combined 2000-2012. Jan 2000 = 100

The graph above displays the indices for grains, along with the indices for meats. Based on these indices, it is difficult to see any connection between grains and meats. Meats appear to be stationary, while grains have been trending upwards. There are signs of hog prices temporarily moving opposite to that of grain prices. This is seen in November 2002, and again in 2007.

Table 7 Correlation matrix for prices 2000-2006 and 2006-2012

		2006-2012					
		Hogs	*Cattle*	*Broiler*	*Corn*	*Wheat*	*Soybean*
2000-2006	Hogs		0.75	0.56	0.68	0.25	0.51
	Cattle	0.41		0.66	0.85	0.52	0.73
	Broiler	0.63	0.67		0.73	0.49	0.79
	Corn	-0.10	0.04	0.33		0.71	0.91
	Wheat	-0.17	0.42	0.44	0.71		0.79
	Soybean	0.23	0.40	0.70	0.80	0.73	

Correlation measures the association that one variable has to another. It does not say anything about causal correlations, non linear relationships or lagged price associations. The grey fill identifies increases in correlations from the first period to the second period. In the lower left corner of the matrix are correlations for 2000-2006, while it in the upper righnert co is correlations for 2006-2012. For the first period, corn and wheat have a negative relationship with hogs. Those are however the only observations with a negative relationship. The other meats have positive correlations with the grains. A not so surprising observation is that correlations among the grains are higher than correlations among the meats. Grain markets are recognized as being closely connected through competition for acreage. Only three correlations were found to decrease from the first period to the second period.

Corn is the most important feed for livestock and broiler, which is why it is the grain used for the price ratios below. The plots would however be similar if one of the other grains had been used instead of corn.

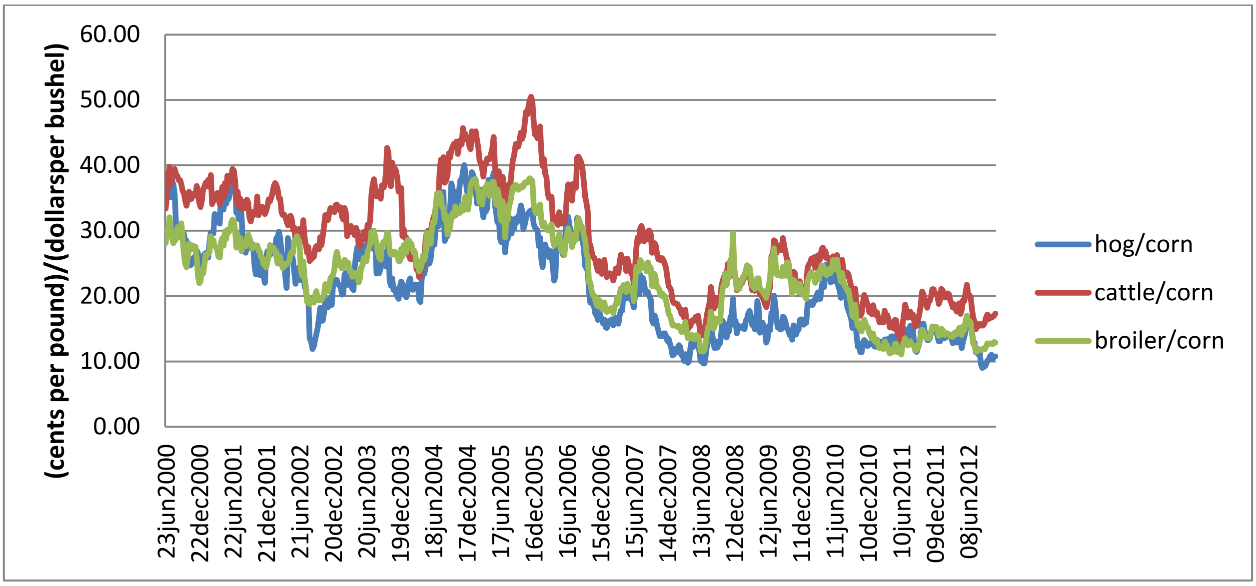

Figure 14 6 month moving average for meat/corn price ratios. 2000-2012.

Meat/corn price ratios are used as an indication of profitability for producers as it is the main feed input to production. High price ratios indicate high meat prices relative to corn prices, and thus signal higher profitability for meat producers. Since 2005, ratios have sunk to historically low levels and it signals a shift in what is considered a normal ratio. The rule of thumb for hogs was that ratios above 18-20 signaled an increase in hog inventories, while a ratio below that signaled a decrease in inventories (Lawrence 2006).

Table 8 Descriptive statistics for ratios 2000-2012

	Hog/Corn	Cattle/Corn	Broiler/Corn
Mean	21.87	28.59	23.53
Standard Deviation	7.78	8.46	6.81

The ratios have similar means and standard deviations. The mean for hog/corn ratio is at 21.87, which is above the rule of thumb mentioned. Ratios were at first around 30.40, but decreased significantly following the introduction of the RFS in 2006. The ratios seen from 2000-2012 are about the same as the historical rates going back to the 1970’s (Irwin & Good 2012). This helps put the ratios seen the last 6 years into perspective, and makes one wonder whether ratios will return to an average of 20-30.

4.3 Summary of stylized facts

Subject	Findings
Grain prices	Grain prices follow each other closely, and they have similar variations in price.
Meat prices	Meat prices follow the same long term trends, but prices behave differently in the short run. Hogs have larger variations in price than broiler and cattle. Hog prices have decreased relative to broiler and cattle.
Meat and grain price relationships	There seem to be a relationship among meat and grains. Cattle seem to have a good fit with soybeans and corn. Hog and corn returns were found to have a negative relationship in the short run. Meat/corn ratios have declined significantly since 2005, signaling that meat and corn prices lack a common long term trend. Correlation among commodities have in general increased over the period 2000-2012

5 Econometrical Analyses of Grain and Meat Prices

In the econometrical analyses, I will often refer to the price or return of a commodity by only referring to the commodity itself. If I refer to something else, it will be made clear in the text. This is done to avoid having to refer to prices or returns all the time.

5.1 Test for non-stationarity

If variables that are trending over time are regressed upon each other, you run the risk of finding spurious correlations. A spurious correlation is one in which a connection is found when there is no real connection between the variables. When running regressions with non-stationary variables you run the risk finding spurious connections. Therefore it is of interest to have stationary variables. The best way to see of prices are stationary is to draw a line plot. If prices appear to be non-stationary, regressions using price levels should not be used. Another reason to want stationary variables is that t-statistics will follow a t-distribution, which enables hypothesis testing on regression coefficients.

The price plots in the previous chapter the prices appears to be non-stationary and can therefore not be used in regression analysis. Because many of the variables are non-stationary, a method to transform prices into stationary data is necessary. Here I have used log returns to transform the data. To test if price levels and log returns are non-stationary an Augmented Dickey Fuller (ADF) test is used. The lag length for the ADF test was chosen using Akaike Information Criteria (AIC)[3]. Autoregressive (AR) models of the following form were run for both price levels and log returns to test for optimal lag length:

$$\Delta P_t = \alpha + \gamma P_{t-1} + \beta_1 \Delta P_{t-1} + \cdots + \beta_{10} \Delta P_{t-10} + \varepsilon_t$$

Maximum lag was set to 10, and the lag length with the lowest AIC value was chosen to use in the ADF test. The ADF test was run with an intercept, and with and without a trend.

