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Agricultural Markets

Linking the corn future market to the fundamental market by term structure modeling

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Executive Summary

This research arose from the peculiar difference that was seen in two years of drought, 1988 and 2012. This difference is plotted in Figures 1a and 1b. In these figures, there is a difference seen in the trend before the drought takes place. In 1988 an upward trend is seen before the big jump, which is more in line with the rationale that when a drought becomes more and more apparent, the price should gradually increase. This is not the case in 2012, where the drought seems to come as a surprise, as the downward trend is suddenly reversed into a huge jump upward.

The fear was raised that such agricultural markets, nowadays, sometimes forget to follow the fundamental market as there are more and more speculators in such markets that have little interest in the underlying market. This means that due to this growth in the amount of speculators and in the number of financial derivatives with this market as underlying (also known as financialization, explained in the article by Ke Tang and Wei Xiong [22]), these markets could have become less efficient, which brings us to the purpose of this research.

The main purpose of this research is to define the way that corn future markets are driven by the factors in the underlying market. In order to do so, two main components have to be defined: the fundamental market and the future market. First, the main factors are that drive the corn prices were established. And secondly, a model was formed for the corn future market.

When corn is on the fields, generally from April until October, the main driver of the corn prices is the condition of the corn, which is highly dependent on the climate conditions. Rain, or precipitation, is the most important factor in the well-being of corn (from the interviews with the US farmers: Appendix C). Without water, the corn plant is unable to fully develop. Besides rain, there are other climatic factors such as: frost, hail, high temperatures and strong wind, that all have a negative effect on the ultimate corn yield.

During the growing season, the corn plant develops in stages. These stages are important to distinguish, as the plant is susceptible to different climatic factors for different stages. For example, the corn plant is most vulnerable to drought when the plant is evolving from the vegetative stage to the reproductive stage. These stages are shown in Figure 5, along with the vulnerability to several climatic factors in each growth stage.

Not only is the impact of such factors dependent on their severity, but also is it important to consider the way that farmers react to these bad weather conditions. Between the two years of drought, 1988 and 2012, there has been a major change in the crop insurance policies. Most of the farmers (>90%) nowadays are insured against crop failure, while in 1988 less than 50% of the farmers were insured. Insurance could influence the way farmers react to factors that cause crop failures, as their income is secured by these insurance policies.

Besides looking at the fundamental market to analyze the drivers of the future market, it is also important to look at the changes in the future market itself. Over the years, there has been a significant change in terms of the market participants. As was addressed before, the amount of speculators in commodity markets have grown significantly over the years, many of which invest in commodity indices such as the GSCI (Goldman Sachs Commodity Index). When comparing the GSCI with our modeled price level (Figures 10a and 10b), it is found that in 2012 much more co-movements are seen between this index and the corn price. It is also found that in the period before the huge jump upward there is a steep negative trend in the GSCI, which could also have caused a negative trend in the corn price.

Next, the corn future market was was fitted into a term structure model. The great thing about future contracts is that there are multiple future contracts each crop year. Combining them would give much more information than looking at individual contracts. To do so, the future contracts of one crop year (October - September) are combined into three components:

1. The level: the general price level of the underlying crop.

2. The slope: a measure for the storage costs or time-to-maturity effect.

3. The level shift: the level difference between two consequent crops.

Between the level and the slope exists a so-called time to maturity effect, which causes opposite movements in the level and the slope, i.e. when the level goes up, the slope goes down. The time to maturity effect implies that a longer time to maturity will allow for more time to cover the risk factors, such that contracts with a longer time to maturity will react less heavily to new input in the market. To account for this phenomenon, a multivariate state space model is formed for the level and the slope simultaneously. This model is based on three important assumptions:

1. **Mean reversion.** Both the level and slope are assumed to be mean reverting, meaning that they both will never diverge from a certain equilibrium.

2. **Level-Slope dynamics.** The model has to account for the opposite movements of the level and the slope. As was explained before, the level and slope show opposite movements.

3. **General noise term.** This model has to account for the fact that that the observations of the level and the slope are driven by their underlying functions along with a random component. This random term in the model contains the random factors that cannot be modeled but do have an effect on the level and the slope. For example, the decision of an investor to buy or sell corn futures today instead of tomorrow or other small decisions that shift price changes from day to day. By itself these factors have unnoticeable effect but together the effect is significant enough to be worthy to introduce into the model.

This model is estimated by a Kalman Filter and the co-movements between the model output and weather and news data is analyzed. These co-movements are analyzed to evaluate the way that the future market (model output) reacts to events in the fundamental market. This is done by an event study, where movements of the level and slope are analyzed around significant events. For the weather data, a significant event is defined as the days that follow a prolonged period of low or no precipitation. For the news data, a significant event is defined as the trading days that have extremely high or extremely low news sentiment. This news sentiment is created by Thomson Reuters in their News Analytics program.

With these event studies two important conclusions can be made. First, it is found that the corn future market, defined in terms of level and slope, reacts significantly to events in the fundamental market, both for news and climate events. Secondly, for the climate events it is even found that there is a greater reaction in the period 2001-2012 than in the period 1988-2000. This means that there is no indication that nowadays, future markets are less responsive to what happens in the underlying market than in earlier years.

A lot has changed over the years in these markets and a lot will change the coming years. And therefore, it will always be important to keep an eye on the behavior of markets, and never lose sight of the fundamentals of these markets. This research has given some insight into the corn future market, and how to model such a market, and could be used for future research on fundamental commodity markets.

Contents

1 Introduction

With over 332 million metric tons grown annually in the United States alone, corn (also known as maize) is the most widely grown grain crop. Not only is it cultivated for human or animal consumption, it is also used as an energy source (approximately 40% of the US crop is used to produce ethanol). It is impossible to imagine everyday life without this widely consumed grain. Corn is traded on a large scale for a price that is, obviously, susceptible to changes in supply and demand. To neutralize the risk of rising or falling prices, buyers and sellers of corn (or any product for that matter) could enter into a future contract. In these contracts a predetermined date, price and amount of a trade in corn is set, leaving almost no room for uncertainty. As the future contracts are exchanged very often, the price at which these contracts trade represents a certain approximation of the future value of corn.

One of the factors that has a great, if not the greatest, influence on the supply of corn is the weather. During the cultivation season (Apr-Oct in the Northern Hemisphere), poor weather conditions could lead to heavy crop losses. This was experienced in 2012, when the USA was hit by an extremely dry growing season that brings back memories of the dry spell in 1988. Both years, heavy crop losses were incurred, which had a huge impact on certain future contract prices, that rose to record heights. In Figures 1a and 1b the corn future contract prices are plotted for the December 1988 and December 2012 contract respectively. A peculiar difference is seen when looking at the period before the large upward movement. What one would expect to see is an upward movement, as weather forecasts will give more and more implications of a drought. This is what is seen in 1988, but not in 2012. On the contrary, the future contract prices in 2012 show a downward movement in the period that a drought, with crop losses as a consequence, should become more and more apparent.

In this research, the nature of this difference will be investigated. Our first intuition is that this difference comes from the way that markets react to news. There could be a tendency that markets overreact to news (official crop reports), instead of reacting to the things that are already happening on the crop fields. Basically, this means that investors are less aware of the developments of the underlying products they are investing in, and official reports (that do not contain surprising news) will then have much more impact on the future prices than they normally would. This could be a result of changing proportions of different market participants.

This research will focus on the corn future markets in the USA in the period from 1988 until 2012. Besides the intuition that the investors are overreacting to non surprising news, this research will focus on what drives these agricultural markets as well as the developments in the underlying market. All in focus to explain the distinct movements in 1988 and 2012.
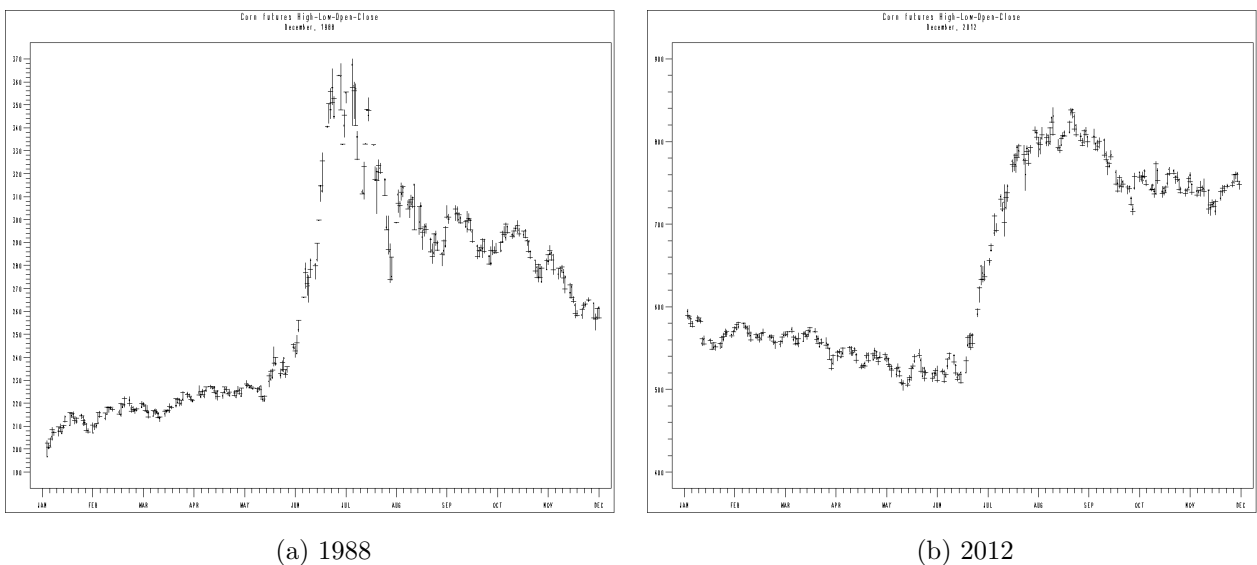

(a) 1988   (b) 2012

Figure 1: The December corn future contract prices (open-high-low-close) in 1988 and 2012

1.1 Research Questions

In this research, the drivers of the corn future markets will be researched, along with its development over the years. The main focus of this research is that it seems that agricultural future markets do not contain the actual information from the crop fields and focus too much on official reports (that most of the time do not contain any surprising news), instead of what is already visible on the fields. The drivers of the corn future markets will be analyzed over the years; trends and changes over the years will be laid out, to, hopefully, weaken the intuition of a less efficient market. Consequently, the main research question will be defined as:

* *What are the main drivers of the corn/grain future market, and has the way these markets react to these drivers changed over the years?*

This broad research question will be divided into the following six subquestions. These questions give a well defined research on the corn future markets.

I. What does the underlying corn market look like in terms of growing process, area/climate of corn cultivation, future markets, official crop reports and market participants?

II. Are there any substantial differences in corn markets, described in the previous question, between 1988 and 2012?

III. What change in the composition or behavior of market players could be the foundation of the changes/trends found in the previous questions?

IV. Is it possible to find significant events by analyzing the spread between the future contracts on different harvests?

V. How do corn/grain future markets respond to the weather (when is a dry spell established that causes crop failure)? And has this behavior changed over the years?

VI. How do corn/grain future markets behave around non-renewing news items?

2 The Underlying Market: Corn

The prices of future contracts are mainly driven by a set of factors that influence the supply and demand of the underlying product. For a better understanding of the future market movements, one first has to understand the underlying market. In this section a clear view of the underlying product, Corn, will be given.

2.1 History

Corn, or maize in most parts outside the USA, is the only grain that originated in the Western Hemisphere. In fact, corn was unknown to the rest of the world until Christopher Columbus returned to Europe with a sample. By the mid-sixteenth century most of the European and Chinese farmers were raising corn crop. Today, there are about 100 to 150 varieties of corn, most of which is used for animal feed. The most common variety is the field corn, also named dent corn for the crease that is formed on top of the kernel (Figure 4). About 99% of the US corn production consists of field corn. There are three grain standards established for field corn; yellow, white and mixed. Yellow field corn is mainly used for livestock feed, wet milling into flour and other products for human consumption. White corn will be processed in dry mills for flour production, for manufacturing hominy and grits and also for many industrial uses. Mixed corn is the corn that is accidentally mixed during storage and is mainly used for livestock feed.

Over the years, the corn yield per acre has steadily been rising due to denser and narrower planting rows, better pesticides and herbicides, but most of all due to stronger genetically modified corn plants (hybrids). While several genetically modified traits now exist in commercial corn hybrids, these traits by themselves have not contributed much to the improvement of the yield potential of hybrids. Genetic modification of corn traits have lead to better protection against insects and herbicides. Both of these modifications help to improve protection against pests, but do not directly imply an increase in yield potential. Still, most of today's hybrids are sold in versions that include one or more genetically modified traits.

General concern exists that there is not enough diversity among these different corn hybrids. Although it is true that only a limited number of genetic corn pools or populations are used to produce these hybrids, these pools contain a large amount of genetic diversity. There is no evidence that this diversity has decreased over the past years, and many of today's hybrids are substantially better than those only a few years old. It is safe to say that farmers can use these genetically modified hybrids without the risk of having too genetically similar species on the field, but do have the advantage of more resistant crops.

Currently, around 96 million acres of land in the US are planted with corn. Acreage was at its lowest point of 60.2 million acres in 1983. Because of provisions in the Federal Agricultural Improvement and Reform Act of 1996, corn acreage has increased to the 96 million acres nowadays. The act permitted farmers to make their own crop planting decisions based on the most profitable crop for a given year. While the number of feed grain farms has decreased in recent years, the number of acreage per farm has increased. Moreover, a trend of growing farms is seen among the grain producing farms.

Corn has food, feed and industrial uses. The majority of the corn is used for feeding purposes. The amount used for feed is closely related to the amount of live stock that are fed corn. This amount depends on the corn's supply and price and also on the amount of supplemental ingredients used in feed rations, along with their supply and price. Corn used for ethanol production has increased significantly over the last few years. Strong demand for ethanol production has resulted in higher corn prices and more incentive to increase corn acreage. As ethanol production increases, the supply of products that are co-produced in the process will also increase. Two methods are used for the production of ethanol from corn; dry-milling and wet-milling. Both these methods generate a variety of economically valuable co-products, the most important of which is Distilled Dried Grains with Solubles (DDGs), which can be used for livestock feeding. In the dry-milling process, each 56-pound bushels of corn generates about 17.4 pounds of DDGs. In the US, DDGs are primarily fed to cattle (both dairy and beef), but the feed rations of DDGs to hogs and poultry is also rising.

With the expanding Latin American population in the US, the market for food made from corn

has also expanded in recent years and is expected to continue growing at the rate of the population growth.

The US is the world's largest producer and exporter of corn. Corn is mainly traded for livestock feed purposes and less for food and industrial uses. To emphasize the importance of corn export for the US; the corn grain exports make the largest contributions to the US agricultural trade balance of all the agricultural commodities. During the 1990s, the corn exports accounted for approximately 11% of all agricultural exports by value of the US. In 2008 this amount has even grown to 12% due to record exports of corn. On a worldwide scale, the US corn exports account for an averaged 60% during the period 2003/2004 - 2007/2008 (a trade year is from October-September). The largest growth of US corn exports is seen in the 1970s. The exports soared from 13 million metric tons at the start of the decade to a staggering 62 million metric tons in 1979/1980. This growth was due to strong demand in the USSR as well as in Japan, Europe and developing countries. After this glorious period, the US export dropped to a bottom at 31 million metric tons in 1985/86. This was due to poor global economic growth and an expanding European Union.

In the second half of the 1980s, the exports bounced back to a top at 60 million metric tons due to large domestic supplies and more competitive prices as the government reduced commodity loan rates. Due to the breakup of the former USSR (1991) and rising Chinese corn exports, the US exports declined again in the early 1990s. A slowing world economy and reduced demand for corn are projected to constrain the growth of US exports. Yet, the global population increase and consumer demand for meat products will continue to support the feed grain exports in the long-term.
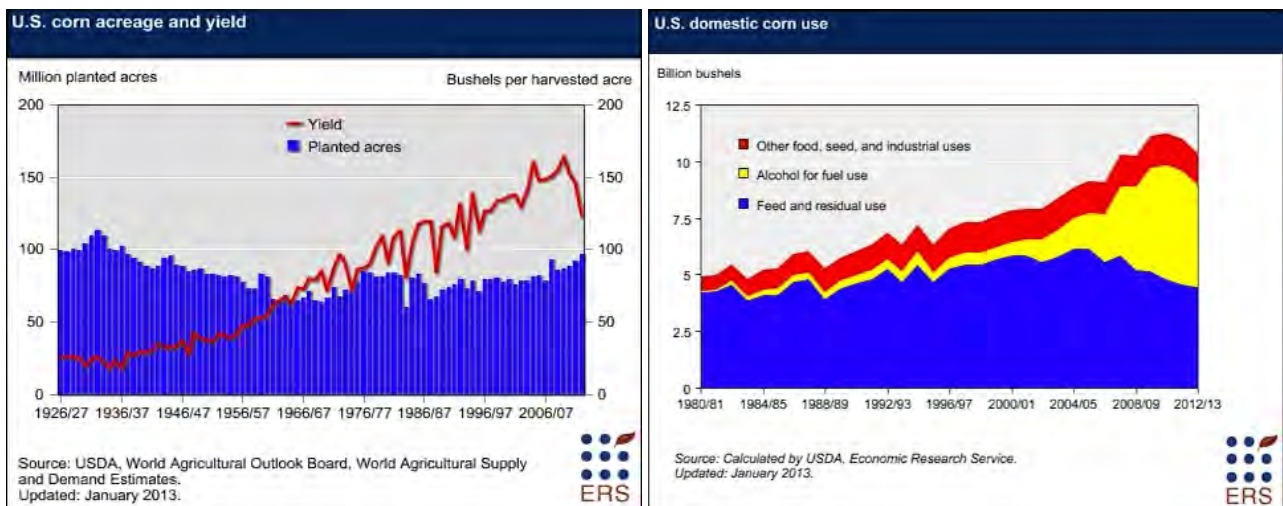
(a) Acreage and yield

(b) Corn use
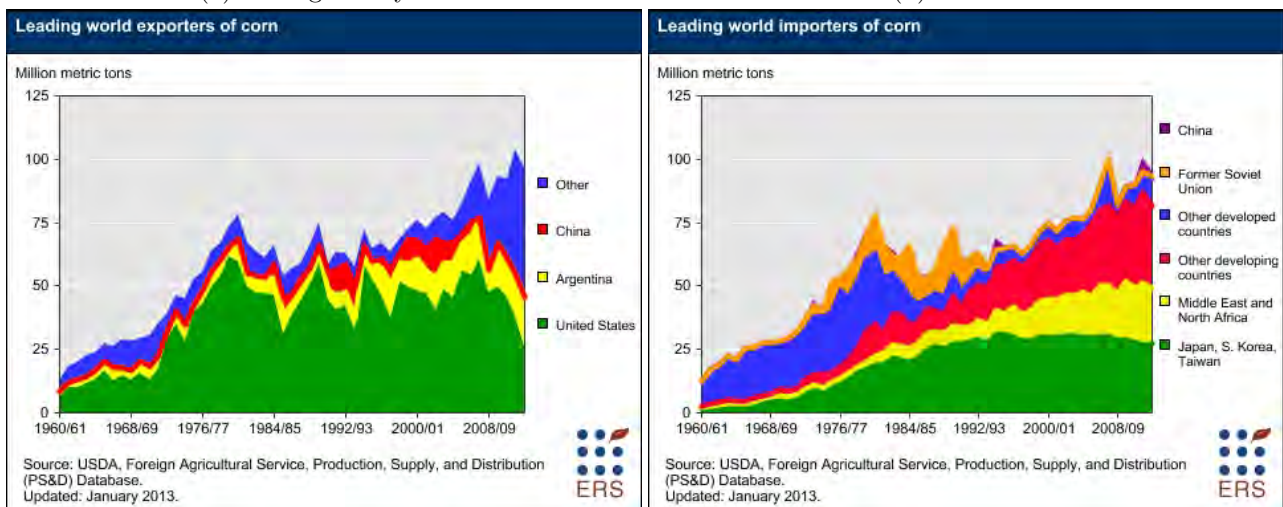
(c) Corn export

(d) Corn import

Figure 2: Historical course of corn

In line with this research, a closer look is given to the developments between 1988 and 2012. Figure 2a shows an upward trend both for planted acreage and the yield per acre. This can be accounted to the greater world population and higher yielding corn hybrids. Obviously, the same trend is found in the corn usage (Figure 2b), where the period between 1988 and 2012 shows a vast growth in ethanol for fuel use. The US exports in Figure 2c show a quite stationary process between 1988 and 2012, yet the world imports in Figure 2d have grown significantly during this period.

2.2 Corn cultivation

Corn is the most widely grown grain crop in America. The US itself is responsible for approximately 40% of the world corn production. Most corn is cultivated in the northeastern part of the US, along the so-called Corn belt, shown in Figure 3. In this area, soils are deep, fertile, and rich in organic material and nitrogen, and the land is relatively level. The warm nights, hot days, and (usually) well-distributed rainfall of the region during the growing season are ideal conditions for cultivating corn.
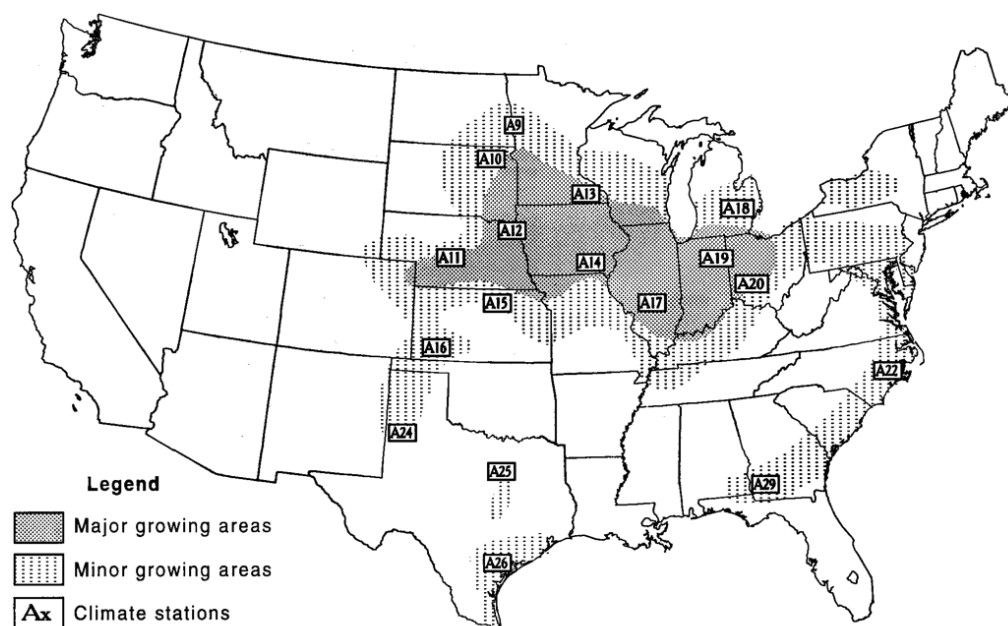

Figure 3: Cultivation area of corn in the US, a list of climate stations can be found in Appendix A

Corn is usually planted between mid April and the beginning of May in the US, when the soil conditions and temperature allow for the corn plant to grow properly. Early planting days are also restricted to the terms in crop insurance policies. Insured farmers will lose replant coverage when planting before the specified earliest planting date, which varies per county. Harvesting usually takes place around mid October, but is determined by the climatic factors that influence the growing process.

The five and a half months that it takes for the corn plant to fully develop is broken down into multiple stages. These stages of the growing process are divided into two categories, the vegetative and reproductive stages. The corn grows in the vegetative stages and pollinates (reproduces) in the reproductive stages. There are approximately 15-20 vegetative stages and six reproductive stages. This uncertainty in the number of vegetative stages comes from the uncertainty of the number of leaves the corn plant will develop; each new leaf is represented as a new stage. It is important to distinguish these stages, as corn is vulnerable to different factors in different stages. For example, corn is more vulnerable to flooding in the vegetative stages, and more vulnerable to drought and strong wind in the reproductive stages. Besides, knowing what stage the corn is currently in gives better predictability of the harvest date and ultimate crop yield.

In Figure 5 the growth process for the corn plant is shown along with the climatic conditions that could harm the crop, starting from planting until maturity. The process starts with the planting, which usually takes place around the beginning of May, but depends on the soil conditions and temperature in the planting area. Planting when soils are too wet is not advised, regardless of the date. Many farmers consider the soil temperature as a guide to decide on the planting date. Planting should not be done when the soil temperature is still below 50° F (10° C). The next stage, emergence, will take place in less than a week at a soil temperature over 70° F (21° C), but at a soil temperature of 50-55° F emergence could take over three weeks (from planting). As the time to the next stage is highly dependent on the temperature, corn producers consider the Growing Degree Days (GDD) as an indication when their crop will progress to the next stage. The GDD is defined as: $GDD = \frac{1}{2}(T_{max} + T_{min}) - 50$, where the temperatures are in ° F and with a minimum and maximum of 50° (10° C) and 86° (30° C) respectively, according to the 86/50 cutoff method (Hanway, 1971 [13]). This means that for temperatures lower than 50° the T_{min} should be substituted with 50 and in the same way with the T_{max} for temperatures higher than 86°. In Table 1 the approximate GDD that are needed to reach each state are found.