[3] Optimal lag lengths chosen are found in Appendix 2

Table 9 ADF test statistics for prices and log returns, with and without a trend. * Statistical significant at 5%

	Prices		Log returns	
	No trend	With trend	No trend	With trend
Hogs	-2.692	-3.694*	-26.646*	-26.626*
Cattle	-1.057	-3.308	-27.532*	-27.525*
Broiler	-1.209	-3.505*	-12.030*	-12.027*
Corn	-0.386	-2.232	-17.981*	-17.989*
Wheat	-1.372	-2.755	-26.352*	-26.335*
Soybean	-1.193	-3.304	-27.515*	-27.499*

From the test statistics we can see that hogs and broiler were found to be stationary when a trend was included. All variables were found to be stationary when returns were used. As log returns are found to be stationary, it will be used in regressions in place of price levels. As some of the price series are stationary, a co-integration analysis cannot be conducted as it requires non-stationary variables.

5.2 Autocorrelations and Autoregressive Models

In this chapter I will present autocorrelation (AC) plots and autoregressive models for each commodity price. This is done to get a better understanding of the dynamics within each variable. AC plots can answer whether there is a need for an AR model, and if there is, how many lags should be included. Significant correlation signals that past values can be used to predict future values. When a lag is observed inside the confidence interval, we cannot conclude on the lag being different from zero.

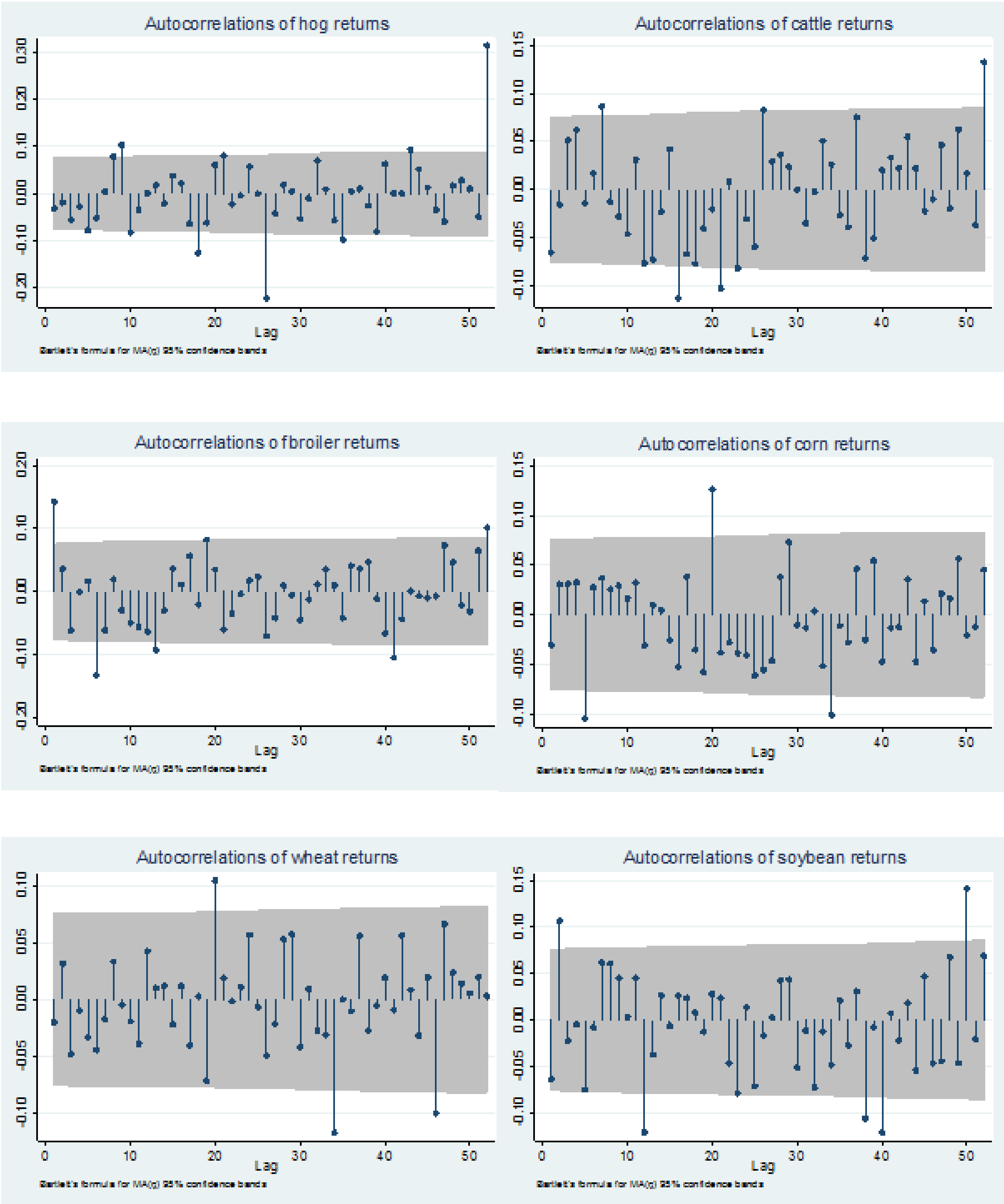

Figure 15 Autocorrelation plots for all 6 price returns. The grey band is the 95% confidence interval

There is no clear indication of autocorrelation based on these plots. Most lags are insignificant and those who are not have coefficients just outside the 95% confidence band.

Most commodities exhibit some sort of a pattern. Cattle in particular seem to have a pattern. The significant lags appear to be random as explanations for them are difficult to find.

AR models are used to see if past values can explain present values in a variable. If past values explain current values it is an evidence of dynamics within that variable. Another way to use these models is to test for an efficient market. If past values can explain current values we have an inefficient market. In an efficient market, agents take advantage of the information to make money off it. This goes on until prices adjust and the information become useless. The AR models were estimated by the following equation:

$$\Delta \log P_t = \alpha + \beta_1 \Delta log P_{t-1} + \cdots + \beta_{10\Delta} log P_{t-10} + \varepsilon_t$$

The lag length for the AR model was chosen by setting a maximum lag at order ten and reducing the number of lags if the last lag is found to be insignificant. This is common way to find the appropriate lag length for an AR model (Koop 2008 p. 189).

Table 9 AR results. Beta coefficients, and R^2 are reported. *, **, * Statistical significant at 5%, 1% and 0.1%. Grey fill identifies a significant variable.**

	Hogs	Cattle	Broiler	Corn	Wheat	Soybean
Lag 1	-0.042	-0.07	0.148***	-0.0287	-0.02	-0.0582
Lag 2	-0.0211	-0.0158	0.0913*	0.0332		0.111**
Lag 3	-0.0522	0.0469	-0.0714	0.0379		-0.00202
Lag 4	-0.0299	0.0641	-0.0372	0.03		-0.0202
Lag 5	-0.0851*	0.00	0.0504	-0.105**		-0.0826*
Lag 6	-0.0583	0.02	-0.146***			-0.00972
Lag 7	-0.00726	0.0835*				0.0775*
Lag 8	0.068					
Lag 9	0.0953*					
Lag 10	-0.0830*					
R-sq	0.037	0.019	0.059	0.015	0	0.027

Hogs have significant lags at order 5, 9 and 10. It looks like some sort of lagged response every fifth week. Broiler has significant and positive lag coefficients at order 1, 2 and 6. Soybeans also have some significant lags. Wheat on the other hand has none.

R^2 values are next to nothing, signaling that past values explain very little of the variability of current values. It is not surprising given that these are markets that are quite heavily traded and it should not be possible to use past values to predict future values in such a market. Broiler has the highest R^2 value. The broiler market is also the only cash market and it is therefore more difficult to take advantage of the information available in past prices.