Stage	GDD from planting	Stage	GDD from planting
VE (emergence)	115	V13	995
V1	155	V14	1,045
V2	235	V15	1,095
V3	315	V16	1,140
V4	395	V17	1,180
V5	475	V18	1,220
V6	555	VT (tassel)	1,350
V7	635	R1 (silk)	1,400
V8	715	R2 (blister)	1,660
V9	795	R3 (milk)	1,925
V10	845	R4 (dough)	2,190
V11	895	R5 (dent)	2,450
V12	945	R6 (mature)	2,700

Table 1: Approximate GDD from planting date to reach each growing stage

The stages V1 to V18 represent the number of leaves that show their collars at the base of the leaf, i.e. V4 means that the collars of four leaves are visible at the stalk of the plant (the parts of the corn plant are shown in Figure 4). The final vegetative state is the tasseling stage, which occurs just before or together with the first reproductive state; silking. The farmer knows that the corn plant is in this stage when the entire tassel is visible, which is the part that sheds the pollen grain to pollinate the other plants. The corn plant usually sheds pollen grain for one week. This is followed by the first reproductive stage known as silking. The growing process has reached this stage when at least 50% of the plants have one or more visible silks (outside the husk leaves that cover the ear). The silk emerges at the top of the ear and serves to catch the pollen grain to initialize fertilization. Silks are receptive and viable to pollen for at least five days. Drought causes silk elongation to slow down and pollen shed to speed up, making fertilization more difficult.

The next four stages are named after the characteristics of the kernel at each stage. First there is the blister stage, where the kernels start to become visible and resemble a blister. In the milk stage, the kernel is already yellow with a "milky" fluid on the inside. Also starch is beginning to accumulate inside the kernel. The interior of the kernel has thickened to a dough or paste-like substance in the dough stage. And in the dent stage, the kernel will dent in at the top with the milk line separating the liquid and solid (starch) portions. The final stage is the maturity, where the kernels have reached a maximum of dry matter accumulation. Black layer occurs after physiological maturity, serving as a visual verification that the plant is mature.
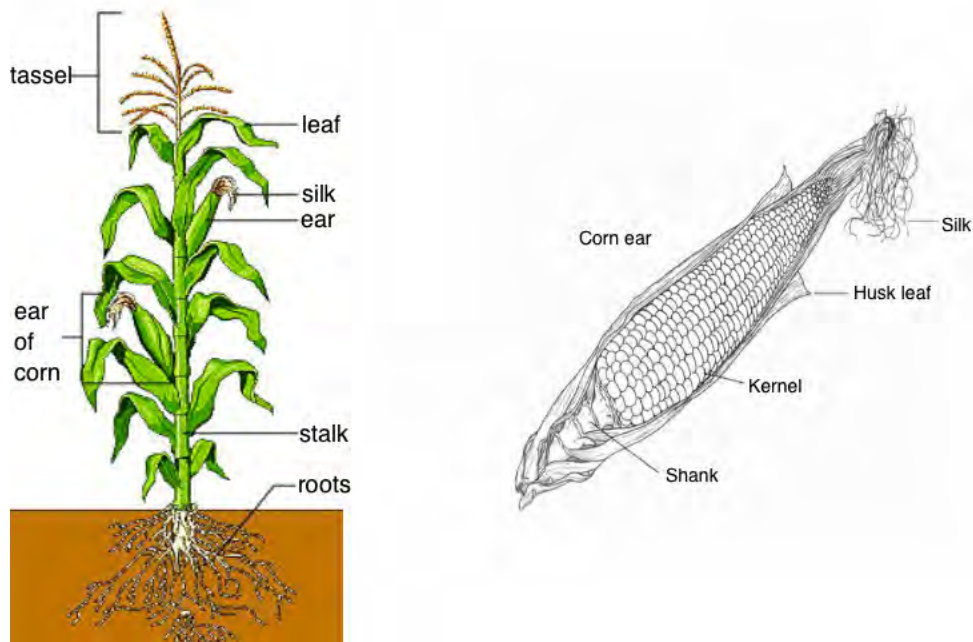
Figure 4: The names of the different parts of the corn plant

In Figure 5 growing process of the corn plant is shown, along with the vulnerability to some climatic factors. In this figure the approximate dates that the plant is in a certain state are also shown, where a planting date of the first of May is assumed. However, as weather conditions are variable from year to year and state to state, so are the planting dates. The time until transition to the next stage is not exact, as the GDD values are dependent on the temperature. Therefore, these dates should only be seen as an approximation to get a general feel of when the stages take place. In 2012, corn was planted earlier than in 1988, because the weather conditions allowed for early planting. During the analysis of the differences between the two droughts, this has to be taken into consideration.

Four climatic hazards are distinguished; drought, flooding, strong wind, frost/hail, as these are the main climatic causes for crop failure. A higher (non-)vulnerability is represented with a darker color of green or red. Different weather conditions influence the time of transition to the next stage. Ideal conditions will speed up the process, where worse conditions can delay the process or even degrade the corn crop. For example: high temperatures can delay some transitions to the next stage, especially in the vegetative stages. This will be discussed in the next chapter about the climate effects on corn.
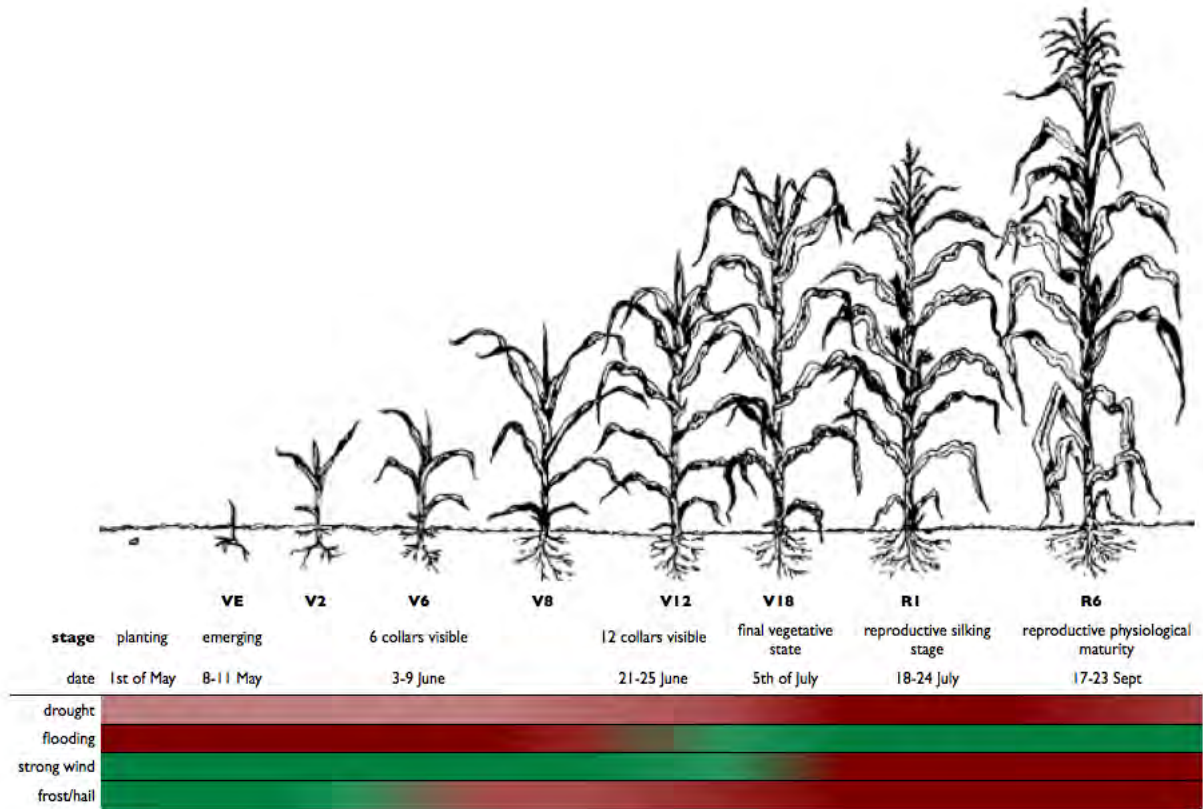
	VE	V2	V6	V8	V12	V18	R1	R6
stage	planting	emerging	6 collars visible		12 collars visible	final vegetative state	reproductive silking stage	reproductive physiological maturity
date	1st of May	8-11 May	3-9 June		21-25 June	5th of July	18-24 July	17-23 Sept
drought								
flooding								
strong wind								
frost/hail								

Figure 5: Corn growing stages

where

(red)	Vulnerable
(green)	Not vulnerable

There are also a wide range of worms and other bugs that feed on the corn crops, which could inflict some crop damage. Diseases and rotting are also problems that should be watched during the growing process. Over the years, corn species have been developed by genetic manipulation that are more resistant to insects.

Another important aspect of corn cultivation is irrigation. The use of irrigation for growing corn has increased steadily the past 30 years. Well laid out irrigation plans will lead to considerably higher yields. Irrigated corn yields are almost 30% higher than non-irrigated corn, this leads to the fact that while only 15% of the US acres are irrigated, the irrigated corn account for nearly 20% of the US production (USDA, 2007). Most of the irrigated corn fields are situated in the semi-arid[1] Great Plains region. However, some recent concerns have been raised regarding the declining surface and groundwater supplies (Clark et al. 2002 [4]) and increased pumping costs (Norwood and Dumler, 2002 [19]) in this region. The trade-off between irrigating and not irrigating corn crops are between the yield gain of irrigation and the costs of irrigation. The yield gain is determined by the soil and the climatic conditions of the area. Mostly, irrigation is used for seed production, as the quality of the seeds is of great importance here.

Understanding the relationship between plants and their water use is essential to effective irrigation management. Evapotranspiration, or crop water use, is the water that is removed from the soil by evaporation from the soil surface and the transpiration by the plant. About 20-30% of the evapotranspiration comes from evaporation and the remaining 70-80% can be assigned to plant transpiration. Daily water use of the corn crop is determined by various climatic factors. High air temperatures, low humidity, clear skies and high wind will result in high evapotranspiration demand.

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[1] semi-arid describes climatic regions that receive precipitation below potential evapotranspiration, but not extremely.

The amount of evapotranspiration is also determined by the growth stage of the corn plant. The smaller corn plant in May, with limited root zone and little leaf area to transpire water, will have a much lower evapotranspiration demand than the much bigger July plant. Corn does not extract the water uniformly throughout its root; generally more water is extracted through the roots closer to the surface. The 4-3-2-1 rule (Kranz et al. 2008 [14]) gives an approximation of the water extraction for different root levels. It states that the top 25% of the root extracts 40% of the water, the next 25% will extract 30% of the water, the next level extracts 20% of the water and the lowest 25% of the root will extract only 10% of the water through the soil. The corn roots can reach depths of 5 to 6 feet. When using a subsurface drip irrigation system an effective root depth of 3 feet is assumed. The total water use of corn will vary from season to season and area to area, yet it will follow a certain pattern determined by the seasonality of climatic factors. Figure 6 shows the average water use of a corn plant along the growing season. This figure shows the 10 year average daily evapotranspiration (A), as well as the fluctuations for a particular year (B). As the evapotransportation of each year is different due to different soil and climatic conditions, it is clear that the farmer must not only keep an eye on the long-term trend in water use, but, more importantly, has to determine the evapotranspiration of the last couple of days.
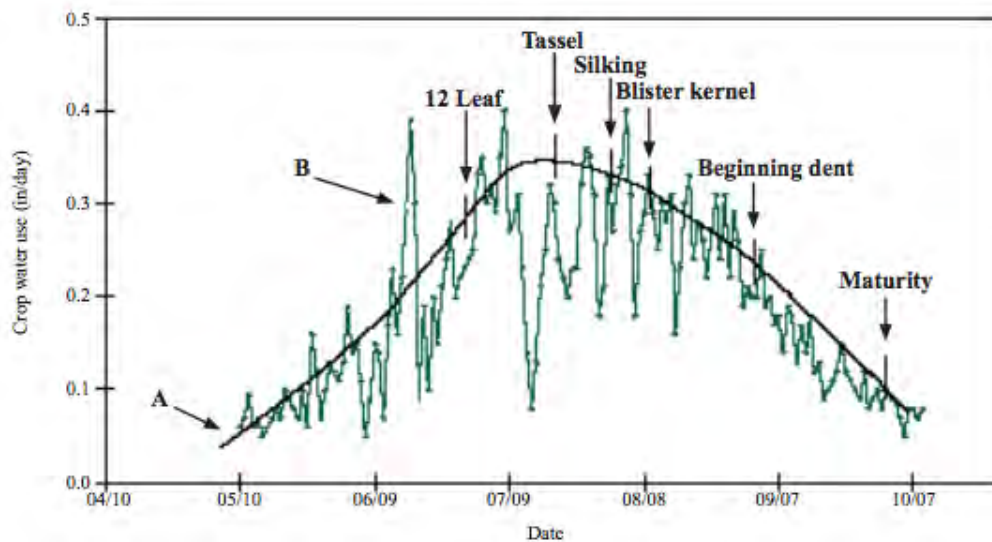

Figure 6: Long-term daily average (A) and individual year (B) corn water use with select growth stages.

2.3 Climate

Corn is a summer crop that is best grown in a climate that offers warm weather and long sun-filled days along with just enough rain. This climate is generally found in the area shown in Figure 3. As was explained in the previous section, the potential yield is influenced by different weather conditions in different stages of the growth process. Any weather analysis with the future markets should keep these factors into consideration. I.e. a drought in the early stages of the corn growth process will have much less impact on the future contract prices than a drought in the later stages.

Drought

Drought is one of the most difficult and damaging problems for the growth of corn. Sometimes, in extreme dry periods, even irrigation of the crops is in vain. Consistent rainfall, i.e. significant rain occurs every 10 to 14 days, is required to prevent crop damage. There are several types of drought that can be explained by the variables precipitation, humidity and soil moisture. In this research, the agricultural drought is most interesting, for obvious reasons. An agricultural drought occurs when there is not enough moisture to support average crop production. Usually this drought takes place in prolonged periods of below average precipitation, but it can also take place in average precipitation periods when soil conditions or agricultural techniques require extra water. Soil conditions and erosion, triggered by poorly performed agricultural endeavors, can cause a shortfall of water available to the crops, even with normal precipitation.

The key to manage drought is to understand the effect of drought on the corn plant in the different stages of the growing process. In the first phase of the corn growth process, from emergence until V8 (eight leaves fully emerged, approximately four weeks after planting), dry weather will reduce the plant and leaf size that the corn crop will achieve. Minor reductions in leaf size will have very little impact on the ultimate yield, but when all the leaves are removed from the plant by the drought, it reduces the potential yield up to 20%. There exists an exponential relationship between the leaf size and the potential yield. In the next phase, from V8 until VT (all leaves emerged, start of tasseling, 4 weeks to 66 days after emergence), drought will reduce the potential ear size of the corn plant. The ear is the most important part of the corn plant, as it is the part that is used for consumption. From V8 until V14 the ear size is determined. In this period drought reduces the potential yield 10 to 30%. From V14 until tasseling, drought could lead to even greater yield reductions, as the number of kernels that can be fertilized is determined in this period.

The most sensitive stage of corn growth to drought is the silking stage. Drought in combination with high temperatures could even lead to a 100% yield loss, as these conditions can kill pollen before it can reach the silks. This will lead to incomplete or even zero pollination. To determine yield loss in this stage, one has to scout the fields. A way to measure whether pollination has occurred is to look at the length of the silks. The silk will continue to grow until pollination has occurred or until it becomes damaged, so the longer the silks are, the less efficient the pollination process has been. In the final stage, after silking until maturity, drought affects the kernel weight. Severe droughts in this period can reduce corn yield by 20 to 30%. Drought has the largest impact near the silking stage, so earlier in this phase.

In Figure 7a the monthly precipitation is shown both in 1988 and 2012, which are the two years with extreme droughts. The average monthly precipitation over the years 1988 to 2012 is shown for comparison. Precipitation is measured as an average of the 17 weather stations that were selected as a representative measure of the total area where corn is cultivated in the US. A list of these stations along with their monthly normal values can be found in Appendix A with their locations in Figure 3.

It is visible that the signs of a drought start earlier in 1988 than in 2012. In 1988 precipitation is already considerably below average in February, where in 2012 below average precipitation starts in May. Striking is the fact that in June (the month that has the highest precipitation on average), the lowest precipitation value of the growing period (Apr-Sep) is found both in 1988 and 2012. This is a crucial period, as the corn is approximately at its most vulnerable point to water stress around this point (Fig. 5).

Figure 8a shows us the percentage of days that succeed a certain number of consecutive days without

any precipitation. For example, the 13.8% for the 1988 dataset at 10 consecutive days tells us that on 13.8% of the days in 1988, there was zero precipitation in the past ten days. In other words, 13.8% of the days in 1988 have ten or more dry days preceding this day. The consecutive days without precipitation are evaluated for all the 17 weather stations individually (Fig. 3). Only the days within the cultivation period of corn (April-October) are taken into account. One can see a higher percentage of days with 10 or more consecutive dry days both in 1988 and 2012 than for the full dataset. Also, a slower decrease is seen in the average (overall) consecutive days without precipitation. This means that both 1988 and 2012 have shorter than average dry periods, despite the higher number of ten or more consecutive dry days. I.e. when defining a dry period as a period of 10 or more days without precipitation, both 1988 and 2012 show more frequent periods of dryness, but these periods are on average shorter than the average length of the dry periods in the whole period between 1988 and 2012. This indicates that the length of a dry period is less important than the frequency of dry periods, when defining a dry period as 10 days without precipitation.
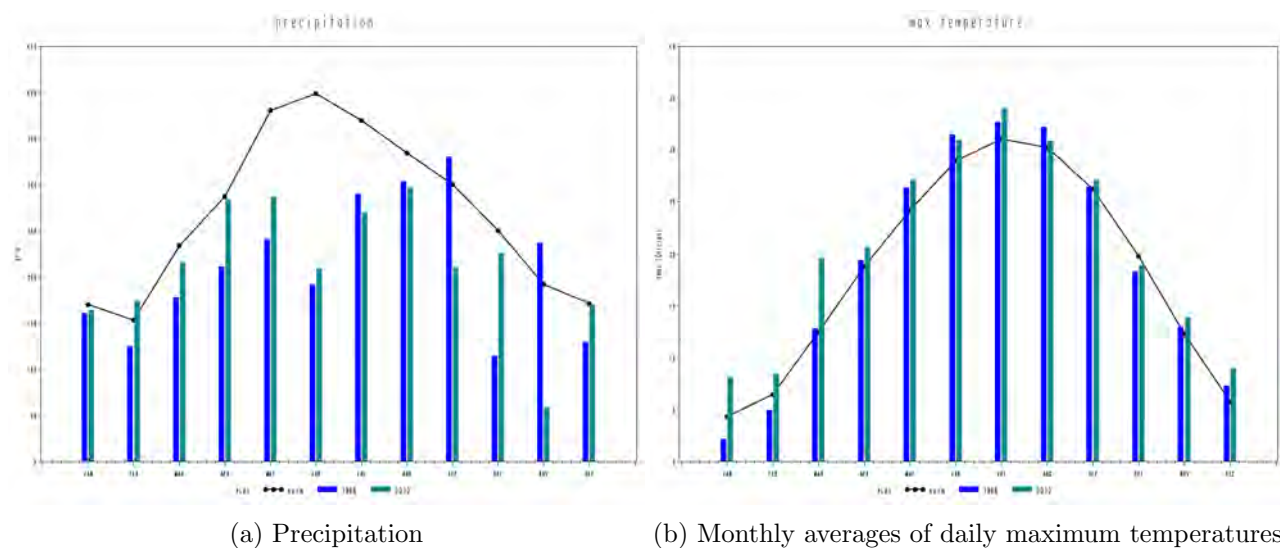

(a) Precipitation (b) Monthly averages of daily maximum temperatures

Figure 7: The monthly averages of precipitation and temperature for 1988 and 2012. The line represents the 1988-2012 average.

(a) Percentage of days succeeding x number of consecutive dry days (zero precipitation) (b) Percentage of days succeeding x number of consecutive hot days (> 93°F)
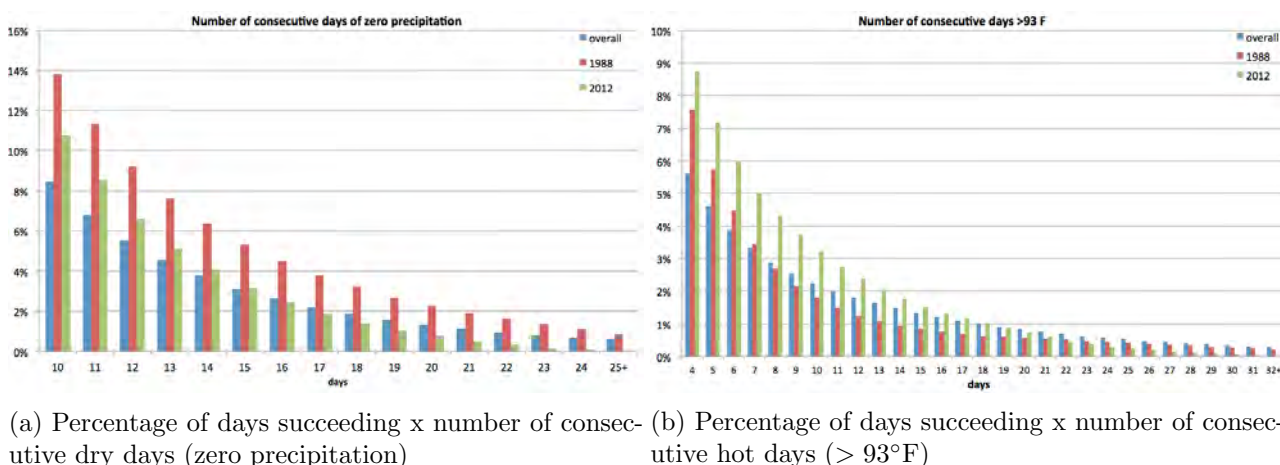
Figure 8: Histogram of the percentages of the minimum number of dry/hot days for the period 1988 until 2012 from April to October. E.g. 4 days 10% means that 10% of the days are the 4th or higher consecutive day that it is hot/dry.

Temperature

As was explained in previous section, the temperature has a great influence on the growing process of the corn plant. The growing degree days, which are a measure of the time it takes the corn plant to progress to the next stage, is purely based on the temperature. This makes it incredibly important for the farmer to keep an eye on the temperature and the forecasts. In contrast to precipitation forecasts, the temperatures forecasts are much better estimated by meteorologists.

Prolonging high temperatures usually go hand in hand with a drought. Heat stress and drought together intensify the damage done to the corn crops, but either can do major damage to the corn plant by itself. As corn originated as a tropical grass, it can take temperatures up to as high as 112° F (44° C) for brief periods. Optimal daytime temperatures of corn lie between 77° F (25° C) and 91° F (32.8° C). According to dr. Emerson Nafziger [7], afternoon temperatures in the mid-90s (35° C) are not a problem for corn plants if they have enough soil water available. In experiments, plant temperatures have been raised to 110° F (43.3° C) or higher without doing direct damage to photosynthetic capacity. The level required to damage leaves depends on the temperature the leaf has experienced before, but it generally takes temperatures above 100 (37.8° C) in field-grown plants. According to Iowa State University agronomist Roger Elmore and climatologist Elwynn Taylor [9], high temperatures may have a double impact on corn. The first impact is the increase in rolling of corn leaves in response to moisture deficiency. By rule-of-thumb, the yield is diminished by 1 percent for every 12 hours of leaf rolling - except during the week of silking when the yield is cut 1 percent per 4 hours of leaf rolling. The second impact is less obvious initially. When soil moisture is sufficient, the crop does not have a measurable yield response to one day maximum temperatures between 93° F to 98° F (33.9-36.7° C). However, the fourth consecutive day with a maximum temperature of 93° F (33.9° C) or above results in a 1 percent yield loss in addition to that computed from the leaf rolling. The fifth day there is an additional 2 percent loss; the sixth day an additional 4 percent loss. Data are not sufficient to make generalizations for a heat wave of more than six days, however firing of leaves then becomes likely and very large yield losses are incurred. Generally a six-day heat wave at silking time is sufficient to assure a yield not to exceed the trend (Iowa trend yield is near 174 bushels per acre). Should warmer than usual nights persist for a six-week period the state is assured a below trend harvest.

The monthly averages in Figure 7b show that both in 1988 and in 2012, temperatures during cultivation season (Apr - Sep) is above average. This will have contributed to the severity of the drought in both years.

Figure 8b shows the percentages of number of consecutive days that the temperature is above 93° F. As was said before, the fourth consecutive day of maximum temperatures above 93° F will lead to potential yield loss. The same pattern is seen as with the consecutive dry days; the frequency of heat wave periods (here defined as 4 days or longer of higher than 93° F) is higher in both 1988 and 2012, but the average length of a heat wave is shorter than the average of the full period. This indicates that there is a maximum heat and water stress a corn plant can take and heat and water stress beyond this point becomes less relevant.

Other

There are several weather conditions that can damage the corn crops. Earlier we have seen the two major climatic factors that have most influence on the potential corn yield. But there are also some other factors left that can lower the potential corn yield considerably. The first factor that will be discussed is flooding. Flooding is extremely harmful at each point in the growing process where the growing point is still below the water level. In the early stages of the growing process a flood can kill the total crop in just a few days, especially when the temperatures are high. Plants can usually survive short periods of flooding of less than 48 hours (Wenkert et al., 1981 [23]). But if the flood does not kill the plants it can still have a long-term negative impact on the potential yield. Excess moisture during the vegetative stages could delay the root development. The corn plant will be subject to greater damages from drought in the later stages of the growing process due to insufficiently developed roots that are unable to contact available subsoil water. Flooding is quite common in the US and can be caused by heavy rainfall, overflowing rivers or catastrophes (e.g. the collapse of a

dam, earthquake or a hurricane).

In the later stages of the corn growth process, when the corn is already far above the soil, the crops are also vulnerable to strong wind. Strong wind can easily break the corn (lodge the stalk) prematurely, causing considerable crop losses. The yield loss due to stalk lodging does not only depend on the strength of the wind, but is also determined by the strength of the stalk. Stalk lodging happens mostly to corn plants that are unhealthy and endure stalk rot. In order for the corn plant to stay healthy, it must produce enough carbohydrates by photosynthesis to keep the root and stalk cells alive, and produce enough to meet demand for the grain fills. When photosynthetic activity is reduced (due to stress during grain fill), the carbohydrate levels available for the development of the ears are insufficient. The corn plant will then remove carbohydrates from the leaves, stalk and roots to compensate. While this process ensures a sufficient supply of carbohydrates to the developing ears, the removal of carbohydrates could result in root and stalk infection by fungi. It also results in a rapid deterioration of the lower part of the corn plants, leaving the lower leaves to be nitrogen stressed, brown and/or dead. Weaker or rotten stalks are more susceptible to lodging, even with small or no winds.

Hail damage is minimal when the corn plant is still in a growing stage earlier than V7 (Table 1). After the corn plants incurred hail damage, it could take 7-10 days for the corn plant to begin growing again, if it can. Warm air temperature will speed up this process. To assess whether the plant is healthy, the growing point needs to be observed. The first signs of damage are a change from healthy cream or light yellow color to a light red or brown within about 4-6 days at the growing point. If the growing point changes color, the plant will most likely not yield well and may even die.

The final hazard that we distinguish is frost, that occurs when the air temperature is below 32°F (0° C). A frost can occur at any moment in the US harvesting area, but are extremely rare in July and August. Therefore, farmers should distinguish two periods of potential frost that can impact potential yield and harvesting time, early- and late-season frost. In the early-season, frost should not be a problem until the growing process reaches stage V5/V6. It takes about one or two days after a frost for the symptoms of frost damage (water soaked leaves that eventually turn brown) to show up. Early frost can have an impact on the potential yield, but the yield loss due to frost damage is smaller than the yield gain from early planting. Furthermore, delayed planting could reduce profitability due to greater moisture in the crops and the consequential drying costs.

Late-season frost before the maturity stage will degrade the corn in quality and decrease the yield. Severe impact of frost on the grain quality is found in the mid dough stage, while moderate impacts are found in the dent stage. Different hybrids, overall plant strength (carbohydrate levels), subsequent temperatures are all factors that influence the impact of the frost. From the article of Carter & Hesterman (1990 [3]), it is found that corn is killed when temperatures are near 32° F (0° C) for a few hours and when temperatures are near 28°F (-2°C) for a few minutes. Differences in wind speed and thermal radiation can also influence whether or not a frost is damaging.

2.4 Crop reports

The majority of information about agricultural markets comes from the United States Department of Agriculture (USDA). The USDA[2] is the United States federal executive department responsible for developing and executing U.S. federal government policy on food, agriculture, natural resources, rural development, nutrition, and related issues based on sound public policy, the best available science, and efficient management. It aims to expand economic opportunity through innovation, to promote agriculture production sustainability and to preserve and conserve the Nation's natural resources through restored forests, improved watersheds, and healthy private working lands.

On May 15th 1862, President Abraham Lincoln signed into law an act of Congress, establishing the United States Department of Agriculture. Two and one-half years later, in what would be his final annual message to the Congress; Lincoln called USDA "The People's Department." At that time, about half of all Americans lived on farms, compared to about 2 percent today. But the USDA thrives to fulfill Lincoln's vision every day, through their work on food, agriculture, economic development, science, natural resource conservation and a host of issues.

The USDA releases many periodic crop reports that evaluate the conditions of the crops on the field as well as the global supply and demand of agricultural products. Many investors await the release of such reports to make investment decisions. Therefore, a general concern was raised that investor's might be looking too much into these reports while forgetting to keep an eye on the fundamental market itself. This could be an explanation for the downward trend in 2012 which was suddenly reversed to a huge jump upwards. To further investigate this issue, the two most important reports to investors in corn are elaborated in this section.

WASDE reports

The World Agricultural Supply and Demand Estimates (WASDE) reports are published monthly by the USDA in association with the WAOB. The World Agricultural Outlook Board (WAOB) serves as USDAs focal point for economic intelligence and the commodity outlook for U.S. and world agriculture. The Board coordinates, reviews, and approves the monthly World Agricultural Supply and Demand Estimates (WASDE) report and coordinates USDA's Agricultural Outlook Forum. WASDE reports contain the global supplies and demand estimates for all types of agricultural products. It is a widely considered benchmark to which many other agricultural forecasts are compared. Many investors wait for the release of these reports and future markets tend to anticipate on the release of these reports.

The first WASDE report was released on September 17, 1973 under the name Agricultural Supply and Demand Estimates. It was originally focused on the supply and demand of the United States. On October 14, 1980, the report was released under the name World Agricultural Supply and Demand Estimates for the first time. This was the first report to provide categorized estimates not only for the US, but also for major foreign importers and exporters. Estimates for individual countries were first included in the report of January 11, 1985.

The WASDE reports find their origin during the "Great Grain Robbery" of 1972. In the years following the New Deal[3], the USDA's economic intelligence became fragmented due to a great expansion of USDA agencies involved in the collection and analysis of agricultural statistics. This fragmentation caused insufficient information sharing between separate agencies within the USDA, which eventually lead to foreign buyer's to secure large portions of that year's US grain crop at subsidized prices. These problems were partly addressed by creating the Agricultural Supply and Demand report.

Today, the WAOB administers the interagency process that generates the WASDE report. For each commodity in the report, the WAOB commodity specialist assigns an Interagency Commodity Estimates Committee (ICEC), consisting of the representatives from four USDA agencies. These agencies are: the Agricultural Marketing Service which provides information on existing prices for livestock and crop commodities, the Economic Research Service which analyzes the impact of market

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[2]mission statement from the USDA website

[3]http://www.britannica.com/EBchecked/topic/411331/New-Deal

conditions on commodity supply and demand fundamentals, the Farm Service Agency which considers the effect of policy environment on producer behavior and finally the Foreign Agricultural Service which provides information about commodity conditions in foreign countries.

The WASDE reports start with a small summary of the most important changes in the global supply and demands for all major agricultural products. The rest of the report is filled with tables containing all the statistics on supply and demand forecasts and realized statistics for all major exporting countries in the world. Statistics that are included in the report are: stocks, import and export numbers, usage numbers, prices, production numbers. Also the forecasts for current and coming year are given for these statistics and month to month changes are monitored.

WASDE reports are released at 8:30 am EDT/EST (Eastern Daylight/Standard Time) between the 8th and the 12th of every month. In 2013 the USDA has changed this release time to 12 p.m. EDT, but will not affect this research. The release dates in the two drought years are shown in Table 2. In Figure 9 the December future contract price movements around the release dates of the WASDE reports are shown. The release dates are shown as an interval starting from 2 days before the release until two days after the report has been published. The general concern that investors are too caught up in these reports, while forgetting to look at the fundamental market which could cause markets to react to reports rather than to the fundamental market is not the case for the drought 2012. It is clear from Figure 9 that the WASDE report was released about a week prior to the big jump upwards. Directly after the release of the report, the December contract even decreased.

WASDE		Grain Stocks	
14-01-1988	12-01-2012	14-01-1988	12-01-2012
09-02-1988	09-02-2012		
09-03-1988	09-03-2012	31-03-1988	30-03-2012
11-04-1988	10-04-2012		
10-05-1988	10-05-2012		
09-06-1988	12-06-2012	30-06-1988	29-06-2012
12-07-1988	11-07-2012		
11-08-1988	10-08-2012		
12-09-1988	12-09-2012	30-09-1988	28-09-2012
12-10-1988	11-10-2012		
09-11-1988	09-11-2012		
12-12-1988	11-12-2012	05-12-1988	

Table 2: Release dates of crop reports

Grain stocks

Another widely watched report in the commodity markets is the Grain Stocks report published by the USDA. This report contains the stocks of all wheat, durum wheat, corn, sorghum, oats, barley, soybeans, flaxseed, canola, rapeseed, rye, sunflower, safflower, mustard seed, by State and by position (on-farm or off-farm storage). It also includes the number and capacity of off-farm storage facilities and capacity of on-farm storage facilities. Grain stock reports can cause movements in future markets, when the numbers published in the report do not match the expectations.

The Grain Stocks report is published four times a year. Part of the information in these reports is also found in the WASDE reports, but it gives a more extensive report on the grain stocks. The report is published around January 11, March 31, June 30 and September 30 (Table 2). The first report was released in 1973, the same year as the first WASDE report (then ASDE).

When looking at the 2012 release dates, there are no indications that the Grain stocks reports could have started the huge jump upward of mid June. The nearest Grain stocks report release was on the 29th of June.
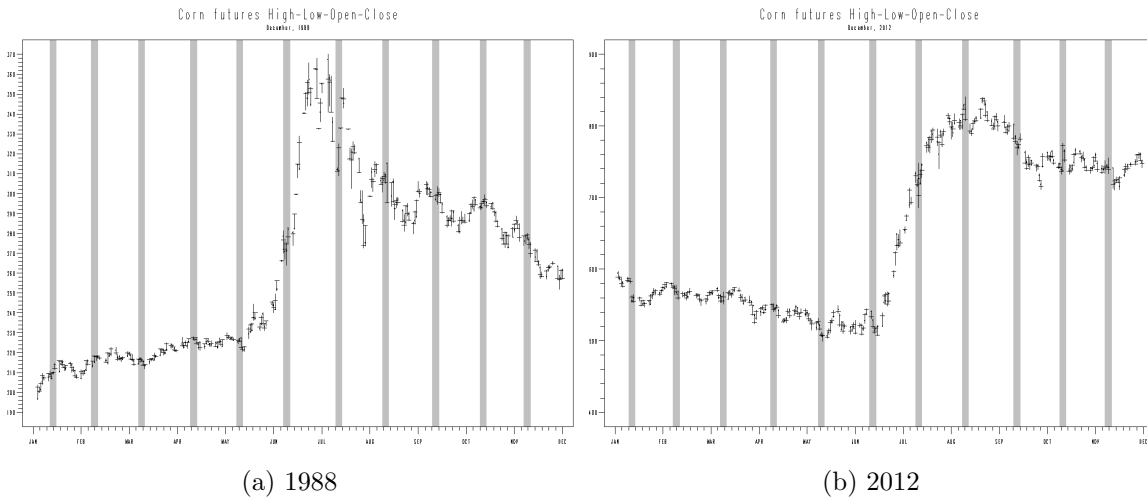
(a) 1988	(b) 2012

Figure 9: The corn futures in 1988 and 2012 with the WASDE report release dates (2 days before until 2 days after the publication)

2.5 Corn future contracts

A future contract is a standardized contract between two parties where they agree upon buying or selling a specified asset or product in the future for a price agreed upon today. The delivery and payment will take place at the specified date in the future, also know as the maturity date of the contract. Future contracts are traded through future exchanges, which provide a venue for buyers and sellers to transact business through an open-auction system. A trading venue can both be physical, in the form of an exchange floor, and in electronic form as a virtual trading pit. Besides providing a trading venue, the exchanges have one more very important function; clearing. Clearing denotes all activities from the time a commitment for a transaction is made until it is settled. As corn future contracts nowadays do not actually trade in the physical product anymore, clearing generally consists of settling the cash accounts between the two parties engaged in the contract. In this process, the difference between the actual price and contract price is paid to one of the parties. This is possible through the clearinghouse, which is a third party that is set up between all the interested investors of both sides of the future contract. The clearinghouse acts as a buyer to every clearing member seller and as a seller to every clearing member buyer. More importantly, the clearinghouses are an important part of the guarantee system that protects futures buyers and sellers from default of the other party. This guarantee system, used at futures exchanges, also provides a platform for the buyer and seller, so that each is free to buy or sell independently from the other.

Corn futures in the US are traded at the Chicago Mercantile Exchange (CME), both electronically and through open outcry[4]. At this exchange several types of financial instruments are traded, but this research focuses on the future contracts. The CME has the largest open interest[5] in these contracts of any futures exchange in the world. Future contracts on the CME are settled every day, this means that at the end of each trading day, the wins or losses between the two parties are settled. This is a risk measure taken by exchanges such that losses cannot accumulate, which could lead to problems when it comes to fulfillment of obligations.

One of the key purposes of futures contracts is to manage price risk, i.e. the risk of changing prices. As these contracts set a fixed price at a future date, both buyers and sellers could use them to hedge against price changes. A seller of corn would buy future contracts when he likes to hedge against decreasing corn prices in the coming period. A buyer of corn on the other hand, would buy future contracts to hedge against increasing prices. Then there are the group of speculators, that enter into future contracts based on their expectations of future price movements. Different types of investors, with different motives, will each trade in their own specific way.

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[4]open outcry is the actual trading at the futures exchange through vocal and hand signals

[5]open interest is the number of contracts that are outstanding, i.e. the number of contracts in which members can trade

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For corn, five different future contracts are traded in each year with maturities in March, May, July, September and December. Both the open outcry and electronic trading of expiring futures contracts on the CME end at noon on the business day prior to the 15th calendar day of the contract month. Open outcry trading happens between 9:30 a.m. and 2:00 p.m., central time, Monday through Friday. Electronic trading is possible between 5:00 p.m. and 2:00 p.m., central time, Sunday through Friday. The contract size of one future contract is 5,000 bushels with three deliverable grades of corn: No. 2 Yellow at par, No. 1 yellow at 1.5 cents per bushel over contract price, No. 3 yellow at 1.5 cents per bushel under contract price. More information on the different grades of corn can be found in the Grain Inspection Handbook[6] by the USDA Grain Inspection, Packers and Stockyards Administration and Federal Grain Inspection Service.

Future contracts on corn are very liquid and traded in great volumes. Besides, their term structure makes them very useful. The fact that at one point in time there are several contracts that are traded, which expire at different dates is very informational. Corn is harvested around October in the US, which means that the first contract on a new harvest is the December contract, which is consequently the most traded future contract by volume. The value of future contracts is sensitive for what the investors believe the corn value will be at the time the contract expires. This means that the price of two contracts that expire after two different harvests will contain different information. E.g. the drought of 2012 had much greater impact on the December 2012 contract than the December 2013 contract, as the 2013 contract expires after the harvest of 2013 and will be consequently less influenced by the 2012 harvest conditions. This term structure allows us to make a distinction between seasonal or long-term effects and incidents.

The rationale of investing in future contracts is a very import aspect that should be understood in order to get a better understanding of certain price movements. There are two sides to a future contract; the buyer and the seller. In the fundamentals of these contracts the seller of the contract wants to hedge against falling prices, as they secure a fixed price for a certain amount of corn. The buyers of the future contracts are mostly corn processors that want to buy a certain amount of corn for a fixed price, and thus are hedging against rising corn prices. But there is an irregularity in this relation. The use of these future contracts for the selling side of the contract could be put into doubt. The selling side of the future contract wants to hedge against falling price, yet prices are for a great part determined by their own production. This means that producers (farmers) would be hedging against very high yields, which actually should not be a problem for them. Therefore, the amount of producers that are involved in the future markets will not be very high. This would mean that there is an imbalance in the future markets between buying and selling parties, but that is where the speculators come in. Speculating sellers of future contracts anticipate on falling corn prices, which means that they can buy back the contracts for a lower price at a later time.

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[6]http://www.gipsa.usda.gov/publications/fgis/handbooks/grain-insp/grbook2/corn.pdf

2.6 Insurance policies

One of the aspects of recent years that has influenced the behavior of farmers are the insurance policies. Crop insurance policies nowadays are highly subsidized by the US government. These insurance policies can be divided into two categories. The revenue and yield policies, covering significantly lower revenues or yields respectively. Most of these policies are multi-peril, meaning that the policy covers multiple events that may trigger low yields or low revenues. Crop insurance policies have evolved the past decade to become the most important crop subsidy program in the US. In 2013, crop insurance programs are projected to account for 63% of all USDA's budgeted outlays for farm subsidies. With the proposed elimination of the direct payment programs, crop insurance policies will serve as the primary subsidy for agricultural producers in the US. This dominant role of crop insurance programs reflects the impact of recent high prices, which have eliminated payments from traditional price-based programs, and congressional efforts to broaden the availability and attractiveness of federal insurance.

The paper by Summer and Zulauf (2012 [21]) states that subsidies for crop insurance may affect environmental consequences through several channels including:

- Incentives to expand onto more environmentally sensitive lands.
- Incentives to use more inputs as average returns rise.
- Incentives to shift across crops toward those, such as cotton, that may have more negative environmental consequences.
- Incentives to use fewer risk-reducing practices and materials.
- Impact from the lack of environmental or conservation compliance rules for crop insurance as have applied to land under the traditional crop subsidy programs.

Insurance policies bring several basic issues along. Two key issues are moral hazard and adverse selection. Moral hazard exists when insurers alter their decisions when having an insurance in such a way that it increases the probability of an insurance claim. With crop insurance, moral hazard consists of the risk that farmers make managerial decisions based on their insurance policy, which could increase the probability of an insurance claim. This could mean that at some point they stop investing money to increase yield as an insurance claim could be more profitable.

Adverse selection exists when a potential insured party knows more about the risk and magnitude of losses than the insuring party. For example, a farmer may know that his crop yields have higher potential for large shortfalls than the insurance policy thinks and that the premium does not fully reflect this higher downside risk.

Neither moral hazard or adverse selection imply acts of fraud or illegal immoral behavior, but they simply reflect the impact that insurance can have on decision making and the lack of knowledge of the insurance company. Because moral hazard and inverse selection increase expected claims, they have to be factored into the premium rates. This contributes to the fact that some farmers, notably those with less moral hazard or adverse selection, think premiums are too high (Glauber, 2004 [11]). These farmers are less likely to purchase crop insurance, which means that premiums are higher.

A standard tool used by insurance companies to manage moral hazard and adverse selection is a deductible. A deductible precludes payments on small losses, which are the losses that are most susceptible to moral hazard and adverse selection. With this measure, insurance companies basically raise the bar to get insurance payments.

Another tool to manage moral hazard and adverse selection is so-called area-wide insurance. These policies cover a whole area collectively. It was pointed out by Halcrow (1949 [12]) that claims due to area-wide causes, such as a county-wide yield shortfall, the moral hazard and adverse selection factors are lower. However, such crop insurance policies did not have a notable marketing success. According to the data from the USDA, Risk Management Agency (RMA), county-wide insurance products accounted for only 2% of the total net acres of insured crop land in the year 2011.

2.7 Relationship of the fundamental market with the futures market

Although it is impossible to link the elements of the fundamental market with future contract price movements with absolute certainty, this section will evaluate the effects that the fundamentals, explained in previous sections, have on the future markets.

During the growing season, when the corn is on the field, many risk factors come into play. All these risk factors will have direct influence on the price, as they all influence the ultimate yield. Because US corn is harvested in October, the contracts that will be mostly affected by the risks are the contracts following this harvest starting in December and with the last contract in September. Between these contracts there is such a thing as a time to maturity effect, which causes the December contract to move harder to events in the underlying market than say, for instance, the May contract. This effect is explained in the next section.

With this in mind, we start by looking at the risk factors that are involved with the development of the corn plant. As more and more risk factors become apparent, the price will start to move more and more upwards. We saw several climatic factors that have a changing effect throughout the growing season. In general, a certain yield is expected according to the acres of land that is planted with corn. Yields much higher than this expectation are not probable. On the other side, there is an existing probability that the yield will be much lower than this expectation. There are several environmental factors that raise this probability. We found the climatic factors: drought, high temperatures, flooding, hail, strong winds and frost, which all have changing probabilities of harming the corn plant according to what growth stage the corn is in. Drought and high temperatures will do most harm when the plant is going from the vegetative stages to the reproductive stage. Flooding is dangerous throughout the growing season, but is less common than the other factors. Hail and frost are more dangerous when the plant is further above the ground. And finally, both early- and late-season frost will have a negative effect on the corn yield.

Besides the climatic risk factors that can negatively affect the yield, there are also the other environmental dangers, like bugs and insects and plant diseases. The corn plant will get weaker as more of previously described risk factors come into play. For instance, the chances of stalk rot are much higher when the plant is already water stressed from the drought and high temperatures. In my interviews with one of the farmers (Appendix C), he compared the corn plant to a human body for that matter. "When the body is already weak and old, diseases are much more fatal than when the body is strong and vital".

Over the years, many things in the corn market have changed that have an effect on the way the future markets behave. Future markets respond to the supply and demand of the underlying product, and with corn many thing have changed on both sides of the equation. The most important change on the demand side is the vast growth of the corn demand for ethanol production. This has caused the corn price to rise significantly since 2005.

The supply side has grown accordingly, not as much in terms of planted acres, but more in terms of yield per acre. Many techniques, like narrower planting, better pesticides and herbicides, but most of all genetically improved seeds have caused the yield per acre to steadily rise.

But future markets do not only change due to changes in the factors that influence the underlying asset (commodity). The way the corn future markets behave is also influenced by which people are active on these future markets, and what their incentives are. For all future contracts there are two sides of the contract; the buying (long) and the selling (short) side. We will now address the selling side as the farmers and the buying side as the corn processors. In the period between 1988 and 2012, one big difference on the selling has come forward from the interviews (Appendix C). This is the fact that the crop insurance has improved significantly in favor of the farmer. This improvement is seen in the amount of farmers that are now insured against crop failures. Over 90% of the farmers is now insured, against less than half in 1988. This huge difference could bring along some changes in the behavior of the selling side of the future contracts, as the insurance policies will significantly reduce the fears of the farmer. Farmers nowadays are in a much stronger position, because whatever yield the harvest brings, they will always be able to pay their expenses due to these crop insurance policies. In the previous section we saw some risks that these insurance policies bring along (adverse selection and moral hazard), which could also change the behavior of these insurance holders. The

decisions that corn farmers make on the land have a direct influence on the corn future market. For example, when it is more profitable to let the crop fail, rather than investing more money to save the crop, as the farmer will receive the insurance claims, then future markets will react more heavily to factors that could cause this crop failure. Therefore it is important to keep in mind, not only the factors that influence the underlying market, but also the way that the market participants reacts to changes in these factors.

Finally, the behavior of the future markets have changed due to a changing composition of market players. Over the years, the amount of speculative traders have grown significantly. With this, a huge growth in commodity index investments is seen. The value of commodity index-related financial instruments purchased has increased from $15 billion in 2003 to at least $200 billion in mid-2008. This increase may have caused unwarranted increases in the cost of these commodities, and induced excessive price volatility. Before early 2000s commodity future contracts were traded, but they carried a risk premium on commodity price risk and they had very little co-movement with stocks. These aspects were in sharp contrast to the price dynamics of typical financial assets. This has led investors to see potential diversification benefits from investing in the segmented commodity markets, which in turn led to a rapid growth of commodity index investment after early 2000s. This rapid growth then, led to the process of financialization amongst commodity markets. The financialization process defines the process of reducing all value that is exchanged into financial instruments or a derivative. In the commodity markets, this process describes the increase of the number of commodity related financial instruments. This is a natural response to the growing interest of investing in commodities. In the paper of Ke Tang and Wei Xiong [22] it is shown how the financialization of commodities has led non-energy commodities to become increasingly correlated with oil. This could also be the case for corn.