When comparing the AC plots and the AR results, one sees a clear connection between the two. For hogs, the six first lags in both the autocorrelations plots and the AR model are negative. The same connection is seen for the other commodities as well.

5.3 Regressing the meat/corn relationship over time

The following regressions reveal how this ratio is developing over time:

$$log\left(P^{meat}/_{Pcorn}\right)_t = \alpha + \beta_1 TIME + \varepsilon_t$$

Interpretation of β_1: Holding all else fixed, $\beta_1$measures the percentage change in price ratio from one week to another due to time passing.

Table 10 Beta coefficients for price ratio regressions. * Statistical significant at 5%.

	β_1	Explanation
Hog/corn	-0.0002*	Price ratio decreases by 0.02% from one week to another due to time passing
Cattle/corn	-0.00017*	Price ratio decreases by 0.017% from one week to another due to time passing
Broiler/corn	-0.00015*	Price ratio decreases by 0.015% from one week to another due to time passing

All beta coefficients were found to be statistical significant. The negative sign tells us what we already know, namely that the price ratio is decreasing over time. Moreover we see that the hog/corn ratio decreases the most due to the passage of time.

5.4 Autoregressive Distributed Lag Models

The ADL model is estimated using past values of itself and other commodities along with contemporary values of other commodities. The model below is a simplification of the model run, using only one lag and two commodities:

$$\Delta \log P_{1_t} = \alpha + \beta_1 \Delta logP_{1_{t-1}} + \beta_2 \Delta logP_{2_t} + \beta_3 \Delta logP_{2_{t-1}}$$

The model is used to determine if there are dynamic effects between the variables. In other words it shows if past and contemporary values of one variable can be used to predict current values of another variable. The model is autoregressive because it consists of lags for the explained variable, while lags for the explanatory variables make it distributed. The model is an OLS model. What the ADL model does is to treat autocorrelation as dynamics in the model rather than disturbances.

Maximum lag length was set to six. It is unreasonable to assume that returns beyond that should have an effect on current week's return. One lag for all commodities was removed if no significant lags at that order. Six lags should be sufficient to capture the dynamics. Not all regressions had significant lags at order six, which is why some regressions have less than six lags for each commodity. The procedure is referred to as a sequential testing procedure (Koop 2008 p.189).

Table 10 ADL results. Beta coefficients, R^2 and number of observations are reported. *, **, * Statistical significant at 5%, 1% and 0.1%. Grey fill identifies significance.**

	Hogs	Cattle	Broiler	Corn	Wheat	Soybean
Hogs		0.0667***	-0.00459	-0.0506*	-0.00165	0.0306
Lag 1	-0.0687	-0.0193	0.0161	0.0021	0.00794	-0.0121
Lag 2	-0.0368	-0.0123	0.0417**	0.0271	-0.015	0.00167
Lag 3	-0.0773*	0.00422	0.012	0.00387	-0.00617	0.0307
Lag 4	-0.0341	-0.0171	-0.00296	0.0509*		-0.0423
Lag 5	-0.112**		0.0262			
Lag 6	-0.0599		0.0418**			
Cattle	0.312***		0.0392	0.0438	0.0146	0.0906
Lag 1	0.131	-0.064	0.0226	-0.0728	0.0596	0.0484
Lag 2	0.0565	-0.00643	0.0226	-0.0329	0.133*	-0.0528
Lag 3	0.061	0.0522	-0.0677*	-0.0485	0.0705	-0.0216
Lag 4	-0.0598	0.0838*	-0.0451	0.000231		-0.00441
Lag 5	-0.0318		-0.0542			
Lag 6	-0.203*		0.0364			
Broiler	-0.0296	0.0537		0.0106	-0.0342	0.0211
Lag 1	0.0946	-0.0281	0.136***	0.0535	-0.0703	0.00495
Lag 2	0.125	-0.0589	0.0959*	-0.00817	0.0261	0.0142
Lag 3	0.283**	0.028	-0.0756	-0.0384	-0.0526	0.0382
Lag 4	0.104	0.0305	-0.0671	0.0402		0.0802
Lag 5	-0.0994		0.0305			
Lag 6	0.116		-0.156***			
Corn	-0.140*	0.0271	-0.00022		0.678***	0.498***
Lag 1	0.0636	0.00812	-0.0248	-0.0292	0.0083	0.0953*
Lag 2	0.0385	-0.016	0.00859	0.0439	-0.134**	0.0693
Lag 3	0.000568	-0.0309	0.048	0.0197	-0.0186	0.0625
Lag 4	0.0547	-0.0104	0.00362	-0.0126		0.127**

Lag 5	0.00449		0.0493			
Lag 6	-0.0166		0.0376			
Wheat	-0.0089	0.00493	-0.00496	0.487***		0.0125
Lag 1	-0.0778	-0.0203	0.0394	-0.0339	0.00175	0.0173
Lag 2	0.0256	0.0203	-0.0139	-0.0256	0.0691	-0.0173
Lag 3	-0.0298	0.00999	-0.0189	0.0345	-0.0840*	0.00135
Lag 4	-0.177**	-0.0208	-0.00889	0.00605		0.00421
Lag 5	-0.0487		-0.0209			
Lag 6	-0.0814		-0.0243			
Soybean	0.0726	0.044	0.0123	0.391***	0.00405	
Lag 1	-0.00971	0.00311	0.0168	0.0176	0.0292	-0.121**
Lag 2	-0.00485	-0.0143	0.0373	-0.04	0.0813*	0.0387
Lag 3	0.0406	0.0479	-0.0515*	-0.0483	0.0940*	-0.0564
Lag 4	0.120*	-0.0211	0.00461	0.0627		-0.124**
Lag 5	0.0143		-0.0219			
Lag 6	0.0406		0.0181			
adj. R-sq	0.068	0.022	0.082	0.53	0.414	0.317
Obs	663	665	663	665	666	665

The explained variable is found horizontally, while the explaining variables are found vertically. The constant is not included in the summary table and is not interesting for this purpose. R^2 values are not to be compared across equations because equations with more lags will yield higher values and it is therefore not fair to compare equations that way. What seems quite clear from the R^2 values however is that variables explaining the grains explain much more of the variability, than the is the case for meats. The main reason for that is that contemporary grain variables have very large explaining power on other grains.

My findings showed that all commodities were useful in explaining hogs. An increase of 10% in corn one week decreases hogs by 1.4%. An increase by 10% in cattle one week is met by an increase of 3.1% in hogs the same week. Further, an increase of 10% in cattle six weeks ago will increase hog by 2% this week. A 10% increase in broiler increases hogs by 2.8%, three weeks later.

The other agricultural commodities are in general doing a poor in explaining cattle. R^2 are at 2%, which means that the other commodities explain only 2% of the variation in cattle. It is by far the lowest R^2 value of the equations run. Contemporary prices of hogs and were found to be significant, though the parameter value is low, which signals a small effect on cattle.

Broiler is well explained by hogs, cattle and own lags. Soybeans four weeks ago are also useful in explaining broiler. No variables are found to have a very strong effect on broiler. It is broiler's own lags which have the strongest effect on current returns.

Corn is explained by current hog prices, though the coefficients are quite small. The coefficient is also negative signaling that corn decreases when hogs increase. A connection is expected given hogs large consumption of corn. A 10% increase in wheat and soybean increases corn by 4.9% and 3.9%. Keep in mind that this is marginal effects, so if wheat and soybean increases by 10% the same week, corn does not increase by 8.8% (add up 4.9% and 3.9%).