Taking a look at Figure 10, where the Goldman Sachs Commodity Index (GSCI) is shown with the modeled (next chapter) price level of corn, one can see much more co-movement between the index and the general corn price level in 2012. Quite remarkable co-movements are seen, even though corn only has a weight of 4.5% (by dollar value) in the GSCI. Indicating that due to this vast growth of index investors, the corn future prices will be influenced by what happens to these indices.

(a) 1988   (b) 2012
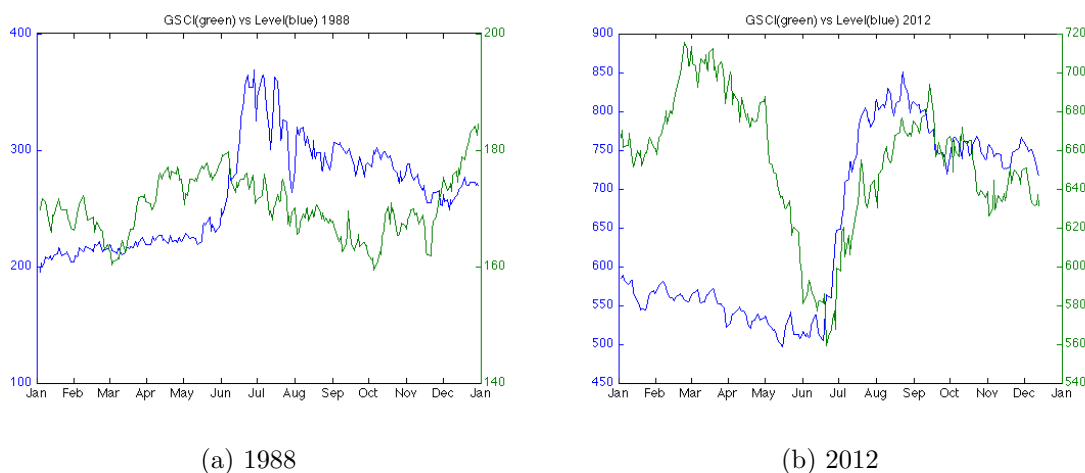
Figure 10: The corn futures (blue) in 1988 and 2012 with the GSCI price (green)

3 Future markets

3.1 Term structure

The main advantage of using future contracts for the analysis of corn prices is the fact that these contracts have a so-called term structure. The term structure reveals information about the supply and demand relationship of the underlying asset. Future contracts are usually offered across multiple contracts with different expiration dates through the year. Between these contracts exists a certain price structure which is called the term structure. Because the corn market (and many other agricultural markets) in the US has a yearly harvest, this market has a cycle that repeats itself every year. This means that the five future contracts in a crop year (from December-September) all have corn from the same harvest as their underlying value.

The number of active contracts at each point in time changes from day to day. There is no predefined time that contracts start to trade, because it depends on the investor's behavior in the future markets. Currently (April, 2013), all contracts are available for trading up to the corn crop year 2014/15 (designated by the USDA, September 1, 2014 - August 31, 2015), the December and July contracts from 2015 are available and even the Dec 2016 contract is available for trading. As the December contract is the first contract after a new harvest, it is the first contract of the corn crop year that starts to trade actively. Over time, the size of these future markets have grown significantly. This has also lead to corn future contracts getting a longer life span, as they start to trade longer before maturity.

The form of the term structure is shown in Figure 11a. In this figure, the average deviation from the mean of the five future prices (of one crop year) is shown for each individual contract calculated over the period from 1987 until 2012. The first four contracts show approximately a straight line, with a very light curve. The angle of the line between these contracts can be explained in two ways. First, the difference between these contracts is approximately the cost of storing the corn between the different maturity dates, the angle of this line could best be described as a measure of the storage costs. Higher storage costs will result in a larger angle. This also explains the fact that the line between the contracts can be approximated by a straight line, as storage costs are linear, i.e. each day of storage costs approximately the same. Storage costs are one of the main reasons for buying corn at a later stage, i.e. without storage costs it would make hardly any difference to buy corn now or later within the same crop year, as all the contract within a crop year have the same corn as underlying. Therefore, a contract that expires later will have a higher price than an earlier maturing contract (in the same corn crop year).

Secondly, the slope is also influenced by a so-called time to maturity effect, which implies that a longer time to maturity will allow for more time to cover the risk factors, such that contracts with a longer time to maturity will react less heavily to new input in the market. Or from another point of view, people are willing to pay extra to cover more uncertainty.

The last contract of the corn crop year, which is September, shows a distinct movement from the line between the first four contracts. This can be explained by the fact that when the September contract expires, a good estimation of the next harvest's yield (October) can be made already. As this information should be incorporated in the market, the price of the September contract already incorporates a lot of information on the next harvest. This means that the price of a September contract shows movements towards the next December contract price, which is in general the lowest price in a corn crop year. For example, in case of an outlook on a crop failure, the September corn suddenly becomes worth much more due to the insufficient supply from the new crop. Instead of selling the corn in September, people would like to keep their corn in September to profit from the price increase due to the insufficient supply. Hence, the price of the September contract will move towards the first contract of the new crop year. In Figure 11a the distinct movement of the September contract is clearly visible.

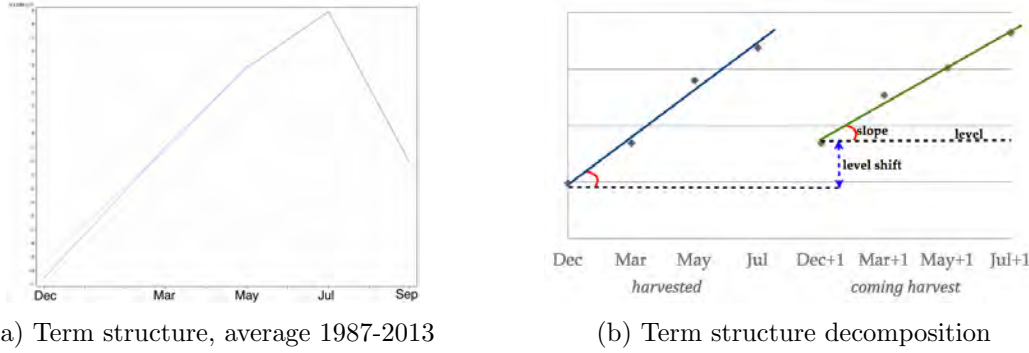(a) Term structure, average 1987-2013   (b) Term structure decomposition

Figure 11: Term structure

Due to this distinct movement of the September contract, the analysis is done with only the contracts expiring in December, March, May and July. This term structure of multiple contracts can be decomposed into three main components: Level, Slope and Level shift. These components are schematically shown in Figure 11b. The level component can be seen as the general price level of the first upcoming crop, which is the crop that is prone to the most risk factors. The slope can be seen as a measure for the storage costs/time to maturity effect which was explained before. The level shift is simply the difference between the estimated levels of two subsequent crop years, which is in this case the difference between the level of the current crop that is on the fields (or is to be planted) and the crop that has already been harvested and is stored. Both crops are sensitive to different risk factors, where the level shift measures the size of this difference. As more information becomes available on the new crop during the growing season (April-October), many risk factors will come into play such as the weather, bugs and soil conditions. This will have an effect on all three of these components. Figure 12 shows the evolution of the three components from the decomposed model over time. Important to understand is the fact that each crop year can be seen as a new cycle, which means that these components are not continuous over time. The transitions from one crop year to another are plotted with the red vertical dotted lines.

The model for the decomposition in a level and slope shown in Figure 11b is:

$$F_c(t, T) = \bar{F}_c(t) + \alpha \cdot (T - 1)$$

Where $F_c(t, T)$ is the price at time t of the future contract of crop-year c with maturity month T ($T_{Dec} = 1$, $T_{Mar} = 4$, $T_{May} = 6$ and $T_{Jul} = 8$), $\bar{F}(t)$ is the level of the available contracts in one corn crop year and α is the slope. The estimates of both the level and slope are their least squares estimates. The contracts on the crop that still has to be harvested will be used to determine the level and slope component, this crop has generally the most actively traded contracts. The level shift can be modeled as: $LevelShift = \bar{F}_c(t) - \bar{F}_{c-1}(t)$. One has to keep in mind that when the harvested crop July contract expires there is no contract left to determine the level shift (as the September contract is not taken into account in this research). This causes a gap between July and December, where there is no data to determine the level shift; on these days the level shift is set to zero. Between the maturity of the May and July contract only one contract on the harvested crop is traded, which makes it impossible to calculate a slope. Level shift in this period will be calculated assuming a constant slope over the years.

The level of the contracts shows an upward trend starting in 2005, for a great part due to increasing demands for ethanol production which is shown in the article by Carter, Rausser and Smith (2012, [5]. This article shows that the Corn price would be 30 percent lower between 2006 and 2011 if ethanol production would remain constant since 2005. The slope shows overall positive values with some negative spikes (huge spikes seen in the two drought years, 1988 and 2012). These spikes go along with large shifts in level caused by large upward movements of all contracts in that crop year. A declining alpha means that the first nearby contract, which is December, lies higher than the following expiring contracts. This indicates that in strong upward (or downward) movements, contracts that mature nearby move harder than contracts that mature further in the future. The reason for this is that when sudden price changes happen, later maturing contracts have more time for alternatives

for both sides of the contract. This is the time to maturity effect that was addressed earlier in this chapter.

When looking at the modeled level shift, there is a big downwards spike seen in 1996. This spike is a result from the late planting of the 1996 harvest. What happens is that, because of the late planting of corn this year, the July and September 1996 contracts moved up a lot. Late planting causes a late harvest, which makes the July and September corn worth much more as the supply for the September corn contract suddenly becomes much lower (because the September corn usually already includes early harvest corn).
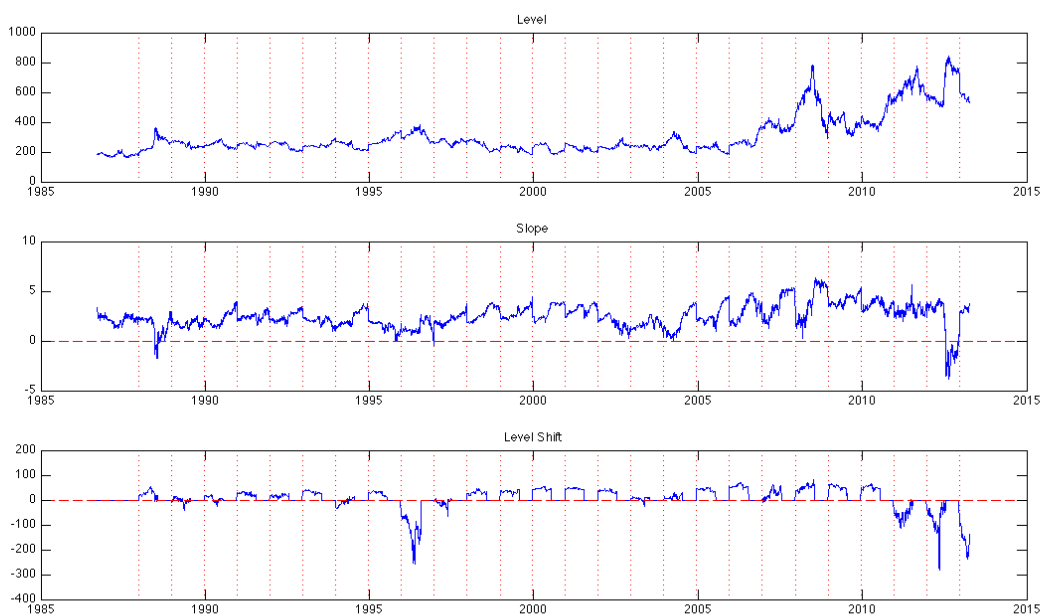
Figure 12: Term structure: Level, slope and level shift between 1987 until 2012

The time-to-maturity effect arises from the fact that, as was stated before, contracts with longer time to maturity are less sensitive to sudden innovations that move the price up or down. This means that when events occur that drive the price, say for instance, up, this will have more effect on the nearer contracts causing the slope between the contracts to go down. At the same time the level will go up, which causes the opposite movements between the level and the slope. To take a closer look at these effects, the negative level is plotted against the slope. Similar movements in these two variables will be visible when the level and slope move in opposite ways.

The same effect can be seen with suddenly dropping corn prices, which rarely occurs, but this will cause the December contract price to drop first followed by the other contracts, resulting in an increasing slope. This effect is better seen in Figures 13a and 13b, where the negative normalized level is plotted against the normalized slope. In these figures two periods are distinguished, 1987-2004 (13a) and 2005-2013 (13b). Figure 13a shows more co-movements between the negative level and the slope than the latter period in Figure 13b. We saw before that 2005 is the year that the level of the contract prices started to show an upward trend partly due to increasing ethanol production, this overall shift in prices does not have direct effect on the slope. The red lines in Figure 13 again indicate the days where the crop year switches to the next. On these days the large jumps in level and slope should be assigned to the switching of crop year, rather than large movements in contract prices. As one would expect, these dotted lines are all in December, as the first contract on the (at that time) harvested crop expires, and will be rolled over to the next crop year.

In Figure 14 the negative level and slope have been plotted for three separate years. First for the two drought years 1988 and 2012, where a clear relationship is shown between the negative level and slope. And secondly, a year where not such a clear relationship is found between the level and the

slope, which is 2008. To get a deeper insight in the relationship between the negative level and the slope, a regression analysis is performed between the first differences of the level and the slope. One can see in Table 3 that for each year, there is a highly significant relationship between the level and the slope. In the final model this has to be taken into account.
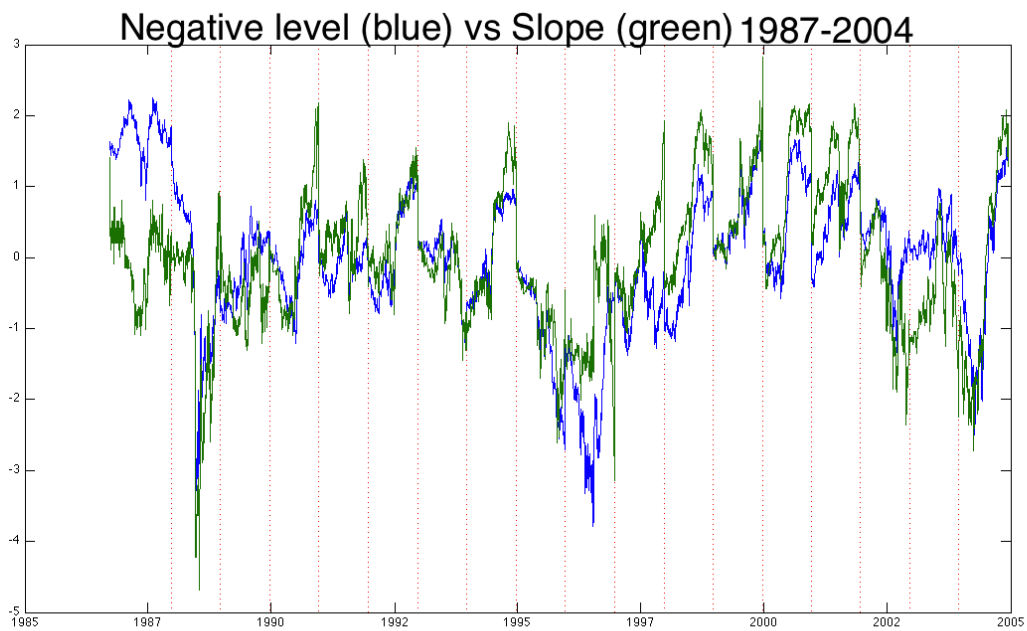
(a) 1987-2004
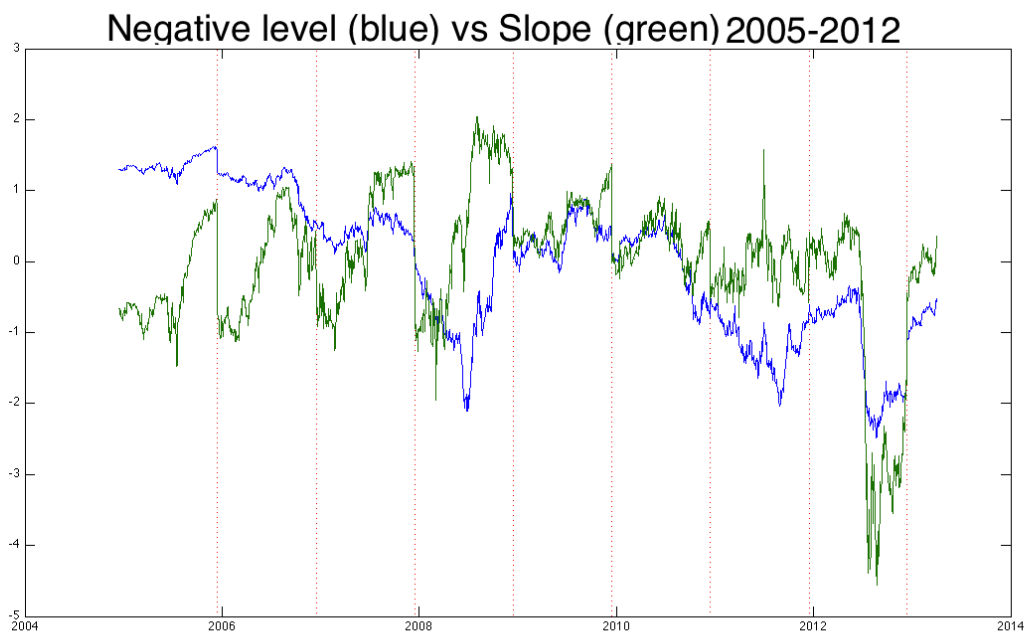
(b) 2005-2013

Figure 13: Negative Level (blue) vs Slope (green) in two periods, the red dotted lines are days where the crop year switches to the next

| (a) 1988 | (b) 2012 | (c) 2008 |
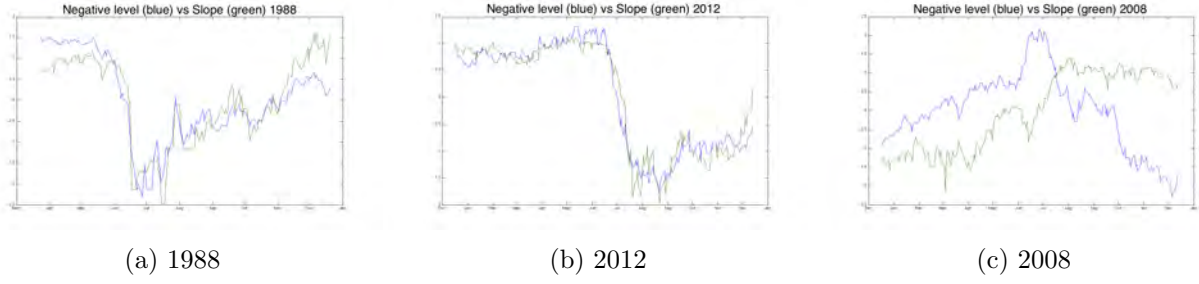
Figure 14: Negative Level (blue) vs Slope (green) for different crop years

Period	β	t-stat	p-val	R^2
Full	-15.2809	-40.3623	0.0000	0.1959
1987-2004	-13.1134	-38.6412	0.0000	0.2453
2005-2012	-16.5706	-21.2346	0.0000	0.1775
1987	-7.1043	-8.5922	0.0000	0.1898
1988	-11.5757	-8.7509	0.0000	0.2318
1989	-6.8640	-4.4733	0.0000	0.0722
1990	-7.8634	-4.7888	0.0000	0.0829
1991	-11.2309	-8.7527	0.0000	0.2339
1992	-12.9820	-9.0714	0.0000	0.2438
1993	-10.5869	-7.5741	0.0000	0.1809
1994	-15.0402	-8.9658	0.0000	0.2406
1995	-13.1582	-10.2386	0.0000	0.2806
1996	-12.4945	-7.0967	0.0000	0.1664
1997	-14.3206	-7.4459	0.0000	0.1815
1998	-14.8124	-6.3648	0.0000	0.1326
1999	-10.0108	-6.4279	0.0000	0.1372
2000	-19.6567	-8.6891	0.0000	0.2340
2001	-15.3332	-10.2055	0.0000	0.2932
2002	-16.7180	-15.1868	0.0000	0.4820
2003	-16.8069	-12.3487	0.0000	0.3807
2004	-17.7247	-9.0092	0.0000	0.2444
2005	-20.0275	-15.9821	0.0000	0.5052
2006	-17.1806	-10.5347	0.0000	0.3016
2007	-16.3695	-8.5622	0.0000	0.2272
2008	-8.1627	-2.5222	0.0061	0.0242
2009	-16.9267	-3.8470	0.0001	0.0559
2010	-15.5353	-5.3087	0.0000	0.0977
2011	-19.8616	-7.6361	0.0000	0.1877
2012	-19.4800	-11.5484	0.0000	0.3466

Table 3: The regression results of δ slope against δ level without intercept

3.2 Model for Level and Slope

The next step in our analysis is to model the evolution of level and slope over time, which are shown in Figure 12. The level shift will be left out of the analysis, as the model can perfectly be formed by both the level and slope. This model is created based upon three very important assumptions:

1. **Mean reversion**

   Both the level and slope are assumed to be mean reverting, meaning that they both will never diverge from a certain equilibrium. For the slope this is intuitive, as the slope represents an angle that can never be infinitely large. And for the level, this is based on the assumption that there exists a balance between the price of a commodity and the demand for that commodity, as higher prices will lead to higher supply (more farmers want to benefit from these high prices) and/or lower demands (replacement by cheaper products).

2. **Level-Slope dynamics**

   The model has to account for the opposite movements of the level and the slope. As we saw before, the level and slope show opposite movements. To model this we would like to introduce a model that allows for covariance between the updates of the level and the slope.

3. **General noise term**

   This model has to account for the fact that that the observations of the level and the slope are driven by their underlying functions along with a random component. This random term in the model contains the random factors that cannot be modeled but do have an effect on the level and the slope. For example, the decision of an investor to buy or sell corn futures today instead of tomorrow or other small decisions that shift price changes from day to day. By itself these factors have unnoticeable effect but together the effect is significant enough to be worthy to introduce into the model.

This can be modeled in the following system of equations:

$$level_t = level_{t-1} + update_{l,t} \tag{1}$$
$$update_{l,t} = \phi update_{l,t-1} + \xi_{l,t} \tag{2}$$
$$\text{and}$$
$$slope_t = slope_{t-1} + update_{s,t} \tag{3}$$
$$update_{s,t} = \phi update_{s,t-1} + \xi_{s,t} \tag{4}$$

The $\xi_{l,t}$ and $\xi_{s,t}$ are negatively correlated, to account for the fact that the level and the slope showed opposite movement such that their updates should be negatively correlated. Equations (5) and (6) show the linear Gaussian state space model. This models a signal that is generated by an AR(1) process, which is a mean reverting process generally used for modeling commodity prices. Here y_t represent a vector of the observations of the level and the slope, which are generated by a selection of the state vector, which is the signal that is driven by the underlying model, $(Z\alpha_t)$ and the random component (ϵ_t) we introduced before. As the signal follows an AR1 process, the state vector (α_t) is updated by a linear transformation of the previous state $(T\alpha_t)$ and also a selection of the update vector $(R\psi_t)$ (see (6)).

A value of 0.9 is chosen for ϕ, because this value resulted in strong convergence when estimating the parameters by maximum likelihood and smaller values for ϕ caused the state variance to go up.

$$y_t = Z\alpha_t + \epsilon_t \qquad\qquad \epsilon_t \sim N(0, H_t) \tag{5}$$
$$\alpha_{t+1} = T\alpha_t + R\psi_t \qquad\qquad \psi_t \sim N(0, Q_t) \tag{6}$$

When writing the system of equations in 1-4 in the State Space form (6) we get:

$$
\begin{pmatrix} level_{t+1} \\ slope_{t+1} \\ update_{l,t+1} \\ update_{s,t+1} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & \phi_l & 0 \\ 0 & 0 & 0 & \phi_s \end{pmatrix} \begin{pmatrix} level_t \\ slope_t \\ update_{l,t} \\ update_{s,t} \end{pmatrix} + \begin{pmatrix} 0 & 0 \\ 0 & 0 \\ 1 & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} \xi_{l,t} \\ \xi_{s,t} \end{pmatrix}
$$
$$
\alpha_{t+1} \quad = \quad\quad\quad T \quad\quad\quad\quad \alpha_t \quad\quad + \quad R \quad\quad \psi_t
$$

where

$$
\psi_t \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma^2_{\xi_{l,t}} & \sigma_{\xi_{ls,t}} \\ \sigma_{\xi_{ls,t}} & \sigma^2_{\xi_{s,t}} \end{pmatrix} \right)
$$
$$
Q_t
$$

With corresponding observation equation from (5):

$$
\begin{pmatrix} y_{level_t} \\ y_{slope_t} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \begin{pmatrix} level_t \\ slope_t \\ update_{l,t} \\ update_{s,t} \end{pmatrix} + \begin{pmatrix} \epsilon_{l,t} \\ \epsilon_{s,t} \end{pmatrix} \qquad\qquad \begin{pmatrix} \epsilon_{l,t} \\ \epsilon_{s,t} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma^2_{\epsilon_l} & 0 \\ 0 & \sigma^2_{\epsilon_s} \end{pmatrix} \right)
$$
$$
y_t \quad = \quad\quad Z \quad\quad\quad\quad \alpha_t \quad\quad + \quad \epsilon_t \qquad\qquad\qquad \epsilon_t \quad \sim N \; (\quad 0 \quad, \quad\quad H_t \quad)
$$

Which leaves the multivariate linear Gaussian state space model in (5) and (6).

The signal (α_t) is an AR(1) process which means that the updates are autocorrelated and not independently distributed. The observations (y_t) are generated by this signal with a random noise factor (ϵ_t). The model thus separates the observations into a noise and signal component. This can be done recursively with the Kalman Filter.

The Kalman filter updates the model, by estimating the state vector and its variance, each time a new observation is brought in. Equations 7 and 8 show the update of the state and its variance. The derivation of the Kalman filter is given in Appendix B.

$$
a_{t+1} = E(\alpha_{t+1}|Y_t) \quad = E(T\alpha_t + R\psi_t|Y_t) \quad = TE(\alpha_t|Y_t) \tag{7}
$$
$$
P_{t+1} = Var(\alpha_{t+1}|Y_t) = Var(T\alpha_t + R\psi_t|Y_t) = TVar(\alpha_t|Y_t)T' + RVar(\psi_t|Y_t)R' \tag{8}
$$

To calculate these updates one has to calculate the conditional expectation of the state vector. This can be done by estimating the parameters in H_t and Q_t. One way to find values these parameter is by maximum likelihood estimation of the Gaussian model ($y_t|Y_{t-1} \sim N(Za_t, F_t)$). This way, we can find the estimates that produce the state space model that is the best fit according to the distribution that is assumed for the observations (y_t). The loglikelihood can be written as

$$
logL(y) = \sum_{t=1}^{n} log\; p(y_t|Y_{t-1}) = -n\; log(2\pi) - \frac{1}{2} \sum_{t=1}^{n} (log|F_t| + v_t F_t^{-1} v_t') \tag{9}
$$

To maximize the loglikelihood, the BFGS maximalization algorithm is used, which is an algorithm proposed by Broyden, Fletcher, Goldfarb and Shanno [6]. This is a quasi Newton method; a method that moves towards the maximum by using the gradients of the function. It's not possible to get reliable estimates when estimating both the variances and the covariance all at once. Therefore, the covariance is estimated by residual analysis of the two separate components, i.e. the level and the slope. The same model, (5) and (6), will be used to estimate the level and slope, only now the observations are univariate. The state vector for the level is assumed to follow the process in (1) and (2) and the state vector of the slope follows (3) and (4). After estimation of the parameters by the same likelihood (9). The covariance of the two models can be approximated by the value of the covariance between the update residuals in (2) and (4). This covariance will be used as constant value

during the estimation of the matrices H_t and Q_t of the bivariate model. This way strong convergence is found in the BFGS function value. Estimation is done per crop year, to avoid problems with the discontinuity between crop years. The estimations are found in Table 4.

Year	$\sigma^2_{\epsilon_l}$	$\sigma^2_{\xi_l}$	$\sigma^2_{\epsilon_s}$	$\sigma^2_{\xi_s}$	$\sigma_{\xi_{ls}}$
1987	2.8919	0.5770	0.0126	0.0008	-0.0119
1988	5.1053	13.1501	0.0185	0.0088	-0.1006
1989	4.0829	2.0553	0.0096	0.0008	-0.0031
1990	2.2064	1.9943	0.0032	0.0022	-0.0121
1991	5.0566	0.5575	0.0094	0.0006	-0.0106
1992	3.3823	0.4288	0.0047	0.0008	-0.0142
1993	2.1762	1.0027	0.0057	0.0005	-0.0092
1994	3.3130	1.3509	0.0051	0.0005	-0.0141
1995	3.2086	0.6741	0.0046	0.0018	-0.0192
1996	6.5512	6.1493	0.0085	0.0041	-0.0467
1997	5.5414	1.8499	0.0078	0.0002	-0.0031
1998	3.5703	1.2019	0.0027	0.0005	-0.0100
1999	2.1395	2.7390	0.0048	0.0013	-0.0089
2000	4.1850	0.4415	0.0022	0.0002	-0.0048
2001	3.3609	1.1840	0.0036	0.0018	-0.0261
2002	3.9972	1.6936	0.0072	0.0030	-0.0668
2003	3.4990	0.8094	0.0051	0.0006	-0.0108
2004	6.3491	2.9169	0.0074	0.0010	-0.0214
2005	2.8293	1.8325	0.0041	0.0018	-0.0516
2006	9.9973	1.9035	0.0081	0.0047	-0.0298
2007	19.4006	5.1109	0.0214	0.0016	-0.0408
2008	62.4137	33.0820	0.0390	0.0028	-0.0477
2009	33.6176	12.5897	0.0098	0.0003	-0.0171
2010	28.5815	9.6201	0.0172	0.0015	-0.0332
2011	81.1199	15.1983	0.0386	0.0066	-0.2233
2012	70.3073	6.5430	0.0574	0.0047	-0.0543

Table 4: The estimates of the parameters in H_t and Q_t

Figure 15 shows us the output of the Kalman filter for the years 1988 and 2012. The red lines in the top figures, show us the state vector extracted with the Kalman Filter recursions (Appendix B). And the bottom figures show us the state variance. It is clear that the state variance converges to a steady value quite rapidly. This variance matrices in the model (H_t and Q_t) have to be initialized on a certain value. I have chosen a diffusion initialization as is described in the book of Durbin and Koopman (2001 [8]), where very large starting values (10^7) are chosen for the variances.

<center>(a) Level 2012</center>

<center>(b) Slope 2012</center>

<center>(c) Level 1988</center>

<center>(d) Slope 1988</center>
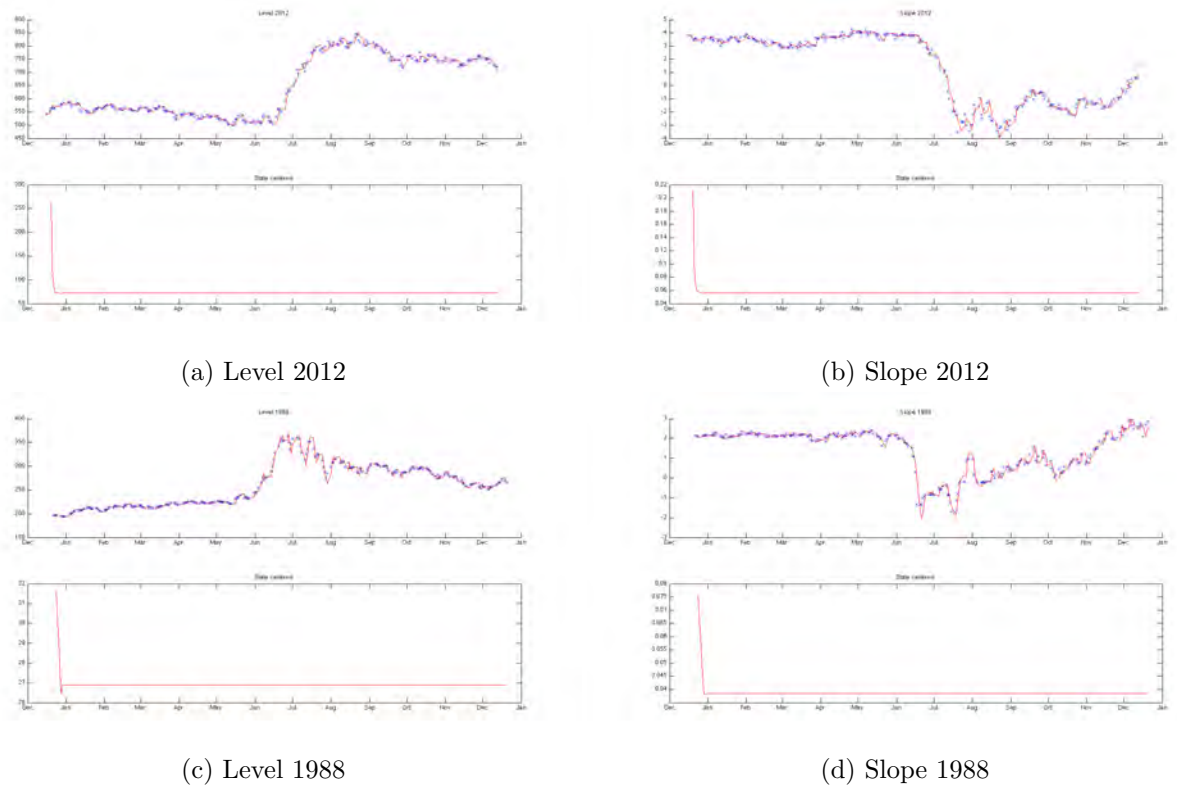
Figure 15: The observations (blue) and Kalman Filter output (red) for the level and the slope in 1988 and 2012, parameters are found in Table 4

3.3 Signal Analysis

The signal found in the previous section, will be used to analyze the co-movements with the both the weather and news data. In this section, an analysis of the climate data will be given, along with an event study, as well as for the news data. Finally, a comparison will be made between the climate data and news data also by performing an event study.

3.3.1 Climate data

The climate data used in this research is collected from the National Climatic Data Center by the National Oceanic and Atmospheric Administration (NOAA). NOAAs National Climatic Data Center (NCDC)[7] maintains the world's largest climate data archive and provides climatological services and data to every sector of the United States economy and to users worldwide. Records in the archive range from paleoclimatic data to centuries-old journals to data less than an hour old. The Center's mission is to preserve these data and make them available to the public, business, industry, government, and researchers.

The NCDC contains climatic information for a large number of weather stations in the United States. For this research data is collected for a selection of 17 the weather stations that are situated in the Corn Belt. The locations of these weather stations can be found in Figure 3. Sufficient data is found for the daily minimum and maximum temperatures, as well as the precipitation. The precipitation data in our dataset are the daily numbers in one hundredths of inches (e.g. 300 is 3 inches). Our climate data ranges from 1988 until 2012. The precipitation will be reduced with the monthly averages (normals) to correct for the difference in rainfall throughout the year. This way, a number for the deviation of the expected rainfall is acquired, rather than a pure precipitation number. The values of the normal precipitation and temperatures can be found in Appendix A. For analysis, the average precipitation of the 17 weather stations and is calculated when at least 14 ($\approx$80%) of the

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[7]from the website: http://www.ncdc.noaa.gov/about-ncdc

17 stations have data. This reduces the number of missing data, while still maintaining significant averages. From the interviews with the farmers (Appendix C) it is found that precipitation plays a bigger role than temperature in the development of the corn plant. Therefore, analysis will be done with the evaluation of the precipitation and the level modeled in the previous section.

Precipitation Score

During the growing season, precipitation plays a great role in the development of the corn plant. Obviously, low precipitation leads to less developed corn plants, which leads to decreasing yields (supply), which eventually will lead to higher corn prices. Prolonged periods of low precipitation, or droughts, are the main reason for corn crop failure. Consistent rainfall, i.e. significant rain occurs every 10 to 14 days, is required to prevent crop damage. Therefore, instead of looking at single precipitation values, the precipitation is modeled in such a way that precipitation of the last 14 days will be relevant. This will be done with a weight scheme, which assigns smaller weights to precipitation further in the past. This decreasing weight scheme will be used to account for the loss of the rainfall. Lots of rain will be lost through evaporation as the is a limit to the speed at which the plant will take in the water. For the decrease in weight the negative hyperbolic tangent function will be used that is shown in Figure 16.
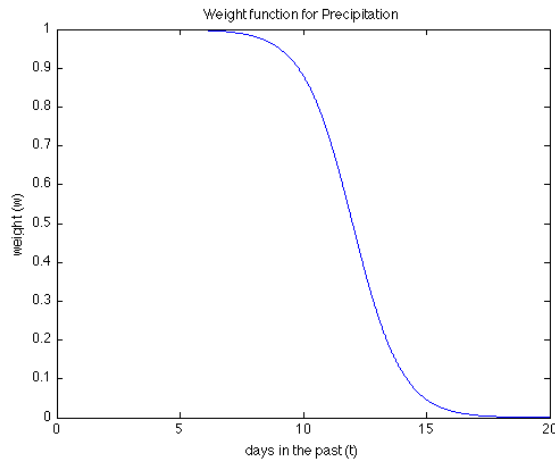
Figure 16: The negative hyperbolic tangent function

The rationale behind the choice of this function for the decrease in weights is the way that the corn plant reacts to precipitation. This function implies that there is a certain period when precipitation will be relevant and it will be followed by a period when precipitation becomes less relevant. One can also interpret this period as the time it takes for the corn plant to become stressed from water deficiency. For example, when the stress period for a corn plant is 14 days without water, all rain that has fallen long before these 14 days will become irrelevant.

The negative hyperbolic tangent function that is used in this research can be written as:

$$w_t = \frac{1 - tanh\left(\frac{t-c}{2}\right)}{2}$$

$$tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

Here t is the time in the past of the precipitation ($t_{now} - t_{precipitation}$), i.e. precipitation further in the past will be given a smaller weight. The parameter c is used to shift the period where precipitation is considered to be relevant. In other words, the window for the precipitation data can be expanded or reduced with this parameter. In the analysis different windows for precipitation are used. In Figure 16 a value of 12 is chosen for c. To allow for a reasonable stress period, where precipitation goes from being relevant to becoming irrelevant, the t-c is divided by 2.

34

In Figure 17 this precipitation score (monthly averages) is plotted with the corresponding level and slope. In this figure, both the drought in 1988 and in 2012 are clearly visible. The difference is that the drought in 1988 is more in the form of a spike, whereas the drought in 2012 show a longer period of low precipitations.
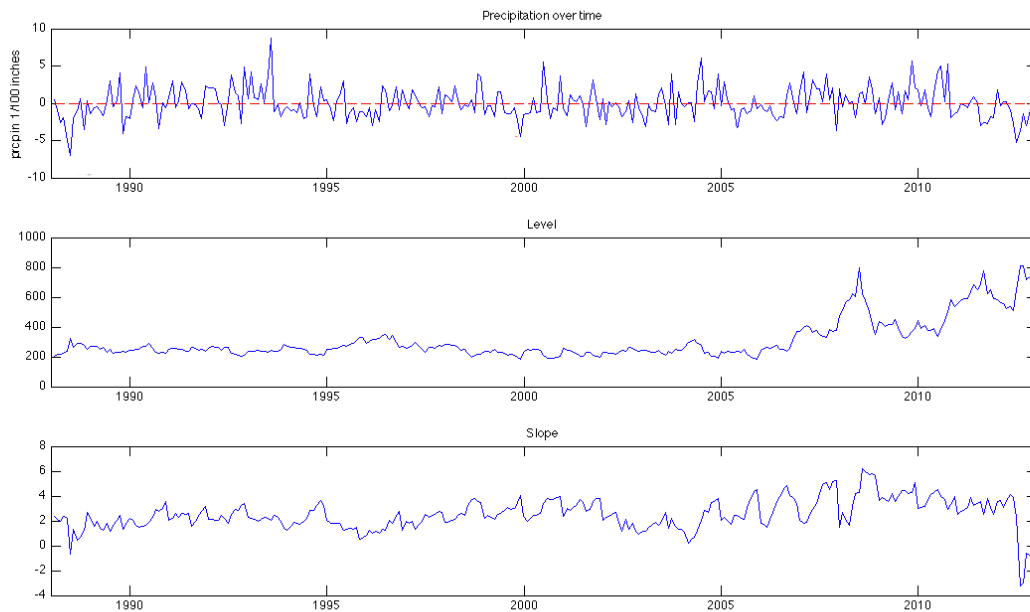
Figure 17: The precipitation score, level and slope (monthly averages) from 1988 until 2012

The modeled precipitation score is plotted against the log returns of the level and against the slope. The data is divided into 50 bins of equal size, where each bin contains a part of the sorted data. This is done to reduce the noise in the data. For each bin the sum of the level returns are plotted against the average of the precipitation scores. For the slope, the average of all the slopes in one bin are used. The scatter plots are found in Figure 18. One can see that there is not a clear relation between the level/slope and the precipitation score, such that correlation or regression analysis will not be very informational. Therefore, we continue this research with an event study.
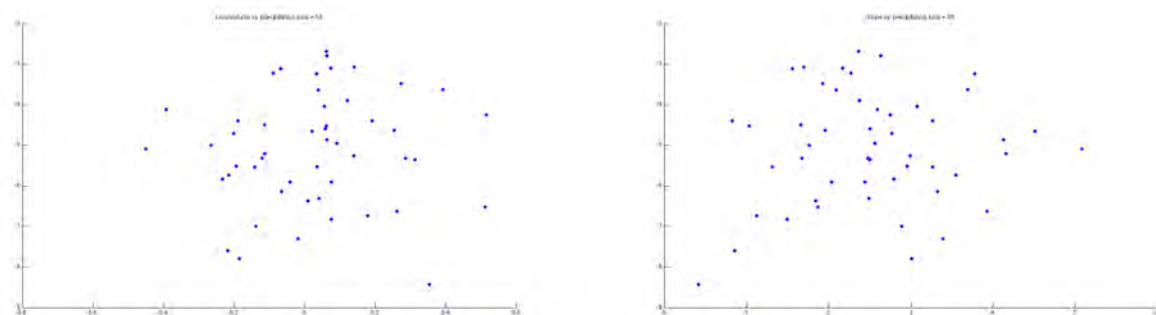
(a) Level returns vs precipitation   (b) Slope vs precipitation

Figure 18: Scatter plot of the level returns and the slope (x-axis) versus the precipitation score (y-axis) for 50 bins

Event Studies

In event studies, the cumulative returns are analyzed around the events. Events are defined as extreme values of the underlying variable the event study is applied to, in our case: the climate and news scores. How exactly an event is defined depends on the underlying variable and will be explained in the corresponding sections. Two variables will be studied around these events: the level and the slope. As the slope does not grow over time, we will simply look at the movements of the slope. The level however, has grown significantly since 1988, and the movements in the level will therefore be expressed in its (daily) cumulative log returns.

To set a benchmark in these event studies, a general level or slope evolution within the window will also be calculated and plotted (red line). This benchmark is calculated by simply taking each day as an event, resulting in a line that corresponds to randomly selecting event days. Instead of simply looking at shifts in the level and the slope, one can now look at the movements relative to the benchmark. E.g. when the slope of the benchmark line is higher than the slope of the level, it would mean that the events that are selected do not show significant movements of the level around these events (while when only looking at the level movements one could assume that any increasing line would be a significant movement).

Each event study is performed on a certain window, which means that the level and slope are evaluated within this window around the event dates. In this research two windows are used, 20 and 50 days, such that analysis is done on the intervals {eventday-20, eventday-20} and {eventday-50, eventday-50}. The events are chosen based on a certain percentage of the dataset, i.e. p% of the data is considered an event. These events are chosen based on the lowest or highest event scores being news or climate scores, which will be defined in the next sections. Four different values of p are chosen: 1, 2, 3 and 5%. And around the selected events, both the movements of the level and slope will be analyzed.

Precipitation Analysis: Event Studies

A prolonged period of low precipitation will be defined as an event. Events in this section are defined as the p% lowest (average of the 17 weather stations) precipitation scores, modeled by the negative hyperbolic tangent weight scheme described before. One must keep in mind that for this data, the event studies will be one sided, meaning that only low precipitation scores will have an effect on the level and the slope. The events in which exceptionally high precipitation will have a negative effect on the future prices (in case of flooding), are so rare that they do not show any significant movements (even for the 1% events).

First, the event studies are done for the full dataset with a precipitation window that is chosen considering the period that a corn plant can live without water, which is 14 days. What is found here is the average of the cumulative returns around the event dates, i.e. the dates on which an event takes place. To avoid many of these event dates will come from the same drought, a minimum time between two event dates of ten days is chosen. An event window of fifty days is chosen, meaning that the cumulative returns from fifty days before until fifty days after the event are evaluated. The averages of these cumulative returns for the top 1, 2, 3 and 5% respectively, are found in Figure 19.

(a) 1%

(b) 2%

(c) 3%

(d) 5%
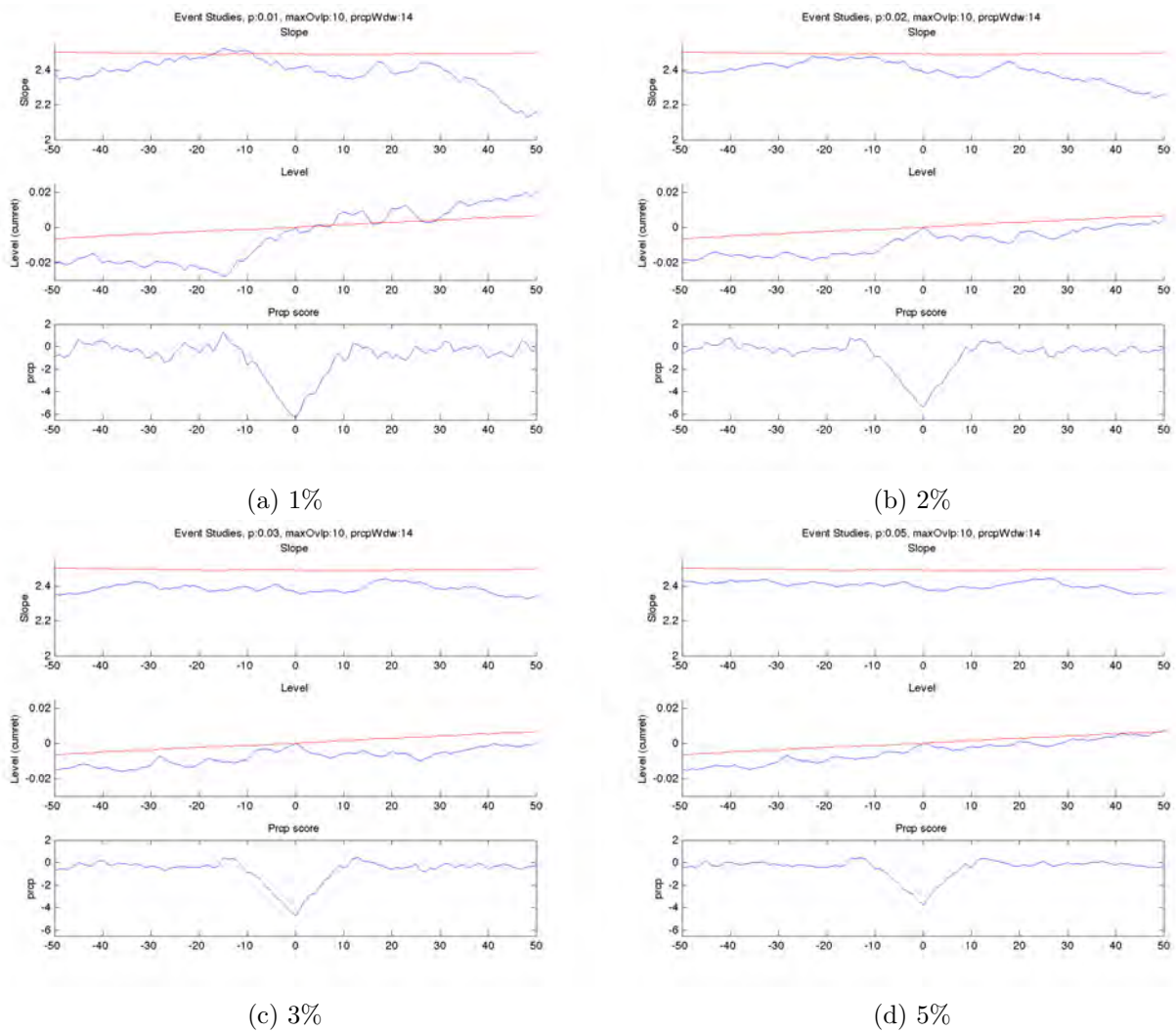
Figure 19: The event studies for the Level and Slope with a precipitation window of 14 days, for the top 1, 2, 3 and 5%

It is clear to see that only the extremely low precipitation scores have a clear effect on the level. The 1 and 2% restrictions show an upward movement in the period before the event. This upward movement starts around 14 days before the event takes place for the 1% events and around 20 days before the 2% events. The 3% events do not show any significant movements around the events anymore, which indicates that only clear movements are seen when restricting events to the lowest 2% or less. The upward movements in level that are visible all take place before the event takes place, because the day after the event there will be significant precipitation. It would not be possible that there is no precipitation the day after the event, as this day would get an even lower precipitation score resulting in a shift of the event to this day. Because a window is taken to create the precipitation score, we must restrict the event dates not to be too close to each other. In this case a minimum distance of ten days is taken between two event dates. Ten days is taken because after ten days the weight significantly decreases (Figure 16).