Cattle are the only meat useful at explaining wheat. A 10% increase in cattle increases wheat by 1.3% in two weeks. When corn increase by 10% one week, wheat increase 6.8%. This shows just how close the wheat and corn are connected. Soybean returns two and three weeks ago are also explaining wheat. The coefficients are small though.

No meat prices were found to explain soybeans. Only past corn returns, in addition to own lags are useful in explaining soybean. A 10% increase in corn increases soybeans by 5% the same week. Corn also explains soybeans one and four weeks ahead. Wheat is not explaining soybeans.

5.5 Vector Auto Regression and Granger Causality

The VAR model is a system of equations where all variables are endogenous. The model allows for dynamic interactions among the variables. Similar to the ADL model, the VAR model includes past values of the explained variable and past values of the explaining variables. The VAR model does not include contemporary values of the other commodities, as the ADL model did.

A common way to choose optimal lag length is to use an information criterion. Using AIC to choose lag length yielded a lag length of zero. It is impossible to do a VAR model with no lags. Another way to choose lag length is to use a sequential testing procedure. The way I did it was to choose a model with (x) lags and test that model versus a model with (x-1) lags. If the former model does not provide a significant difference from the latter model, the latter model will be tested versus a (x-2) lags model. The procedure goes on until there is a significant difference between models. A Likelihood ratio (lr) test was used to test models[4]. The maximum lag was set to eight and the significance level required to choose a model was set to 0.10. A lag length of 5 was found to explain significantly more than a lag length of 4 and was therefore chosen.

Interpreting the VAR results as causality should be done with care. Even with sound economic theory behind the model, one cannot be certain whether it is X causing Y or Y causing X. And one cannot know whether X is just explaining Y or if it is causing Y. That is why Granger Causality is commonly used to illustrate the relationship between two variables. When X is found to lead Y it means that X might cause Y, or at least have explanatory power on future values of Y. Using past values is better than using contemporary values when trying to prove causality. With contemporary values it is more difficult to say which commodity is causing the other. The null hypothesis of the test is that there is no Granger Causality. A low p-value increases the probability of the null hypothesis being incorrect.

A VAR model using the moving average of four weeks was also used to test if results differed from when using weekly data. The lag length was set to two for that model[5]. The results of the Granger Causality test for the moving average VAR model is found in Appendix 11.

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[4] Observations between models tested were not equal, but the test was still carried out. Results of the lr test is found in the appendix

[5] No formal test for lag length was completed as it is not taken into consideration when making the conclusion.

Table 11 Explanation of Granger Causality tables

Explanation	
Equation	Explained variable.
Excluded	Commodity that is excluded from the equation. It is excluded in order to test if that commodity had no significant effect on the explained variable.
chi2	Chi square test statistic.
df	Degrees of freedom.
Prob > chi2	P-value used to test if the removed parameters had no effect on the explained variable. A + sign behind the p-values signals significance at 10% level, while a grey fill signals significance at the 5% level.

Table 12 Granger Causality on hogs

Equation	Excluded	chi2	df	Prob > chi2
Hogs	Cattle	2.7758	5	0.735
Hogs	Broiler	18.176	5	0.003
Hogs	Corn	3.1767	5	0.673
Hogs	Wheat	16.94	5	0.005
Hogs	Soybean	3.8102	5	0.577
Hogs	ALL	44.652	25	0.009

Broiler and wheat was found to lead hogs at the 5% level. All commodities were found to lead hogs.

Table 13 Granger Causality on cattle

Equation	Excluded	chi2	df	Prob > chi2
Cattle	Hogs	5.3344	5	0.376
Cattle	Broiler	3.659	5	0.599
Cattle	Corn	0.82284	5	0.976
Cattle	Wheat	3.4442	5	0.632
Cattle	Soybean	7.4082	5	0.192
Cattle	ALL	25.783	25	0.419

No commodities were found to lead cattle.

Table 14 Granger Causality on broiler

Equation	Excluded	chi2	df	Prob > chi2
Broiler	Hogs	10.351	5	0.066+
Broiler	Cattle	9.3579	5	0.096+
Broiler	Corn	7.8166	5	0.167
Broiler	Wheat	4.8977	5	0.428
Broiler	Soybean	10.315	5	0.067+
Broiler	ALL	39.924	25	0.03

Hogs, soybean and cattle were all found to lead broiler at the 10% level. All were found to lead broiler at the 5% level.

Table 15 Granger Causality on corn

Equation	Excluded	chi2	df	Prob > chi2
Corn	Hogs	6.1345	5	0.293
Corn	Cattle	2.7374	5	0.74
Corn	Broiler	8.307	5	0.14
Corn	Wheat	4.0756	5	0.539
Corn	Soybean	4.0207	5	0.546
Corn	ALL	23.641	25	0.54

No commodities were found to lead corn.

Table 16 Granger Causality on wheat

Equation	Excluded	chi2	df	Prob > chi2
Wheat	Hogs	1.3379	5	0.931
Wheat	Cattle	3.9597	5	0.555
Wheat	Broiler	3.5776	5	0.612
Wheat	Corn	13.657	5	0.018
Wheat	Soybean	10.707	5	0.058+
Wheat	ALL	28.396	25	0.29

Corn was found to lead wheat at the 5% level. Soybean is also leading wheat at the 10% level.

Table 17 Granger Causality on soybean

Equation	Excluded	chi2	df	Prob > chi2
Soybean	Hogs	7.2778	5	0.201
Soybean	Cattle	0.90668	5	0.97
Soybean	Broiler	5.6668	5	0.34
Soybean	Corn	15.682	5	0.008
Soybean	Wheat	0.83813	5	0.975
Soybean	ALL	36.938	25	0.059+

Corn was found to lead soybeans. All commodities were found to lead soybeans at the 10% level.

One should be careful at putting too much emphasis on findings at the 10% significance level. 1 out of 10 significant findings will on average be incorrect when significant at the 10% level. For the VAR model it is useful to compare R^2 estimates as the same number of lags is used for all commodities and no contemporary values are included[6]. 9% of the variation in broiler is explained by the variation in the other variables. Hogs and soybeans had R^2 at 7%. Cattle, corn and wheat only had R^2 values at 4%

When using the moving average VAR model, slightly different results were found for the GC test. There were three findings that were common for both the moving average, and the weekly GC test; broiler leads hogs, all commodities lead hogs and corn lead wheat. Three findings were unique for the weekly GC test; wheat lead hogs, all commodities lead broiler and corn lead soybeans. Two findings were unique for the moving average GC test: Soybeans lead wheat and all commodities lead soybeans. This being said, p-values did not differ a lot from the two GC tests, such that one should not put too much emphasis on unique findings.

[6] R^2 values are found in Appendix 4

5.6 Summary of results

Table 18 Summary of econometrical results based on subject

Subject	Chapter	Finding
Dynamics within each commodity	5.2	The autocorrelation plots showed signs of seasonality or trends in the data. Significant lags appear to be random.
Long run price relationships	5.3	Meat/Corn ratios are decreasing due to time passing. Hogs/corn ratios decrease the most.
Short run price relationships	5.4, 5.5	Negative contemporary relationship between hogs and corn. Positive relationship between hogs and cattle, corn and soybeans, corn and wheat. Broiler, wheat and all commodities lead hogs. All lead broiler. Corn leads wheat. Corn leads soybean.

6 Discussion

6.1 Price relationships within the grains and meats

In the AC plots and AR models prices were found to show signs of seasonality, or at least some sort of a pattern. That being said, there was only a few significant lags in each return series and those lags seemed to be a bit random. Speculators might be able to take advantage of the apparent seasonal trends in the commodity prices.

Dynamics within grain prices and dynamics within meat prices were found to be more significant than the dynamics between grain and meat prices. This is in line with expectations. Similar markets tend to be more closely connected than markets with fewer similarities.

Grain prices are closely connected in the short run. Soybean & corn and corn & wheat had strong connections. In particular, the contemporary connections were strong. Soybeans and corn compete for acreage as the two have the same growing regions in the US. So a drought in the region affecting corn will also have an effect on soybeans. The two are also connected as they are both important feed inputs. Wheat and corn are related through competition for feed use. When corn prices increase, meat producers will look to wheat for replacing corn as feed. Corn prices were found to lead both wheat and soybean prices. Corn prices do seem to be the most influential grain price.

For meats, the strongest contemporary connection was between hogs and cattle. They are substitutes in consumption, so the finding is in line with expectations. It is not clear which commodity is causing the other as prices are set at the same time. Broiler was found to lead hogs. The two meats are substitutes in consumption and prices are expected to be related to each other. In the long run, meat prices move in the same direction, but cattle and broiler have increased more than hogs.

6.2 Long run price relationship between grains and meats

The price plots revealed no obvious connections between meats and grains. Prior to 2006, prices looked to be moving in the same direction with moderate increases for most commodities. Since then, grain prices have increased significantly while meat prices have stayed on same path. In 2010, meat prices did have a little jump though. Perhaps grain prices had an effect here.

The meat/corn price plot showed decreasing ratios and it looks to be stabilizing at these low levels. The question that remains to be answered is whether the ratio will return to more "normal" levels. It has been argued that a new era of crop prices has begun (Irwin & Good 2009). Given that crop price remain high; something will need to happen to meat prices for ratios to increase to "normal" levels. Grain prices have increased, which should push meat supply down and prices up. We are yet to see such an increase in meat prices. To explain why meat prices have not increased more it is useful to look at the forces of supply and demand. The demand has probably increased as a consequence of increased population. This has pushed price up by some, but not enough to explain the huge deviations seen from "normal" meat/corn ratios. By looking at the supply equation in chapter 3.1, we see that the price of grains (feed), other inputs, institutional factors and technology affects supply. As we are evaluating prices in the long run, supply should be elastic and able to change. Since increasing feed prices lead meat prices to increase, other factors in the supply equation must have pushed the prices down. Costs of labor, supply of livestock/eggs, capital costs have all increased, so it cannot explain why prices have only had moderate increases (*Production Fact Sheet* 2007). What is left in the equation is institutional factors and technology. No major changes to institutional factors have been found and they more often lead to cost increases, rather than decreases. There must have been some increases in technology over the past few years which have reduced the pressure on prices. Examples of increasing productivity are more animals per square feet, higher feed conversion ratios, new and cheaper sources of feed and more effecting processing. A paper reviewing the hog industry found that productivity gains likely contributed to a 30% reduction in the price of hogs for the period 1992-2004 (Key & McBride 2007). Larger and more specialized operations have attributed to the cost reductions. Significant productivity gains have probably taken place in the broiler and cattle industry as well. This being said, improvements in technology can not alone explain why meat prices have not increased further, and the reports above was based on periods prior to 2006. In the introductory chapters, I made a distinction between short run and long run. In the long run, supply is assumed to be elastic and able to change once grain prices increase. It seems as if it takes several years for meat prices to respond properly to the grain price increases, which can be explained by an inflexible industry. Its inability to respond quickly to increasing feed costs by reducing the supply of animals leads meat prices to respond slowly to changes in grain prices. This is probably why one has not seen meat prices increase more.

Since Jan. 2011, hog and cattle producers have at times been producing with losses (Henderson & Kauffman 2012; Hunt 2012). This cannot continue and I therefore expect herd liquidation and rising prices over time. It shows that, despite any increases to productivity, grain prices are too high for meat producers to be producing with profits. This is interesting as there might be a lower limit to meat/corn prices ratios around 10-15, as producers are facing losses at these ratios. This is an opportunity for speculators to invest in meat as chances are that meat prices will increase at these ratios as producers can only produce with losses for so long.

The meat/corn price ratio is not of equal importance for all meat producers. Corn (and other feed) costs are more significant for hog and broiler farmers than for cattle farmers as seen in the farm expense table in chapter 3.2. Consequently, the ratio will be more important for those, than it is for cattle. Research has showed that the broiler/corn ratio also is important for determining broiler profits (Hamm et al. 2008). More specialization and higher capital investments have however made it more difficult to respond to price changes (Lawrence 2006). Consequently, the meat/corn price ratios have perhaps lost some of its importance. That being said, the same article did find a clear correlation between price ratios and future price changes.

When time was regressed on each of the price ratios it showed that time had different effects on each of the ratios. The hog/corn ratio decreased by 0.02% each week due to the passage of time, while cattle/corn and broiler/corn decreased by 0.017% and 0.015%. If the numbers represent an ongoing trend, the three ratios will deviate from each other over time.

6.3 Short run grain and meat price relationship

Price correlations in

Table 7 revealed that correlations have increased from 2000-2006 to 2006-2012. It is likely that there is an outside factor causing it, rather than prices having become closer connected. The US dollar could have such an effect on correlation.

I did not find a lot of dynamics going from grain to meat prices. All grain prices were found to have significant variables explaining hog prices, but no significant leads were found. Wheat prices were however found to lead hog prices. It is a bit surprising as corn and soybeans are considered to be more important feed inputs. That being said, Pozo and Schroeder (2012) did not find any leads at the 5% level going from corn or soybeans to hogs and cattle either. Corn prices have a negative contemporary relationship with hog prices as predicted by theory in Figure 2. Whether corn prices causes hog prices or the other way around is not clear, as causation is difficult to prove when using contemporary prices. Leads were found for all commodity prices on hog prices. Hogs are closely related to the other commodities, so it is not surprising that they have explanatory power on hogs. No grain prices were found to have significant variables explaining cattle. Grain feed constitutes a relatively small part of total costs and it is not surprising that the other commodities have little explanatory power on cattle prices.

No meat prices were found to lead grain prices. Grains have a lot of additional uses, which may explain why no leads were found. Pozo and Schroeder (2012) found no leads going from hogs or cattle to corn or soybeans (at the 5% level) either. Contemporary prices of hogs and lag of hogs were however found to explain corn. The hog-corn relationship is well documented and is thus not a surprise. Cattle also had a lag explaining wheat but that finding is a bit suspicious as wheat is at best, a small part of the cattle diet.

A possible reason for why so few connections were found is that the period analyzed is relatively heterogeneous. Corn’s new connection to ethanol, the financial crisis and adverse weather conditions have made this period different from others. Adverse weather is common, however the combination with the other factors is not. Finding connections in unstable environments is more difficult than finding a connection in a stable one. A way to deal with that problem would be to divide the period into pre and post 2006. Tejeda and Goodwin (2011) found connections going from soybeans to cattle both pre and post 2006.

They did not use data for hogs and broiler, so additional findings might have been discovered if included. It is also possible that prices behave differently depending on the price level. Perhaps meat prices are more responsive to grain prices once they are high. Another reason for the lack of relationship could be that the grain prices used do not represent current costs very well. Meat producers store feed for longer periods of time, so changes in prices does not affect current costs and likewise do not affect meat prices in the short run. Greater specialization and use of production contracts can also explain why so few connections were found.