For the slope it is also found that only the 1 and 2% events show clear movements around the events. What is visible is that after the event takes place, there is still a downward trend visible in the slope for about ten to eleven days. This means that after the event takes place, later maturing contracts will move down first.

It is obvious that the corn prices should only be susceptible to climatic influences when the corn is on the fields. Therefore, the data will be separated into two datasets; one with data when the corn is on the fields and one dataset containing the rest of the data. The corn is assumed to be on the fields between the 1st of April and the 1st of October. Now the same event studies are done on these separate datasets. We expect to see a great difference between the event studies on these two datasets, where the growing season data obviously shows much more movements around events. The results are shown in Figure 20.

Starting by looking at the growing season data, one can see that even for the 5% selected event dates there is some movement visible in the level. Comparing these results to the full dataset, the greatest differences are found in the 1% events. Evaluating only growing season data, the cumulative return from 14 days before the event until the event is approximately 0.06 (equivalent to a 6.18% increase) compared to 0.03 for the full dataset ($\approx 3.05\%$). The movements seen in the level when using only growing season data and selecting the 1% event dates is thus approximately twice as big than when using the full data set.

Also the slope shows much greater movements when performing the 1% event study, with a very long downward trend after the event takes place.

When looking at the non-growing season data, there are no clear reactions to the low precipitation events, as one would expect. The 2, 3 and 5% do show some long term trend before the event dates. But these trend end approximately eight to nine days before the event. Because only a window of 14 days is used to calculate the precipitation score, these movements cannot be accounted to the precipitation data. So it is clear that outside the growing season, no co-movements between the precipitation and the level/slope are apparent.

The event studies on the climate data are therefore continued with the growing season dataset. The next step is to evaluate different windows taken to calculate the precipitation scores. In the previous event studies, a precipitation window of 14 days was taken. The next step is to vary this precipitation window, and to see what happens to the level and the slope. In Figure 21 event studies are show for different windows to calculate the precipitation score. One can see that even with larger windows (50) there is still a co-movement visible between the precipitation score and the level and slope. This means that even when considering precipitation up to 50 days in the past, the cumulative level returns and the slope still show significant movements towards the event. The analysis is done with the lowest 1% event days. Also, the minimum time between two events is also adjusted based upon the window that is chosen. For the 14 day precipitation window, a minimum distance of 10 days was chosen ($\approx 70\%$). This percentage is chosen for all different precipitation windows. The benchmark line is now calculated for only the data during the growing season. And one can see that while the slope benchmark slightly increases within the window, the benchmark for the cumulative level returns are now slightly decreasing. This means that during the growing season there is an overall declining trend in the level. This comes from the fact that during the growing season, when the corn gets closer and closer to maturity, more and more risk factors are eliminated.
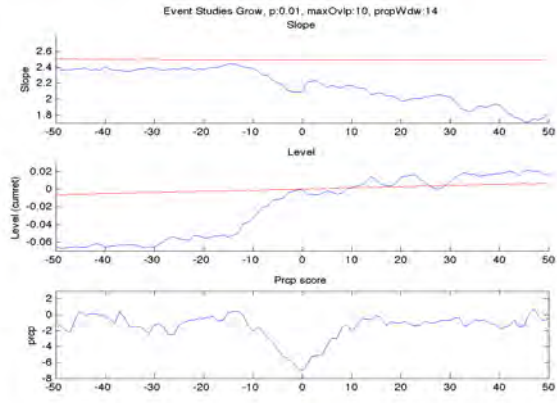
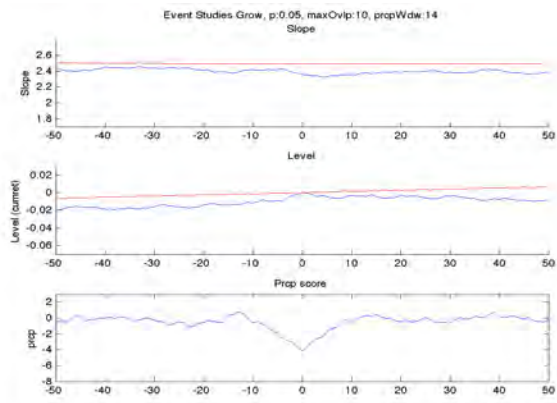(a) Growing season, 1%
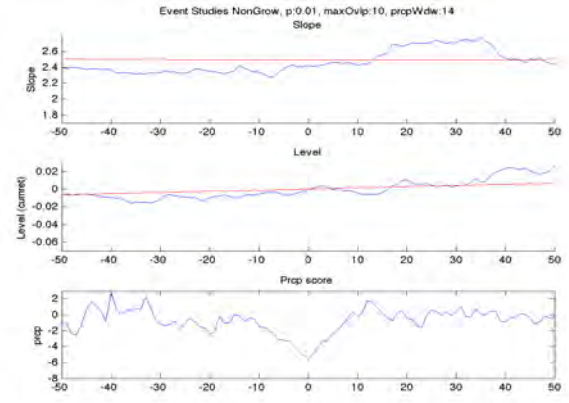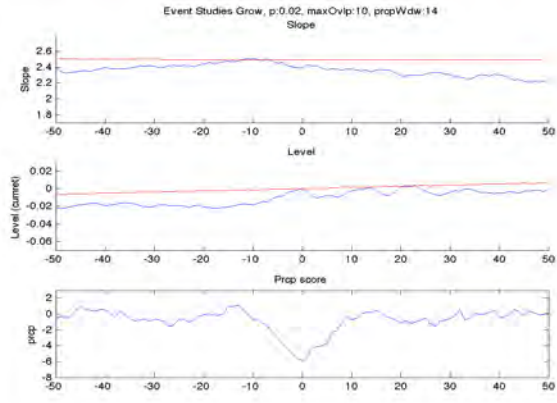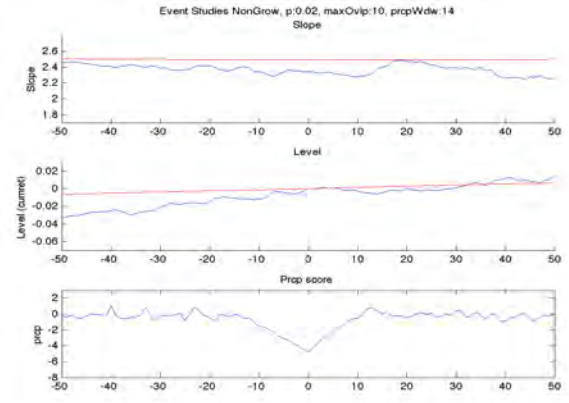
(b) Non-Growing season, 1%

(c) Growing season, 2%

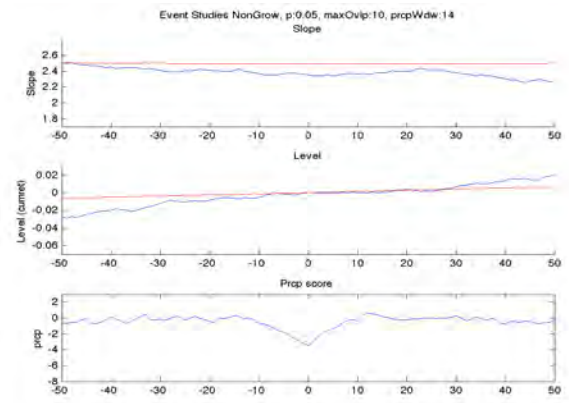(d) Non-Growing seasoning season, 2%
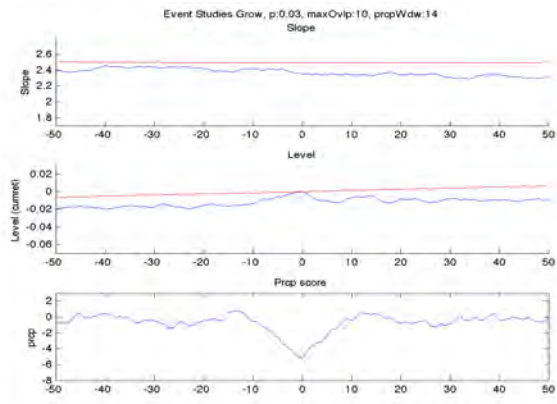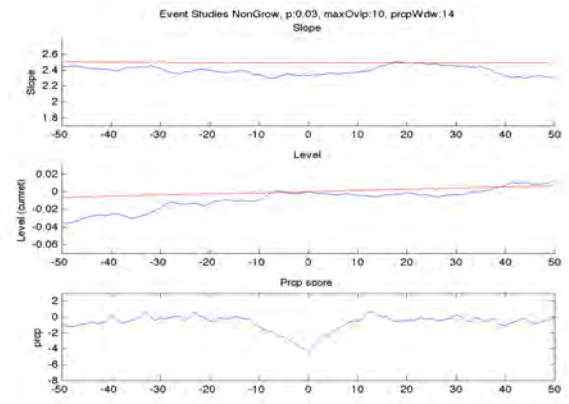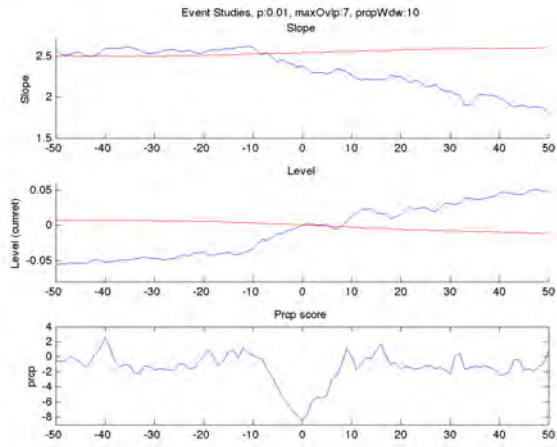
(e) Growing season, 3%

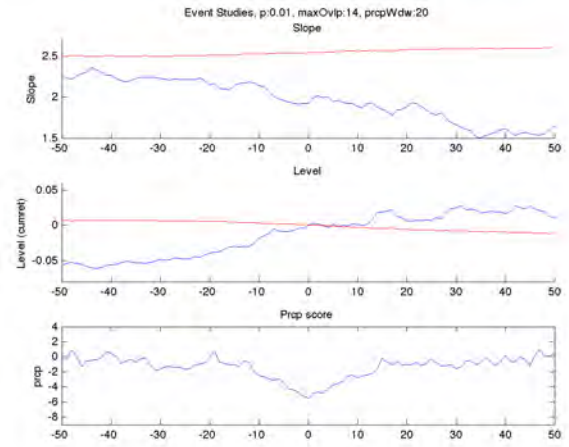(f) Non-Growing season, 3%

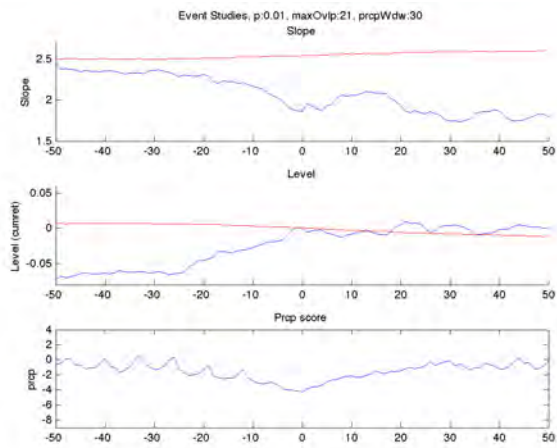(g) Growing season, 5%

(h) Non-Growing season, 5%

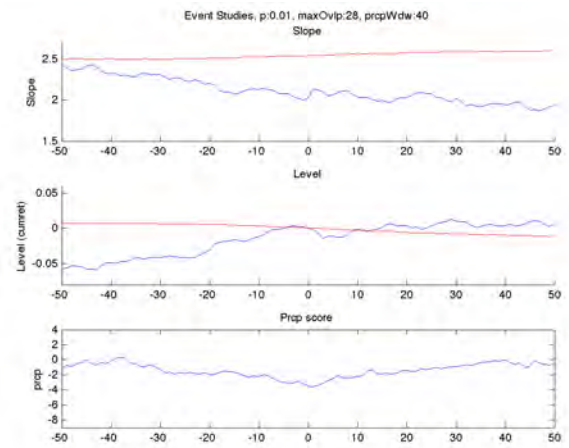Figure 20: Event studies on the level for the growing and non-growing season datasets (1988-2012)
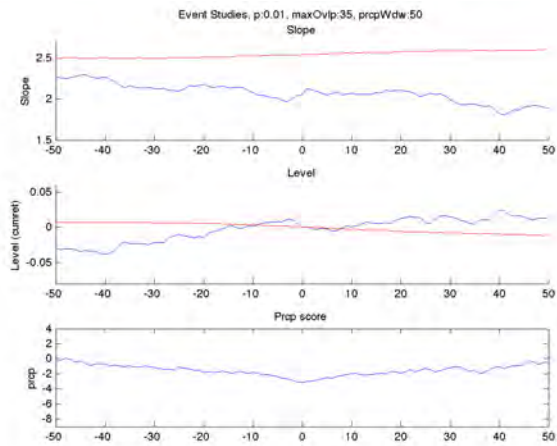
(a) Precipitation window = 10

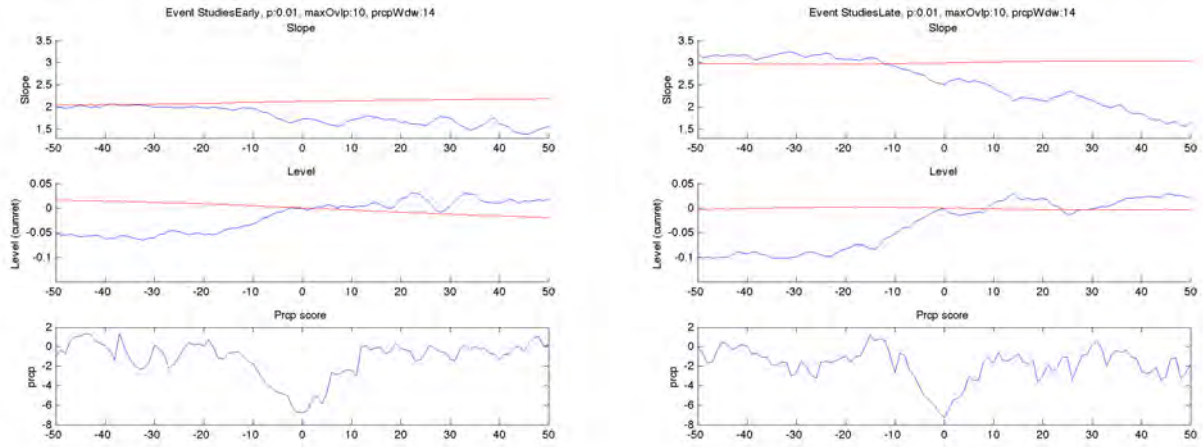(b) Precipitation window = 20

(c) Precipitation window = 30

(d) Precipitation window = 40

(e) Precipitation window = 50

Figure 21: The event studies comparison for the Level and Slope (only growing season data), for different precipitation windows evaluating the 1% events

The final event study that is done on the precipitation data is done by making a distinction between earlier data and more recent data. The reason this distinction is made is because one of the fears at the initiation of this research was that there was a possibility that the corn markets would react less to the underlying factors nowadays than they used to do. Figure 22 shows that this is not the case for the reaction on the precipitation score. In fact, the later period (2001-2012) show even greater movements in both the level and the slope before the event days.

<center>(a) 1988-2000   (b) 2001-2012</center>

Figure 22: The event studies comparison for the Level and Slope with a precipitation window of 14 days between two periods: 1988-2000 and 2001-2012 (only growing season data), for the top 1%

3.3.2 News Data

The Thomson Reuters news engine provides a dataset with 82 variables, including the sentiment scores. Sentiment scores indicate what sentiment the news item will have towards the price of the underlying commodity. The dataset includes articles, appends (extensions of articles), alerts (small news flashes) and rewrites (copies of articles). Only articles and alerts will be used in this research, as append and rewrites generally do not contain any new information. The News articles are divided per commodity for 37 different commodities. In this research, only corn news will be used.

Due to growing interest in commodity investing, Thomson Reuters has extended their News Analytics engine in 2009 with commodities. Besides the news items on over 25000 equities, sentiment scores are also available for articles related to nearly forty commodities, such as natural gas, crude oil, gold and also corn. Sentiment scores date back as far as 2003. This news sentiment engine generates a sentiment value to the positivity/negativity of the article regarding the commodity at matter. These values represent the probabilities of the article to be positive, neutral or negative. The values of the positive, neutral and negative sentiment therefore always add up to 1. Positive sentiment in essence is the effect that the news has on the commodity price, which can be the opposite of the sentiment for corn itself. For instance, headlines such as "Rising temperatures to stress US corn" or "Jump to two-week height on dollar" are both classified as being positive articles. Among the negatively classified articles are headlines such as: "GRAINS-US corn drops on bearish acreage view" and "CBOT corn, soy fall to day's lows on wetter US weather, profit-taking". Unfortunately, the classification algorithm does not always classify articles this way, causing faulty observations in the data. For instance, "CBOT corn, wheat, soy higher on weather worries" or "GRAINS-Corn rises 1.4 pct on weather risks, soy slips", are negatively classified, while they have a positive effect on the price. The same goes for the positively classified articles, which contain headlines such as, "Strategie grains raises 2012 eu barley crop forecast by 500,000 t to 53.2 mt (+3 pct vs 2011) on good weather" and "Record Argentine rains to help world grain supplies". Unfortunately, the way the scores are produced is black box, i.e. the way that the scores are calculated is unknown to me. Therefore, it can only be assumed that these scores are in general representative for the article.

We start by analyzing the news data set. After filtering the data on the relevance (which is a real valued number indicating the relevance of the news item to the asset. A relevance smaller than 0.3 is deleted from the dataset) and double stories (by their Primary News Access Code, or PNAC, which is unique for each different story, same stories have the same PNAC), the articles shown in Table 5 remained. One can see in this table that news is more often classified as positive, where it has to be kept in mind that positive news equals negative news for corn (as this is positive for the price).

<center>41</center>

Corn 2003-2012	Positive	Neutral	Negative	Total
Articles	5977(52.42%)	1320(11.58%)	4104(36.00%)	11401
Alerts	949(34.76%)	914(33.48%)	867(31.76%)	2730
Total	6926(49.01%)	2234(15.81%)	4971(35.18%)	14131

Table 5: News data general information

Further analysis is done on the arrivals of the news items. Figure 23 shows the volume of the news items over the years. Figure 23a shows the number of articles each month over time and Figure 24b shows the number of trading days each year that have at least one news item. From these figures, one can see that the years 2003 until 2005 contain significantly lower amounts of news data. Therefore, the analysis will be continued with the news data starting in 2006.
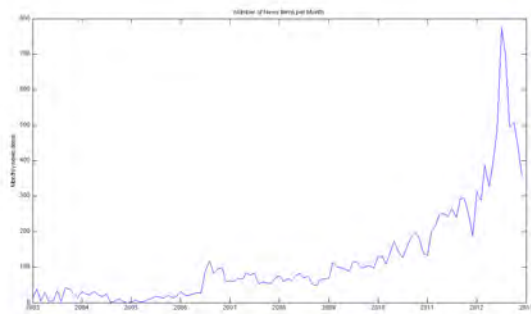
(a) Number of corn news items per month
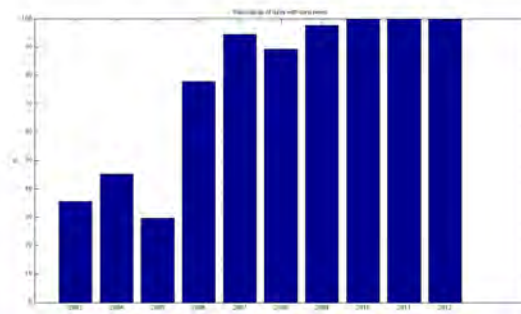
(b) # days that contains at least one corn news item

Figure 23: The volume of the corn news items over time

For this period (2006-2012) we look at the arrival times of the news during the day, week and year, shown in Figures 24a, 24b and 24c respectively. Transtrend sets the open and close time of the CBOT on 6:00AM and 1:15PM respectively (marked in red in Figure 24a), it is clear that in this time interval there are in general sufficient news arrivals. When looking at arrivals during the week, it is visible that the weekends do not contain many news items and that Thursdays have the most news arrivals. During the year, July shows the most news items, which is probably caused by the fact that this is a crucial period in the US corn production. The second peak we see is in October when the US corn is harvested and the actual corn production numbers are published.

(a) The corn news arrival during the day in Chicago time, with open and close time
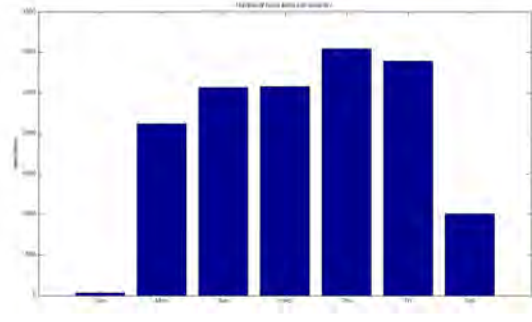
(b) Number of corn news items per weekday
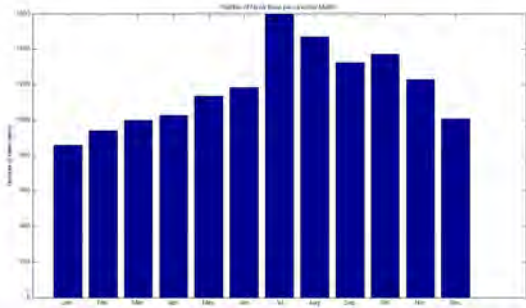
(c) Number of corn news items per calendar month

Figure 24: Analysis of the corn news arrivals (2006-2012)

News aggregation: creating the news sentiment score

From this raw dataset of news articles and alerts, a score has to be created on a trading day basis. This will be done by aggregating the articles that arrive between close to close times. Articles are aggregated based on a weight scheme that assigns lower weights to news that is further in the past. According to the article by Anderson and Tweney [1], memory decay follows a power function. Therefore, with the implementation of the rolling sentiment score, a power function of the form $w = t^{-c}$ is used as well to determine the weight decrease of older news arrivals. Here c is a measure for the speed at which the weights will decrease.

The rate at which the weights will decrease is based on the research by George A. Miller [16]. In this article the 7±2 rule is discovered, which states that a person will only hold the last 7±2 items in their short term memory. Therefore, the weights are chosen in such a way that in the long run, 90% of the weight will be in the nine most recent articles. On average the 9 last articles arrive within the last three days (≈ 3.1 days). Therefore, a window of 3 days is chosen in which 90% of the weight function must be. The value of the parameter of a power function can only be approximated as the function goes to infinity for t close to zero. We find the value of 1.53 for c by solving the following equation: $\int_{1/24}^{3} t^{-c} dt / \int_{1/24}^{\infty} t^{-c} dt = 0.9$. This means that when using a parameter c of 1.53, the function has 90% of its weight between one hour and three days.