The results for the Granger Causality test using moving averages were found to be somewhat different from the Granger Causality using weekly data. Ideally, I would like to see the same results come out, which would make conclusions on price relationships easier. But as the moving average model uses lags for more weeks as a basis for the VAR model, in addition to being averages, it is not surprising that different results were found. What is important to take from the results of the two VAR models is that price relationships will differ based on the data frequency chosen, so one should be careful about making too strong statements about connections found between two commodities.

7 Conclusions

In the introductory chapter I asked the following three questions:

- Are there any stable connections between meat and grain prices?
- Are meat prices responding to changes in grain prices on a weekly basis or are there lags involved?
- Can observed prices ratios, be used to forecast subsequent price ratios or price changes?

The answer to the first question is yes. Wheat was found to lead hogs. In addition, hogs and corn was found to have a contemporary negative relationship. More connections were however found among the meat prices and among the grain prices than was found between them. One plausible reason for the lack of finding stable connections is that the period investigated included events such as the financial crisis and the introduction of the RFS.

There is not a straight answer to the second question. Hog prices did respond quickly to corn prices, while prior wheat prices lead hog prices. Conclusively, both contemporary price responses and leads were observed. In general though, not a lot of connections were found going from grains to meats in the ADL and the VAR model. It is more correct to talk about price relationships between the individual commodities, as a grain-meat price relationship was not necessarily found in my models for the short run.

The third question is difficult to answer because the meat/corn price ratios seen the last few years are far from normal and does usually not last for this long. Livestock and chickens still eat corn and soybeans, therefore I expect price ratios to increase, but perhaps not back to the price ratios seen in the past. I believe the ratios still have valuable information for how prices will move over the next one to two years.

My findings have some implications for market participants. Commentators and market analysts should take care when they are using past prices to explain future price movements. Neither of the grain prices was found to lead cattle and broiler prices. What is useful for the U.S. government to know is that meat prices seem to respond slowly to grain price increases. This is positive for consumers, but negative for producers. If the U.S.

government wants to continue having a large meat industry in the country they should look for ways to support it as they are partly to blame for the situation that meat producers are in. The industry itself is also to blame as they has set themselves in a situation in which makes it difficult for producers to adjust production when faced with high grain prices.

Future research on this topic should take a closer look at price ratios to see if they yield information useful for speculators wanting to make money in these markets.

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Appendix

	Pork	Cattle	Chicken
Production increase 1990-2011	48 %	15 %	97 %

Appendix 1 Production increases in the United States for pork, cattle and chicken (*FAOSTAT* ... 2013).

	Prices	Log Returns
Hogs	10	1
Cattle	10	1
Broiler	10	5
Corn	5	1
Wheat	1	1
Soybean	8	1

Appendix 2 Lag lengths used for the ADF test.

	LR chi2 value
8 lags versus 7	9.74
7 lags versus 6	18.83
6 lags versus 5	45.1
5 lags versus 4	50.77*

Appendix 3 Chi square values for Likelihood Ratio test to choose lag length for the VAR model. * Significance at a 5% level.

```
Vector autoregression

Sample:  18feb2000 - 02nov2012                    No. of obs      =       664
Log likelihood =  8075.999                        AIC             = -23.76506
FPE            =  1.92e-18                        HQIC            = -23.27679
Det(Sigma_ml)  =  1.10e-18                        SBIC            =   -22.505
```

Equation	Parms	RMSE	R-sq	chi2	P>chi2
rhogs	31	.050081	0.0747	53.57472	0.0051
rcattle	31	.023903	0.0487	33.98409	0.2815
rbroiler	31	.019689	0.0911	66.58002	0.0001
rcorn	31	.043773	0.0490	34.22611	0.2719
rwheat	31	.046311	0.0456	31.71833	0.3807
rsoybean	31	.04055	0.0725	51.88276	0.0078

Appendix 4 Stylized facts for the VAR model.

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
rhogs						
rhogs						
L1.	-.0692343	.0391336	-1.77	0.077	-.1459348	.0074661
L2.	-.0284286	.0386751	-0.74	0.462	-.1042304	.0473732
L3.	-.0700669	.0386138	-1.81	0.070	-.1457485	.0056146
L4.	-.0463631	.0385882	-1.20	0.230	-.1219947	.0292684
L5.	-.0979223	.0386802	-2.53	0.011	-.1737342	-.0221104
rcattle						
L1.	.1091546	.0820457	1.33	0.183	-.051652	.2699612
L2.	.0423968	.0820073	0.52	0.605	-.1183345	.2031281
L3.	.0684234	.0820004	0.83	0.404	-.0922944	.2291412
L4.	-.0353201	.0821469	-0.43	0.667	-.1963252	.1256849
L5.	-.0086023	.082238	-0.10	0.917	-.1697859	.1525813
rbroiler						
L1.	.0953253	.0966508	0.99	0.324	-.0941069	.2847574
L2.	.1304029	.0971722	1.34	0.180	-.0600511	.3208568
L3.	.300358	.0960604	3.13	0.002	.1120831	.4886328
L4.	.0898555	.0959161	0.94	0.349	-.0981366	.2778477
L5.	-.1012914	.0908277	-1.12	0.265	-.2793104	.0767275
rcorn						
L1.	.0767529	.0645602	1.19	0.234	-.0497827	.2032885
L2.	.0333153	.0644735	0.52	0.605	-.0930504	.1596809
L3.	-.0125219	.0647923	-0.19	0.847	-.1395125	.1144687
L4.	.0693112	.0650751	1.07	0.287	-.0582337	.1968561
L5.	.037566	.0653403	0.57	0.565	-.0904986	.1656305
rwheat						
L1.	-.0730349	.0548047	-1.33	0.183	-.1804501	.0343802
L2.	.043024	.0547554	0.79	0.432	-.0642946	.1503426
L3.	-.023106	.0543829	-0.42	0.671	-.1296947	.0834826
L4.	-.2025057	.0540291	-3.75	0.000	-.3084008	-.0966106
L5.	-.0529321	.0546494	-0.97	0.333	-.160043	.0541787
rsoybean						
L1.	-.0315214	.0571612	-0.55	0.581	-.1435553	.0805125
L2.	-.0132089	.0568213	-0.23	0.816	-.1245766	.0981588
L3.	.0470801	.0569263	0.83	0.408	-.0644934	.1586536
L4.	.0981823	.0573457	1.71	0.087	-.0142132	.2105778
L5.	.015927	.0575205	0.28	0.782	-.0968111	.128665
_cons	-1.46e-06	.0019198	-0.00	0.999	-.0037642	.0037613

Appendix 5 Hog equation in the VAR model.