In Figure 25, the monthly averages of the sentiment are plotted along with the Kalman Filter estimates of the level and the slope. The net positive sentiment is defined as the positive sentiment minus the negative sentiment, which gives a better measure of the positivity or negativity of the article. Scores close to zero indicate that the sentiment of the article is hard to determine. Therefore, these are the scores that will be used for the event studies. The sentiment score is created for each day that contains level and slope data and is acquired by aggregating all the news articles that appear after the previous close time until the current close time. This is based on the assumption that all the news is incorporated in the corn future market. Figure 25 shows the moving average of the three sentiment scores over time, with the net positive sentiment in blue.
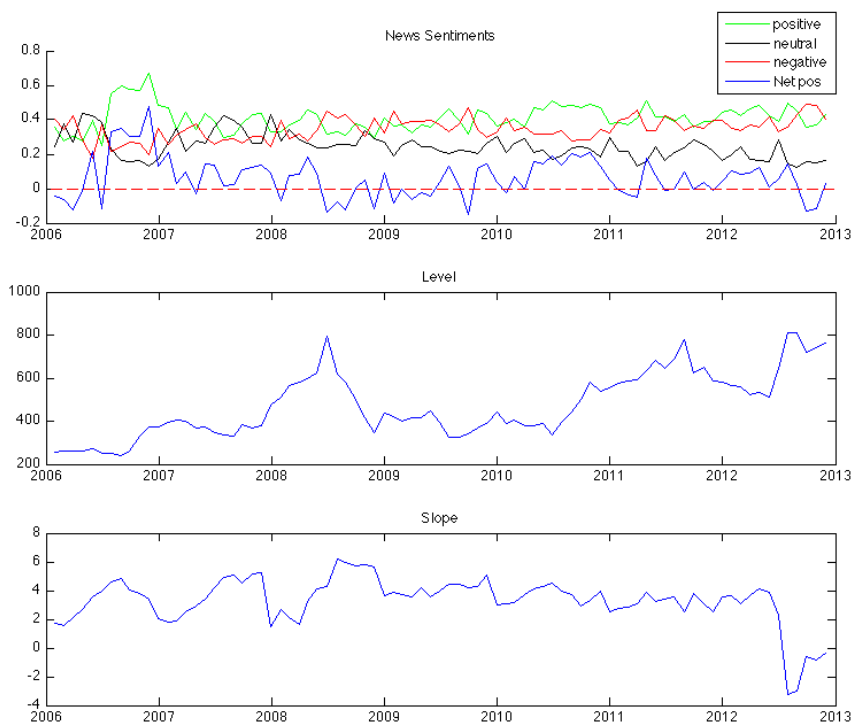
Figure 25: The News sentiment 1-month moving average with the level and the slope

News Data: Event Studies

Again the event studies are performed, but now on the aggregated news sentiment scores modeled in the previous section. Figure 26 shows the event studies on both the highest and lowest sentiment scores, again for the top 1, 2, 3 and 5% events. The first thing that stands out is the fact that there is no clear relation between negative news sentiment and the level and slope. As was explained before, negative news is in general news that should cause negative returns in the prices of the future contracts. Yet, with agricultural future markets like corn, the price risk side is much more on the upward side, as increases in supply are much easier to predict, while decreases could happen much more sudden. There is an upside for the yield that comes from the field, which can be calculated with the acres of land that is planted with corn, which will not unexpectedly become much more. On the other hand, drops in the supply, in case of a drought for instance, will happen in a much faster and unexpected way such that it will cause much more rapid price movements. This is why both the level and the slope do react to positive news (news that causes price increases), while they do not show any significant movements around negative news.

When looking at just the extremely positive news sentiment, clear movements are visible around these events for both the level and the slope. These movements are visible on a much wider window than the period where the news sentiment sharply increases ({-1,+1}). It is clear to see that in the entire window {-20,+20} the net positive sentiment scores is higher than the average (average = 0.0421). This means that in the entire window the news sentiment is generally positive around such events.
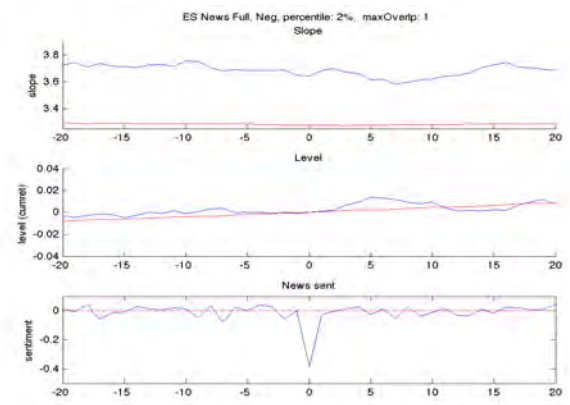
44
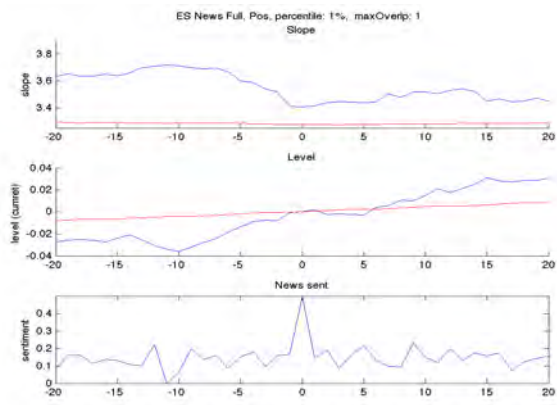
(a) Highest sentiment, 1%
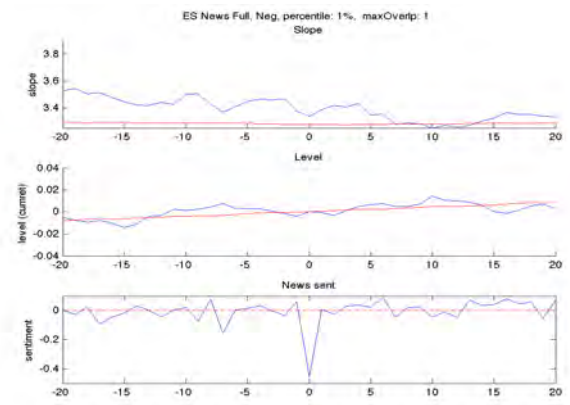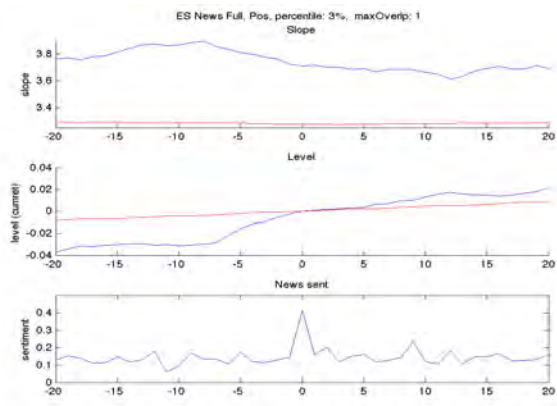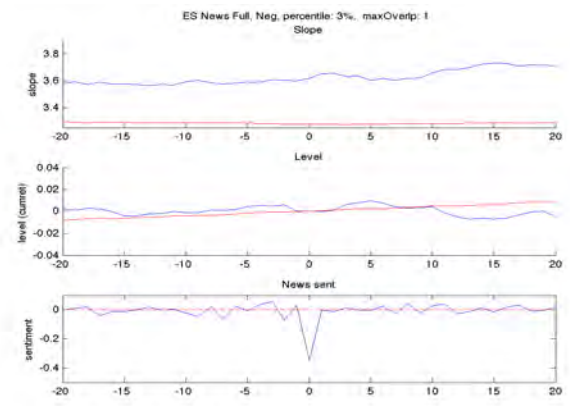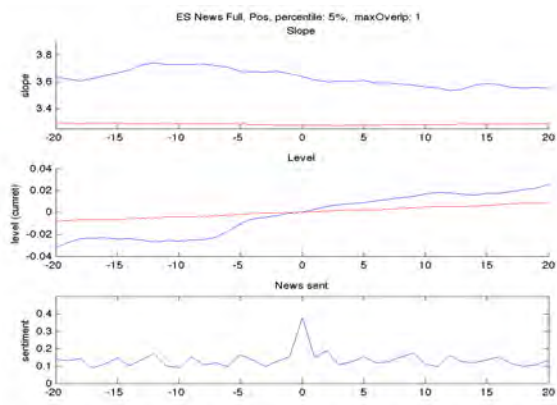
(b) Lowest sentiment, 1%
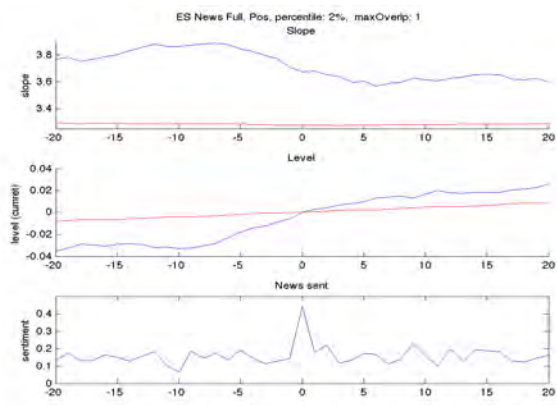
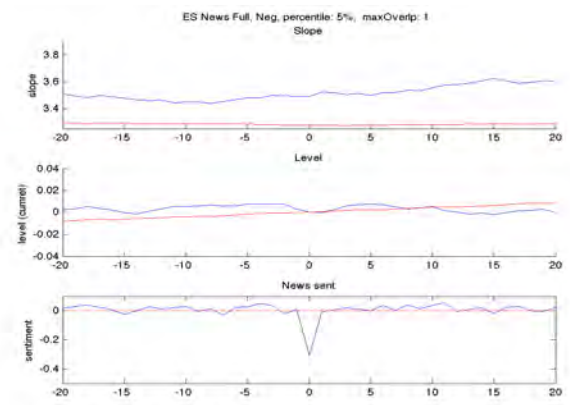(c) Highest sentiment, 2%

(d) Lowest sentiment, 2%

(e) Highest sentiment, 3%

(f) Lowest sentiment, 3%

(g) Highest sentiment, 5%

(h) Lowest sentiment, 5%

Figure 26: Event studies on the net positive sentiment for the level and the slope on the full dataset (2006-2012)

Once again, this research is continued by separating the growing season and non-growing season in the dataset. In Figure 27, the event studies are done around the days with the highest net positive sentiment. One can see that there are no co-movements during the growing season between the level, slope and the highest net positive sentiment, while there are clear co-movements outside the growing season. This difference is an indication that during the growing season, a lot of positive news is confused with negative news, or the other way around.

The non-growing season does show significant co-movements between the level and the positive news sentiment around the events. Even the 5% events still show a significant upward trend around the event dates.

The same studies is done on the lowest sentiment events in Figure 28. Using the full dataset, there were no apparent co-movements found between the lowest net positive sentiment and the level/slope (Fig. 26b, 26d, 26f and 26h). When separating the growing and non-growing season data, there are co-movements found around the 1% events for both datasets. In contrast to the highest sentiment events, the growing season data now shows greater movements in both the level and slope around the 1% events than the non-growing season data.

The question arises why in the growing season there is more reaction of the future markets to positive news sentiment and outside the growing season there is more reaction to negative news sentiment. There is a large possibility that this duality comes from the difference between the type of news that is published during the growing season and that which is published outside the growing season. During the growing season, it is likely that much of the positive news, i.e. the news that should cause price increases, will be classified as negative. And vice versa outside the growing season. This could be the case due to the nature of the news. During the growing season, much of the news will be about the development of the corn plant, along with yield expectations. In this case, what's negative for the corn plant development, will cause an upward (positive) price movement. This could cause some misclassification in the news engine, which was addressed earlier this chapter.
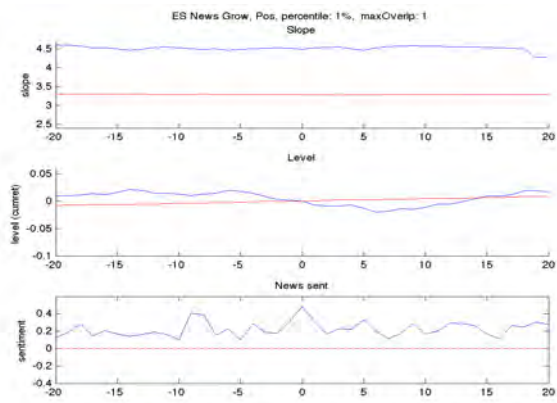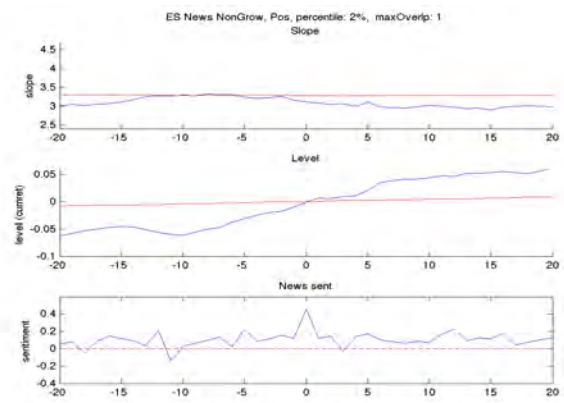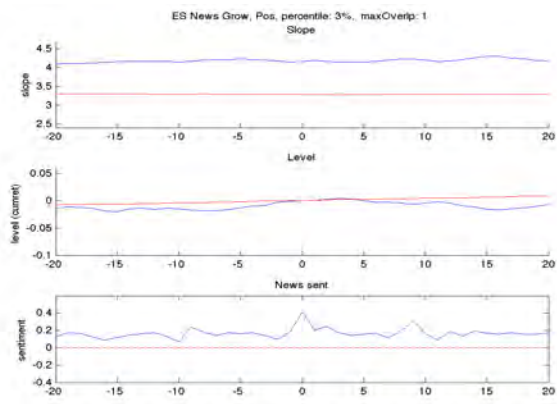
(a) Growing season, 1%
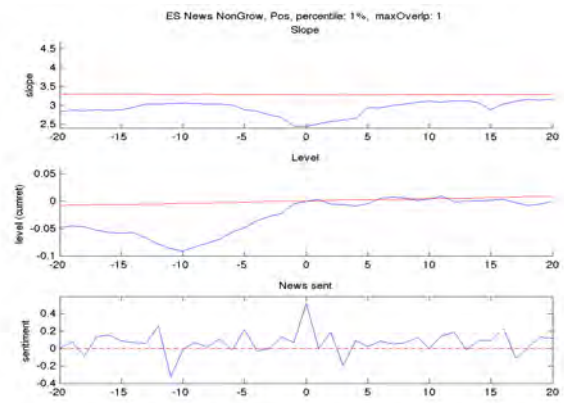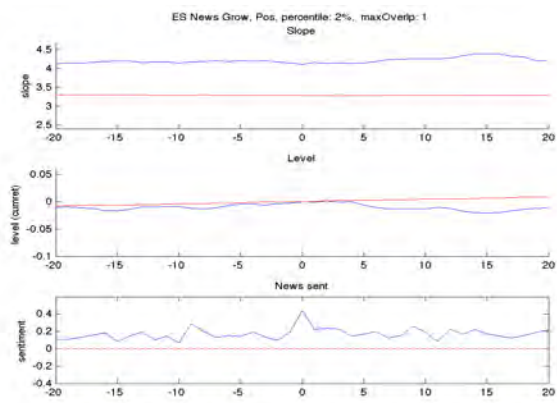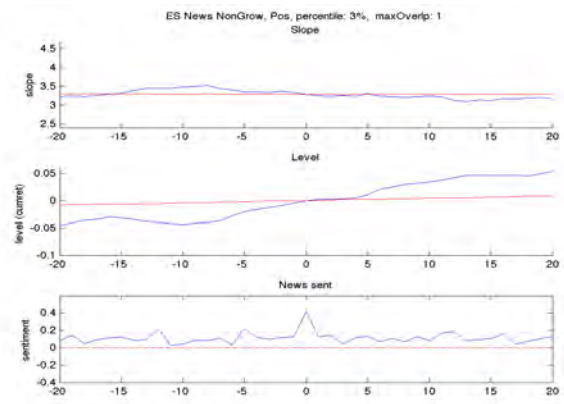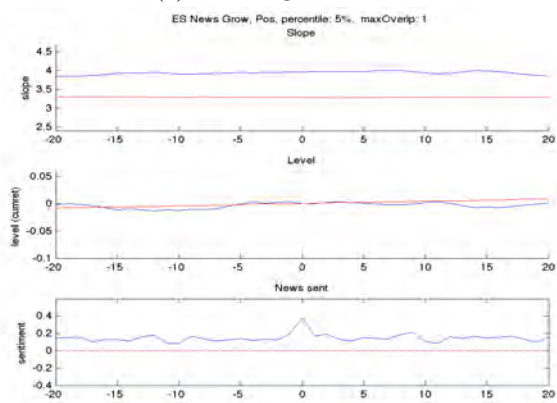
(b) Non-Growing season, 1%

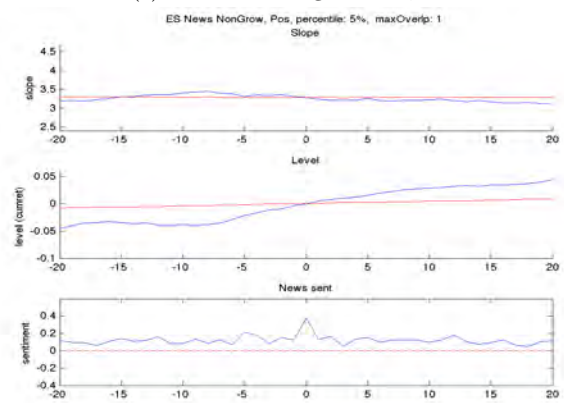(c) Growing season, 2%

(d) Non-Growing season, 2%

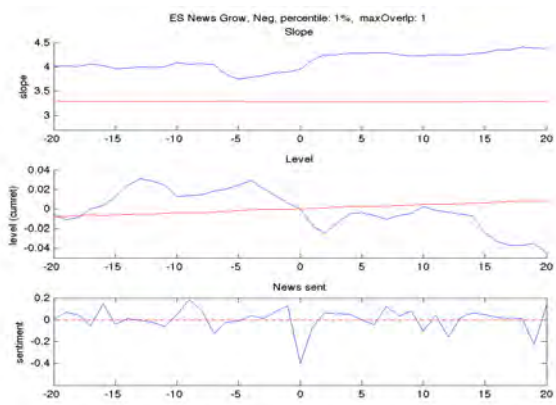(e) Growing season, 3%

(f) Non-Growing season, 3%

(g) Growing season, 5%

(h) Non-Growing season, 5%

Figure 27: Event studies on the HIGHEST net positive sentiment for the growing and non-growing season datasets (2006-2012)

(a) Growing season, 1%

(b) Non-Growing season, 1%

(c) Growing seasoning season, 2%

(d) Non-Growing season, 2%

(e) Growing season, 3%

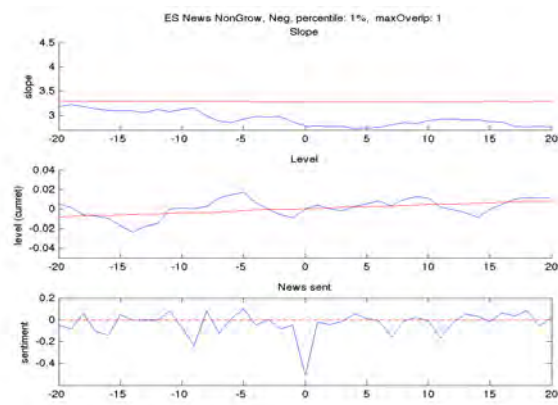(f) Non-Growing season, 3%

(g) Growing seasoning season, 5%

(h) Non-Growing season, 5%
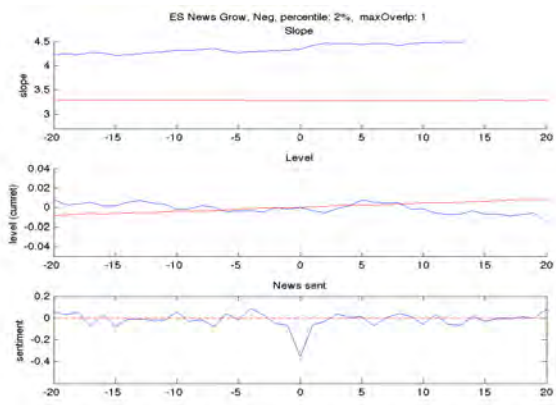
Figure 28: Event studies on the LOWEST net positive sentiment for the growing and non-growing season datasets (2006-2012)
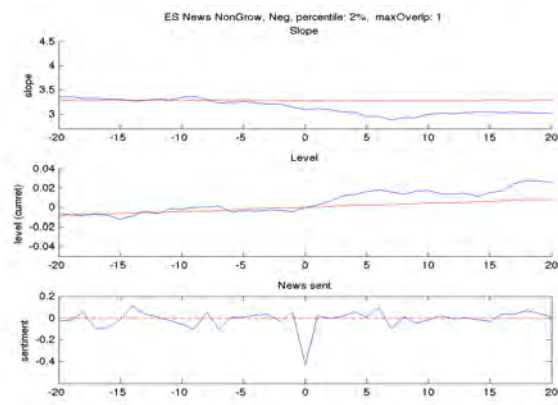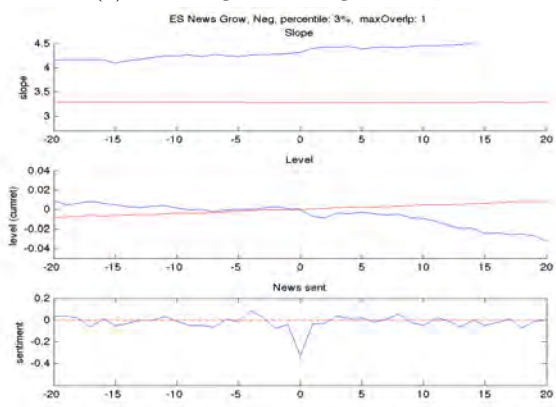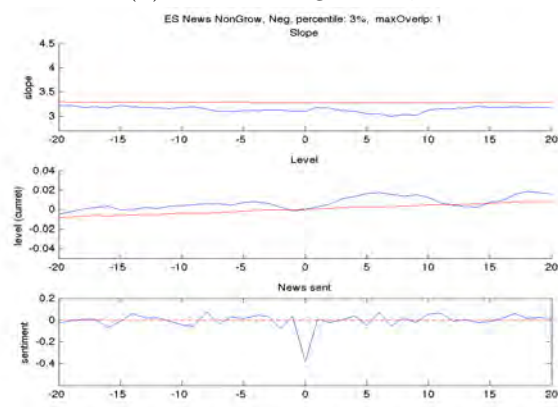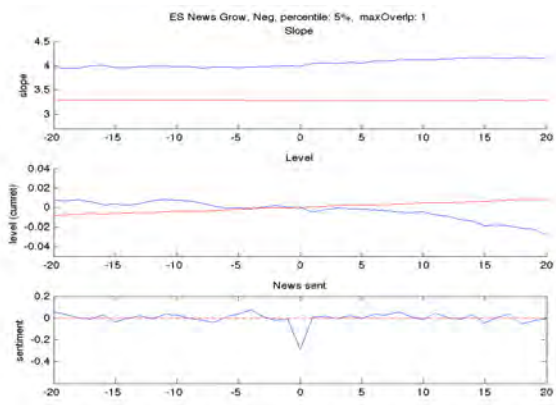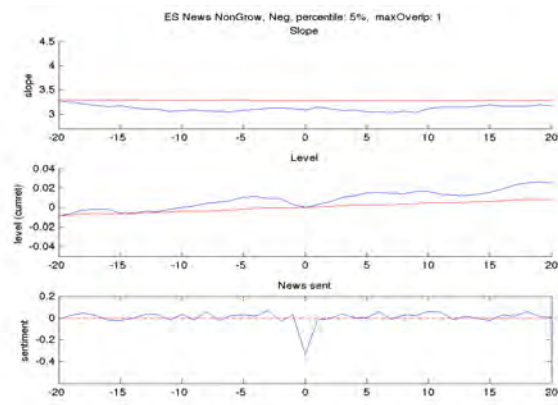
3.3.3 Climate and News data Event Studies

The final step in the event studies research is to compare the movements of the news and the climate. As the news data is only sufficiently available from 2006, the analysis will be done for the period from 2006 until 2012 for both the news and climate data. The climate event days will again be selected according to the precipitation score calculated for a 14 day window with the hyperbolic tangent weight scheme. The news data will be weighted by the power function and aggregated from close to close time.

Figure 29 shows the comparison of the event studies for 2006 until 2012 between the news events and climatic events. As the climatic events are one-sided, meaning that they are only performed on the lowest precipitation scores, only the highest sentiment scores will be selected (news that has a positive effect on the price of corn). One can see in Figure 29a that the level shows bigger movements around the news events than around the climate events for all percentages of event selection. As we are still using the full dataset here, the movements of the level around the climate events will be contaminated by the event days that happen outside the growing season. The news event studies are not affected by this problem. Besides, there exists an overlap between the news and climate data, as there will be a lot of news on the weather during the growing season.

In Figure 29b, the slope is shown around both the climate and news event days. There are no clear movements around either the climate nor the news event days, yet there is one clear difference between the two. In the entire window around the news events, the slope is above the benchmark. While the slope remains strictly below the benchmark around the climate events. From the time-to-maturity-effect point of view, the slope is lower in case of increasing levels, as the December contract moves the most, and vice versa. This would mean that around climate events, where there is a lower slope, the price is at an elevated level. On the contrary, around news events, the price is at a lower level compared to the days before.