rcattle						
rhogs						
L1.	-.0225482	.0186781	-1.21	0.227	-.0591565	.0140602
L2.	-.0042993	.0184592	-0.23	0.816	-.0404787	.0318801
L3.	.0039386	.0184299	0.21	0.831	-.0321835	.0400606
L4.	-.0177996	.0184178	-0.97	0.334	-.0538978	.0182986
L5.	.0303591	.0184617	1.64	0.100	-.0058251	.0665434
rcattle						
L1.	-.0447966	.0391596	-1.14	0.253	-.1215479	.0319548
L2.	-.0096848	.0391412	-0.25	0.805	-.0864002	.0670306
L3.	.0519689	.0391379	1.33	0.184	-.02474	.1286779
L4.	.0799741	.0392079	2.04	0.041	.003128	.1568201
L5.	-.0285372	.0392514	-0.73	0.467	-.1054684	.0483941
rbroiler						
L1.	-.0119731	.0461304	-0.26	0.795	-.1023872	.0784409
L2.	-.0423382	.0463793	-0.91	0.361	-.1332399	.0485635
L3.	.0260705	.0458486	0.57	0.570	-.0637912	.1159321
L4.	.0418166	.0457798	0.91	0.361	-.0479101	.1315433
L5.	-.0642671	.0433511	-1.48	0.138	-.1492337	.0206995
rcorn						
L1.	.0081579	.0308139	0.26	0.791	-.0522362	.0685521
L2.	-.0103661	.0307725	-0.34	0.736	-.0706791	.0499469
L3.	-.0239867	.0309247	-0.78	0.438	-.084598	.0366246
L4.	.0016201	.0310597	0.05	0.958	-.0592558	.062496
L5.	-.0069007	.0311862	-0.22	0.825	-.0680246	.0542231
rwheat						
L1.	-.0238142	.0261577	-0.91	0.363	-.0750824	.0274539
L2.	.0196995	.0261342	0.75	0.451	-.0315225	.0709216
L3.	.0052535	.0259564	0.20	0.840	-.0456202	.0561271
L4.	-.0365212	.0257875	-1.42	0.157	-.0870638	.0140215
L5.	.0169456	.0260836	0.65	0.516	-.0341773	.0680685
rsoybean						
L1.	.0046738	.0272825	0.17	0.864	-.0487988	.0581465
L2.	-.0092611	.0271202	-0.34	0.733	-.0624157	.0438936
L3.	.0381568	.0271703	1.40	0.160	-.0150961	.0914097
L4.	-.0126579	.0273705	-0.46	0.644	-.0663031	.0409873
L5.	.0547964	.0274539	2.00	0.046	.0009877	.1086051
_cons	.0008468	.0009163	0.92	0.355	-.0009491	.0026428

Appendix 6 Cattle equation in the VAR model.

rbroiler						
rhogs						
L1.	.0139443	.0153849	0.91	0.365	-.0162095	.0440981
L2.	.0407203	.0152046	2.68	0.007	.0109197	.0705208
L3.	.004263	.0151805	0.28	0.779	-.0254902	.0340163
L4.	-.0087259	.0151705	-0.58	0.565	-.0384595	.0210076
L5.	.0248906	.0152067	1.64	0.102	-.0049139	.0546951
rcattle						
L1.	.03724	.0322552	1.15	0.248	-.0259791	.1004591
L2.	.0151506	.0322401	0.47	0.638	-.0480389	.0783401
L3.	-.0617462	.0322374	-1.92	0.055	-.1249304	.001438
L4.	-.0417914	.032295	-1.29	0.196	-.1050885	.0215057
L5.	-.0611153	.0323309	-1.89	0.059	-.1244826	.0022521
rbroiler						
L1.	.1413116	.0379971	3.72	0.000	.0668387	.2157845
L2.	.0873668	.038202	2.29	0.022	.0124922	.1622414
L3.	-.0660968	.0377649	-1.75	0.080	-.1401147	.0079211
L4.	-.0483382	.0377082	-1.28	0.200	-.1222449	.0255686
L5.	.0142133	.0357078	0.40	0.691	-.0557726	.0841992
rcorn						
L1.	-.0237815	.025381	-0.94	0.349	-.0735274	.0259643
L2.	.0150799	.0253469	0.59	0.552	-.0345992	.0647589
L3.	.0473319	.0254723	1.86	0.063	-.0025929	.0972566
L4.	.0073709	.0255835	0.29	0.773	-.0427718	.0575136
L5.	.0451714	.0256877	1.76	0.079	-.0051756	.0955184
rwheat						
L1.	.0377017	.0215458	1.75	0.080	-.0045272	.0799306
L2.	-.0161384	.0215264	-0.75	0.453	-.0583294	.0260526
L3.	-.0114224	.02138	-0.53	0.593	-.0533264	.0304816
L4.	-.0110119	.0212409	-0.52	0.604	-.0526433	.0306194
L5.	-.016381	.0214847	-0.76	0.446	-.0584903	.0257283
rsoybean						
L1.	.019521	.0224722	0.87	0.385	-.0245237	.0635657
L2.	.0291934	.0223386	1.31	0.191	-.0145894	.0729762
L3.	-.052671	.0223799	-2.35	0.019	-.0965347	-.0088073
L4.	.0068175	.0225447	0.30	0.762	-.0373694	.0510044
L5.	-.0206598	.0226134	-0.91	0.361	-.0649814	.0236617
_cons	.000841	.0007547	1.11	0.265	-.0006382	.0023203

Appendix 7 Broiler equation in the VAR model.

rcorn						
rhogs						
L1.	.0113555	.0342046	0.33	0.740	-.0556843	.0783953
L2.	.0597233	.0338039	1.77	0.077	-.0065311	.1259776
L3.	.0465545	.0337502	1.38	0.168	-.0195948	.1127037
L4.	.0410915	.0337279	1.22	0.223	-.025014	.107197
L5.	.0017648	.0338084	0.05	0.958	-.0644983	.068028
rcattle						
L1.	-.0715952	.0717118	-1.00	0.318	-.2121477	.0689573
L2.	.0263717	.0716782	0.37	0.713	-.114115	.1668585
L3.	-.0655296	.0716722	-0.91	0.361	-.2060045	.0749453
L4.	-.0232908	.0718003	-0.32	0.746	-.1640167	.1174352
L5.	-.0524419	.0718799	-0.73	0.466	-.1933239	.0884401
rbroiler						
L1.	.0321053	.0844774	0.38	0.704	-.1334673	.1976778
L2.	-.0063159	.084933	-0.07	0.941	-.1727816	.1601499
L3.	-.0840803	.0839613	-1.00	0.317	-.2486413	.0804808
L4.	.1270148	.0838352	1.52	0.130	-.0372991	.2913288
L5.	-.1935961	.0793876	-2.44	0.015	-.349193	-.0379992
rcorn						
L1.	.0367974	.0564286	0.65	0.514	-.0738007	.1473954
L2.	.0040489	.0563528	0.07	0.943	-.1064006	.1144984
L3.	.0587689	.0566315	1.04	0.299	-.0522268	.1697647
L4.	-.0233744	.0568787	-0.41	0.681	-.1348547	.0881058
L5.	-.1408763	.0571104	-2.47	0.014	-.2528107	-.0289418
rwheat						
L1.	-.07588	.0479019	-1.58	0.113	-.1697659	.0180059
L2.	.0008194	.0478588	0.02	0.986	-.0929821	.0946209
L3.	-.0083001	.0475332	-0.17	0.861	-.1014635	.0848634
L4.	.0252968	.047224	0.54	0.592	-.0672605	.1178542
L5.	.0488509	.0477662	1.02	0.306	-.044769	.1424708
rsoybean						
L1.	-.0065035	.0499616	-0.13	0.896	-.1044264	.0914194
L2.	.0489838	.0496645	0.99	0.324	-.0483568	.1463244
L3.	-.0220678	.0497563	-0.44	0.657	-.1195883	.0754526
L4.	.0700769	.0501228	1.40	0.162	-.0281621	.1683158
L5.	-.0174372	.0502756	-0.35	0.729	-.1159756	.0811011
_cons	.0020066	.001678	1.20	0.232	-.0012822	.0052954

Appendix 8 Corn equation in the VAR model.

rwheat						
rhogs						
L1.	.0108439	.0361877	0.30	0.764	-.0600828	.0817706
L2.	.0275147	.0357638	0.77	0.442	-.042581	.0976104
L3.	.0260909	.035707	0.73	0.465	-.0438936	.0960754
L4.	-.0104383	.0356834	-0.29	0.770	-.0803765	.0594999
L5.	.0116592	.0357685	0.33	0.744	-.0584459	.0817642
rcattle						
L1.	.0092751	.0758695	0.12	0.903	-.1394264	.1579767
L2.	.1413087	.075834	1.86	0.062	-.0073233	.2899407
L3.	.0278378	.0758277	0.37	0.714	-.1207816	.1764573
L4.	-.0392174	.0759632	-0.52	0.606	-.1881025	.1096677
L5.	-.0369489	.0760474	-0.49	0.627	-.1859991	.1121013
rbroiler						
L1.	-.0599003	.0893753	-0.67	0.503	-.2350726	.115272
L2.	.0357736	.0898574	0.40	0.691	-.1403436	.2118908
L3.	-.1019035	.0888292	-1.15	0.251	-.2760056	.0721986
L4.	.0390545	.0886958	0.44	0.660	-.1347862	.2128951
L5.	-.1028779	.0839904	-1.22	0.221	-.2674962	.0617403
rcorn						
L1.	.0317714	.0597003	0.53	0.595	-.085239	.1487818
L2.	-.1239061	.0596201	-2.08	0.038	-.2407593	-.0070528
L3.	.010197	.0599149	0.17	0.865	-.1072341	.1276281
L4.	-.1027946	.0601765	-1.71	0.088	-.2207384	.0151491
L5.	-.1475818	.0604216	-2.44	0.015	-.266006	-.0291575
rwheat						
L1.	-.0594455	.0506792	-1.17	0.241	-.1587748	.0398838
L2.	.0621807	.0506336	1.23	0.219	-.0370594	.1614207
L3.	-.0902309	.0502892	-1.79	0.073	-.1887958	.0083341
L4.	.014137	.049962	0.28	0.777	-.0837867	.1120607
L5.	.0334046	.0505356	0.66	0.509	-.0656433	.1324525
rsoybean						
L1.	.0420371	.0528583	0.80	0.426	-.0615632	.1456374
L2.	.1207829	.052544	2.30	0.022	.0177986	.2237672
L3.	.089411	.0526411	1.70	0.089	-.0137636	.1925857
L4.	.0918751	.0530289	1.73	0.083	-.0120597	.1958098
L5.	.0451518	.0531905	0.85	0.396	-.0590997	.1494032
_cons	.0018333	.0017753	1.03	0.302	-.0016462	.0053128

Appendix 9 Wheat equation in the VAR model.

rsoybean						
rhogs						
L1.	-.0037682	.0316861	-0.12	0.905	-.0658717	.0583354
L2.	.0353058	.0313148	1.13	0.260	-.0260701	.0966817
L3.	.0530266	.0312651	1.70	0.090	-.008252	.1143052
L4.	-.0238139	.0312445	-0.76	0.446	-.0850519	.0374242
L5.	.0515434	.031319	1.65	0.100	-.0098407	.1129275
rcattle						
L1.	.0088528	.0664315	0.13	0.894	-.1213506	.1390561
L2.	-.0370196	.0664004	-0.56	0.577	-.167162	.0931229
L3.	-.05078	.0663948	-0.76	0.444	-.1809115	.0793515
L4.	-.0045648	.0665135	-0.07	0.945	-.1349288	.1257993
L5.	.0124347	.0665873	0.19	0.852	-.118074	.1429433
rbroiler						
L1.	.0336309	.0782572	0.43	0.667	-.1197503	.1870121
L2.	.0063229	.0786793	0.08	0.936	-.1478857	.1605314
L3.	.0003423	.0777791	0.00	0.996	-.1521019	.1527864
L4.	.1514012	.0776623	1.95	0.051	-.000814	.3036164
L5.	-.1102729	.0735422	-1.50	0.134	-.2544129	.0338672
rcorn						
L1.	.1146816	.0522737	2.19	0.028	.0122271	.2171361
L2.	.0671224	.0522035	1.29	0.199	-.0351945	.1694394
L3.	.0863287	.0524616	1.65	0.100	-.0164942	.1891517
L4.	.1190858	.0526906	2.26	0.024	.015814	.2223575
L5.	-.0544296	.0529053	-1.03	0.304	-.1581221	.0492629
rwheat						
L1.	-.0198139	.0443748	-0.45	0.655	-.1067868	.0671591
L2.	-.009243	.0443349	-0.21	0.835	-.0961378	.0776517
L3.	-.0037999	.0440333	-0.09	0.931	-.0901036	.0825037
L4.	.0070678	.0437468	0.16	0.872	-.0786744	.0928099
L5.	.0319677	.044249	0.72	0.470	-.0547589	.1186942
rsoybean						
L1.	-.1244008	.0462828	-2.69	0.007	-.2151134	-.0336881
L2.	.0592734	.0460076	1.29	0.198	-.0308999	.1494467
L3.	-.0583963	.0460926	-1.27	0.205	-.1487362	.0319436
L4.	-.0905651	.0464322	-1.95	0.051	-.1815706	.0004403
L5.	-.0661687	.0465737	-1.42	0.155	-.1574515	.0251141
_cons	.0014375	.0015544	0.92	0.355	-.0016092	.0044842

Appendix 10 Soybean equation in the VAR model.

Equation	Excluded	chi2	df	Prob > chi2
Hogs	Cattle	1.0967	2	0.578
Hogs	Broiler	11.112	2	0.004
Hogs	Corn	1.1635	2	0.559
Hogs	Wheat	3.9776	2	0.137
Hogs	Soybean	2.6773	2	0.262
Hogs	ALL	19.752	10	0.032
Equation	Excluded	chi2	df	Prob > chi2
Cattle	Hogs	3.4038	2	0.182
Cattle	Broiler	1.9918	2	0.369
Cattle	Corn	0.74371	2	0.689
Cattle	Wheat	1.8678	2	0.393
Cattle	Soybean	2.6791	2	0.262
Cattle	ALL	10.613	10	0.388
Equation	Excluded	chi2	df	Prob > chi2
Broiler	Hogs	2.8781	2	0.237
Broiler	Cattle	2.9595	2	0.228
Broiler	Corn	5.1859	2	0.075
Broiler	Wheat	5.2326	2	0.073
Broiler	Soybean	2.153	2	0.341
Broiler	ALL	16.668	10	0.082
Equation	Excluded	chi2	df	Prob > chi2
Corn	Hogs	4	2	0.135
Corn	Cattle	0.89557	2	0.639
Corn	Broiler	2.5735	2	0.276
Corn	Wheat	3.6347	2	0.162
Corn	Soybean	0.11954	2	0.942
Corn	ALL	10.341	10	0.411
Equation	Excluded	chi2	df	Prob > chi2
Wheat	Hogs	0.17599	2	0.916
Wheat	Cattle	1.0905	2	0.58
Wheat	Broiler	1.1837	2	0.553
Wheat	Corn	5.9975	2	0.05
Wheat	Soybean	8.4965	2	0.014
Wheat	ALL	12.262	10	0.268
Equation	Excluded	chi2	df	Prob > chi2
Soybean	Hogs	3.0699	2	0.215
Soybean	Cattle	0.81825	2	0.664
Soybean	Broiler	4.0062	2	0.135
Soybean	Corn	18.08	2	0
Soybean	Wheat	1.92	2	0.383
Soybean	ALL	29.669	10	0.001

Appendix 11 Granger Causality test on VAR model using moving average of 4 weeks. Lag length for the VAR model was set to two. Grey fill: Unique finding for the GC test using weekly observations. Red fill: Unique finding for the GC test using moving average of four weeks. Green fill: Similar findings in the GC test using moving average and weekly observations.