(a) Level   (b) Slope
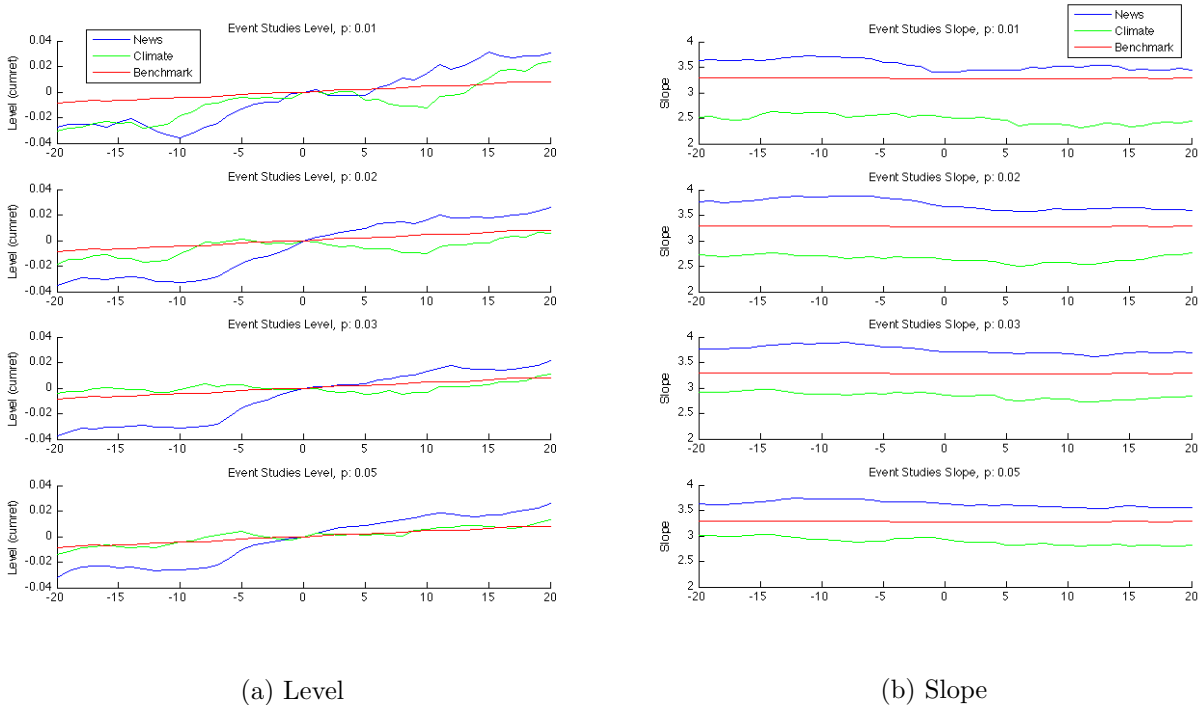
Figure 29: The event studies on the news (blue) and climate (green) for top 1, 2, 3 and 5% events of the full data (2006-2012), with the benchmark (red)

As there is no information in the climate events that happen outside the growing season, we will again separate the growing and non-growing season dataset. Again, we can see in Figure 30a that with the positive news events within the growing season, there are no clear movements of the level around these news event dates. The level does show an upward trend around the lowest 1% precipitation score

days, meaning that, during the growing season, the precipitation scores are much more informative to the corn future market than the news sentiment scores. This is probably, due to the difficulty of identifying positive news as positive (as negative event in the development of corn have positive (upward) effect on the price), which was addressed earlier this section.

Outside the growing season (Figure 30b), obviously the level shows much more movements around the positive news events. During this period, the climate data should have no effect on the level and the slope, as there is no corn on the fields.
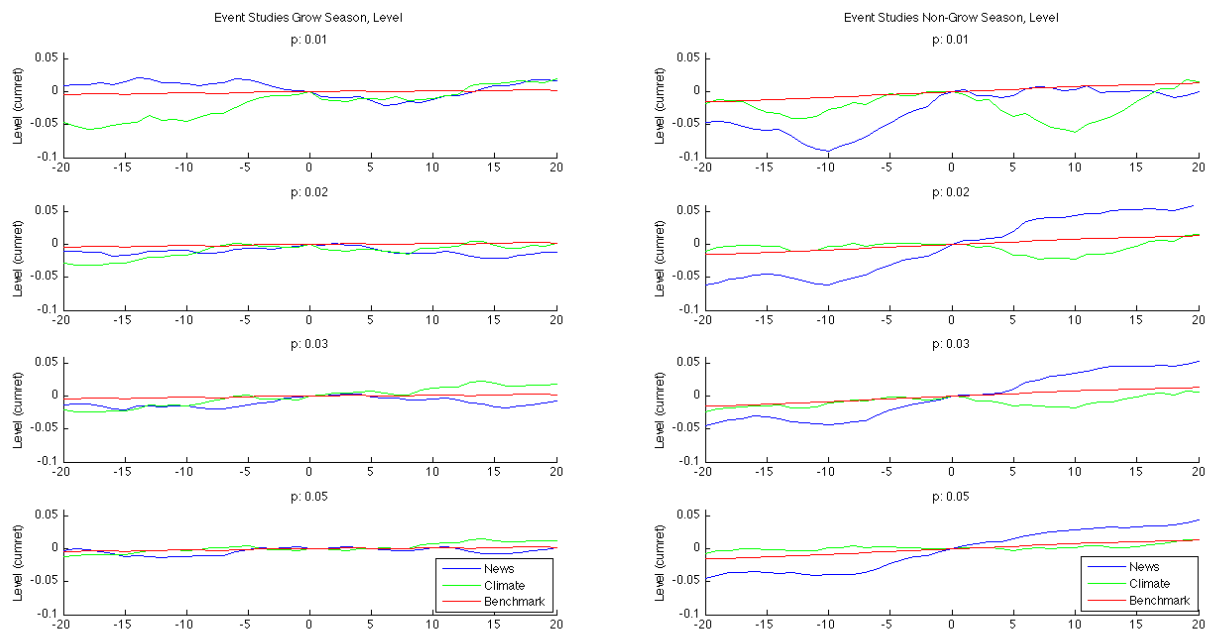
(a) Growing season   (b) Non-Growing season

Figure 30: The cumulative returns of the level around the news (blue) and climate (green) events for top 1, 2, 3 and 5% events of the Growing/Non-Growing season data (2006-2012), with the benchmark (red)

In Figure 31 the same studies is shown for the slope. During the growing season, one can see the same effect as was seen in the full dataset; the slope around news events is above the benchmark and the slope around the climate events is below the benchmark. This effect is much less apparent outside the growing season, where we saw greater movements in the level around the news events and consequently also in the slope.

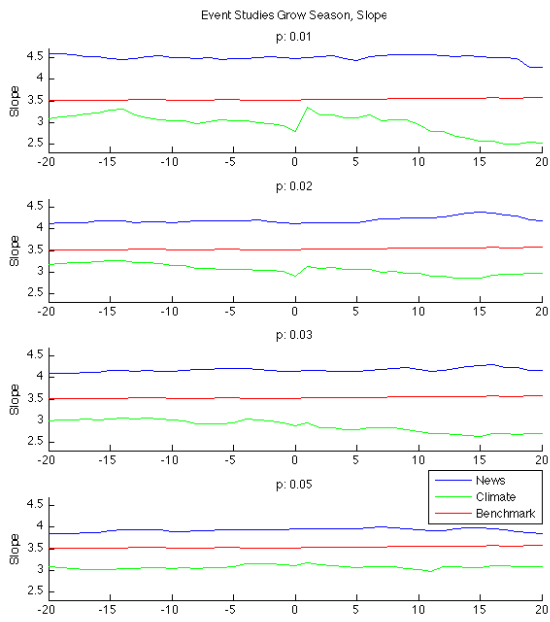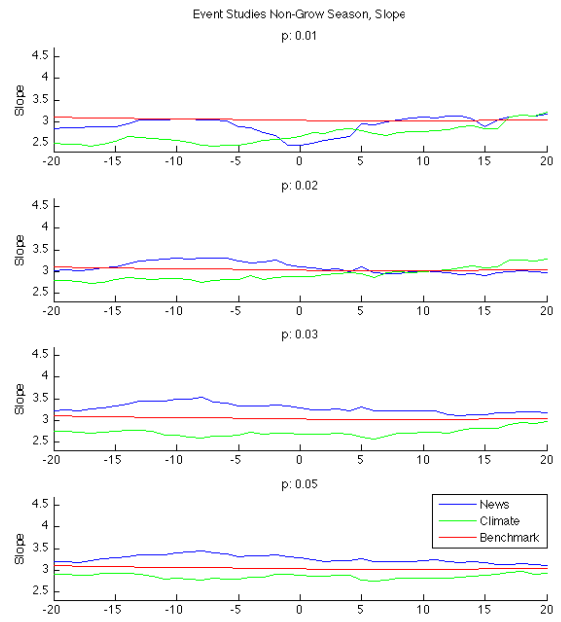(a) Growing season   (b) Non-Growing season

Figure 31: The slope around the news (blue) and climate (green) events for top 1, 2, 3 and 5% events of the Growing/Non-Growing season data (2006-2012), with the benchmark (red)

4   Conclusion

After six months of extensive research on the corn future market and the fundamentals of this market, we are now able to give a well substantiated answer to the main question addressed in the introduction:

∗ *What are the main drivers of the corn/grain future market, and has the way these markets react to these drivers changed over the years?*

The problem arose from the distinct price movements of the corn future contracts in the two drought years, 1988 and 2012, where in 2012 the drought seemed to cause a very sudden shift in price. A downward trend turned around into a huge jump upward, which made it seem like the drought came out of nowhere. This was not the case in 1988, where the huge jump followed an upward trend. Therefore, this general overview of the corn market along with a term structure model for the future market is given. This will be done by answering the six subquestions that were proposed in the introduction. In this section each research question will be answered individually, and finally a general conclusion will be given. These were the six research questions proposed in the introduction:

  I. What does the underlying corn market look like in terms of growing process, area/climate of corn cultivation, future markets, official crop reports and market participants?

 II. Are there any substantial differences in corn markets, described in the previous question, between 1988 and 2012?

III. What change in the composition or behavior of market players could be the foundation of the changes/trends found in the previous questions?

IV. Is it possible to find significant events by analyzing the spread between the future contracts on different harvests?

 V. How do corn/grain future markets respond to the weather (when is a dry spell established that causes crop failure)? And has this behavior changed over the years?

VI. How do corn/grain future markets behave around non-renewing news items?

This research was started by investigating the fundamental corn market to answer the first research question.

US corn is cultivated, for the most part, in the Corn Belt: Figure 3. The growing season is approximately from April (planting) until October (harvest). During this period the corn plant undergoes a series of stages (Figure 5). It is important to distinguish these stages, because for different stages the corn plant is affected by different climatic factors. The following climatic factors were distinguished: Drought, strong wind, flooding, frost and hail. And the vulnerability of the corn plant for different stages to these factors is also shown in Figure 5. Besides these climatic factors that affect the corn development and yield, there are the reports that give information on the development of the plant along with other supply and demand factors. This information is published by the USDA (US Department of Agriculture). The most important report regarding the supply and demand estimates are the WASDE reports, which are published monthly. One presumption for the distinct movements of the future contracts in 1988 and 2012, was that investors nowadays react too heavily to these reports. Where information that should have already been incorporated in the market, is now actually incorporated too late, causing a less efficient market. Gladly, Figure 9 shows us that this is not the case. The WASDE reports are not released at the point at which the market changes from the downward trend into the huge jump upward.

When looking at the evolution of the fundamental corn market, a big difference between 1988 and 2012 is that the demand for corn has grown significantly due to the increased use for ethanol production. Also the yield per acre has improved significantly due to better techniques in planting, bug control and genetically improved seeds. This answers the second subquestion.

Besides looking at the factors that drive the future prices, it is also important to look at the incentives

of the active participants on these markets. Between 1988 and 2012 there is one big difference that could affect the incentives of some of the market participants. The number of crop insurances have increased from less than 50% in 1988 to about 90% in 2012. Farmers nowadays, have a much more secure position in the corn market, as most of them are sufficiently insured to cover their expenses even in case of a crop failure. Which brings us an answer to the third subquestion and also completes the answer to the second subquestion.

This research was continued with a model for the term structure between the corn future contracts. The first four contracts of each crop year (the last contract, September, shows distinct behavior and is therefore left out of the model) are modeled into three components: level, slope and level shift. We found a way to model the level and slope simultaneously by using a multivariate linear Gaussian state space model (Eq. (5) and (6)). This model is based on three main assumptions: Mean reversion, level-slope (opposite) dynamics and randomness in the market. Mean reversion is based on the fact that the price level of corn will never diverge from a certain equilibrium, due to the balance between the price and the supply/demand. If the price becomes extremely high, either the supply will increase and/or the demand will decrease and vice versa. Furthermore, there exists a so called time to maturity effect between the future contracts, causing a negative correlation between the level and the slope. In other words, when the level jumps up due to some event in the underlying market, the nearby contracts will be more affected by this, causing the slope between the contracts to move down. This effect is also incorporated in the model by allowing a (negative) covariance between the updates of the level and the slope. The final assumption is based upon the fact that there exists some randomness in the market, that should be accounted for. This randomness are small decisions or factors that do influence the prices, but are not incorporated in the underlying model. For example, the event that a farmer decides to buy future contracts today instead of tomorrow. These factors will not be very large, but they will affect the price today and should therefore be accounted for in the model. This is done by distinguishing the underlying model (α_t) and the randomness (ϵ_t) in the observation equation (Eq.5). This is the first step towards an answer for the fourth subquestion. The model is estimated by the Kalman Filter recursions (Appendix B), which separates the signal (underlying model) from the random component in the observations. After extracting this signal, an event studies is done to answer the fourth, fifth and sixth subquestion.

Event studies were started with the precipitation data acquired from the NCDC (National Climatic Data Center). This data consists of daily precipitation numbers for 17 climate stations inside the corn belt (Fig. 3). This precipitation data is modeled in such a way that for each day, a precipitation score can be calculated that considers a window instead of a single day. All the precipitation inside this window is weighted according to how far in the past it is. The event studies select the lowest p% of these precipitation scores and look at the movements of the level and the slope around these 'events'. These event studies are done for different values of p and varying windows for the precipitation score. The general conclusion that is found, is that both the level and the slope show clear movements around the events when they are defined as the lowest 1% precipitation scores. Even for very large precipitation windows, i.e. precipitation further in the past is still considered relevant, there are still significant movements around the selected events. The most important conclusion was found when separating the dataset in an early (1988-2000) and late (2001-2012) dataset. Here it was found that the late dataset showed greater movements around the low precipitation events, meaning that there is no indication that nowadays, future markets are less responsive to what happens in the underlying market than in earlier years. This answers subquestion five.

The same event studies are done for the news data. This data consists of sentiment scores created by Thomson Reuters in their News Analytics program, which is sufficiently available from 2006. From these sentiment scores, a daily news score is created. These event studies are done for different values of p and now both highest and lowest news scores will be evaluated. It is found that prices react more to news that drives the prices up, which is in general news that is negative to corn. This is quite intuitive, as people tend to react heavier to negative news than positive news. When separating the growing and non growing season data, a surprising result was found. It was found that during the growing season there is more reaction to news that should drive the price up and outside the growing season there is more reaction to news that should drive the price down. There is a great probability

that this has to do with the difference in nature of the news that is published during the growing season and that which is published outside the growing season. During the growing season most news will be about the development of the corn plant, along with the yield expectations. Outside the growing season, news will be about general price developments. The most likely explanation for this difference is that the classification in these two seasons (growing/non-growing) will be different due to the different nature of the news that is published. To answer the sixth and final research question, we can conclude that there are strong movements seen around these news events, while it has to be taken into account that the selection of news events highly depend on the way that the news items are classified.

Finally, when comparing the effects of climate and news events it was found that during the growing season, there was a stronger effect caused by the precipitation events. Obviously, outside the growing season, news events have a stronger effect on the corn price levels.

Combining all the findings in this research, one has a clear insight in the factors that drive the corn market and in the way the future market is structured. At the beginning of this research, there was a concern that there might be a possibility that the corn future market did not respond to the underlying market the way it should. A general concern was raised that, maybe, the corn future market is less effective than before. This could mean that for trend following investors, like Transtrend, their strategies would be less profitable than they could be. Gladly, this research has shown, by creating a general model for the term structure in the corn future market, that the market is not less effective and still shows significant movements around events in the fundamental market. A lot has changed over the years in these markets and a lot will change the coming years. And therefore, it will always be important to keep an eye on the behavior of markets, and never lose sight of the fundamentals of these markets. Hopefully, this research has given some insight into the corn future market, and how to model such a market, and could be used for future research on fundamental commodity markets.

5   Further research

Research is never finished and therefore there are numerous things in this field that can be done in future research. In this section, some suggestions for further research will be given.

First of all, this research could be expanded by a more extensive investigation on the water use of a corn plant. There must be a certain underlying process for the water intake of a corn plant, which will also depend on the temperatures and soil conditions. The state space model that was used to model the corn future market, also allows for more underlying processes. Therefore, finding out these underlying process could lead to an improved state space model, where the water stress could also be incorporated in the model.

Secondly, a very important future research is that on the changes of the composition of the market participants on agricultural future markets. The way future markets behave depends, for a great part, on the behavior of the participants on that market. This behavior is of course different for different types of participants. These participants can be divided into two groups, fundamental investors (hedgers) and non-fundamental investors (speculators). These two groups both have different incentives and trading behavior, where a shift in ratio between these two groups could also change the way markets behave in relation to underlying factors. We saw before that the growth in crop insurances could also have an effect on the behavior of farmers, which could have a direct effect on the future markets. Also, over the years, the amount of speculators in the commodity markets have grown significantly. This brings us to the final point of this section.

There is a phenomenon called financialization of commodities, which states that, due to this huge growth of index investors on the commodity market, commodities show more and more co-movements with each other. The research by Ke Tang and Wei Xiong (2011 [22]) shows that this is the case for oil, with other commodities. This research could also be done for agricultural markets. As we saw in Figure 10, 2012 showed much greater co-movements between the Goldman Sachs Commodity Index and the corn futures than 1988. This gives great incentive to do such a research on agricultural markets.

6 Appendices

6.1 A: US Corn Area Climate stations

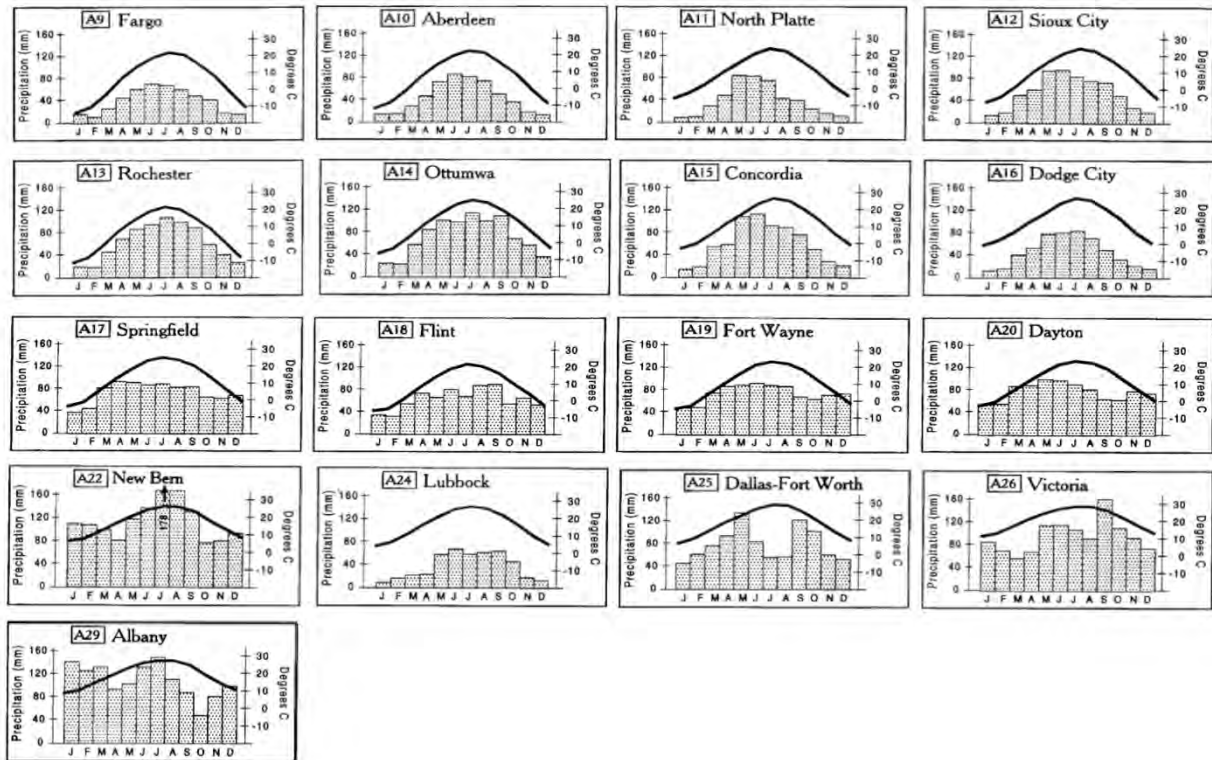**United States: Climate stations**

Figure 32: 17 weather stations in the US corn area, with their monthly average precipitation (bars) and temperature (line) measured from 1961 until 1990.

6.2 B: Derivation Kalman Filter on the Linear Trend Model

Derivation of the Kalman Filter for the linear trend model (10) with normally distributed innovations.

$$y_t = Z\alpha_t + \epsilon_t \qquad\qquad\qquad \epsilon_t \sim N(0, H_t) \qquad\qquad (10)$$
$$\alpha_{t+1} = T\alpha_t + R\psi_t \qquad\qquad\qquad \psi_t \sim N(0, Q_t)$$

where $E[\epsilon_t \psi_t] = 0 \ \forall \ t$.

$$\alpha_t | Y_{t-1} \sim N(a_t, P_t)$$

such that the state updates are defined as:

$$E[\alpha_{t+1}|Y_t] \equiv a_{t+1}$$
$$\mathrm{Var}[\alpha_{t+1}|Y_t] \equiv P_{t+1}$$

Derivation of the state expectation update:
we define:

$$
\begin{aligned}
\text{State error} &= v_t = y_t - Za_t \\
\mathrm{Var}[v_t] \equiv F_t &= \mathrm{Var}[Z\alpha_t + \epsilon_t - Za_t] = Z\mathrm{Var}[\alpha_t|Y_{t-1}]Z' + \mathrm{Var}[\epsilon_t] = ZP_tZ' + H_t \\
\mathrm{Cov}[\alpha_t v_t] \equiv M_t &= E[\alpha_t(y_t - Za_t)'] = E[\alpha_t(Z\alpha_t + \epsilon_t - Za_t)] \\
&= E[\alpha_t(\alpha_t - a_t)'Z'] = E[\mathrm{Var}[\alpha_t|Y_{t-1}]Z'] = P_tZ' \\
\mathrm{Cov}[\psi_t, v_t] &= E[\psi_t(y_t - Za_t)] = E[\psi_t(Z\alpha_t + \epsilon_t - Za_t)] = 0
\end{aligned}
$$

With the following properties of v_t:

$$E[v_t|Y_{t-1}] = E[y_t - Za_t|Y_{t-1}] = E[Z\alpha_t + \epsilon_t|Y_{t-1}] - Za_t = 0 \qquad\qquad (11)$$
$$E[v_t] = E[E[v_t|Y_{t-1}]] = 0 \qquad\qquad (12)$$
$$\mathrm{Cov}[v_t, y_j] = E[(v_t - E[v_t])(y_j - E[y_j])] = E[y_j E[v_t|Y_{t-1}]'] = 0 \text{ for } j = 1....t-1 \qquad (13)$$

We can split the update for the state vector expectation:

$$E[\alpha_{t+1}|Y_t] = TE[\alpha_t|Y_t] + RE[\psi_t|Y_t] \qquad\qquad (14)$$

Because v_t has expectation 0 and is independent of y_j we can split the conditional expectation in 15. By using the multivariate normal lemma, cited in the book by Durbin and Koopman [8], we find that:

$$
\begin{aligned}
E[\alpha_t|Y_t] &= E[\alpha_t|Y_{t-1}, v_t] \qquad\qquad\qquad\qquad\qquad\qquad\qquad (15) \\
&= E[\alpha_t|Y_{t-1}] + \mathrm{Cov}[\alpha_t, v_t]\mathrm{Var}[v_t]^{-1}v_t \\
&= \quad a_t \quad + \quad M_t \quad \quad F_t^{-1} \quad v_t
\end{aligned}
$$

and

$$
\begin{aligned}
E[\psi_t|Y_t] &= E[\psi_t|Y_{t-1}, v_t] \\
&= E[\psi_t|Y_{t-1}] + \mathrm{Cov}[\psi_t, v_t]\mathrm{Var}[v_t]^{-1}v_t \\
&= 0
\end{aligned}
$$

filling this in in equation 14 we get the update equation for the state expectation:

$$E[\alpha_{t+1}|Y_t] = Ta_t + TM_tF_t^{-1}v_t$$

Derivation of the state variance update:

$$\text{Var}[\alpha_{t+1}|Y_t] = T\text{Var}[\alpha_t|Y_t]T' + R\text{Var}[\psi_t|Y_t]R' \qquad (16)$$

$$\begin{aligned}
\text{Var}[\alpha_t|Y_t] &= \text{Var}[\alpha_t|Y_{t-1}, v_t] \\
&= \text{Var}[\alpha_t|Y_{t-1}] - \text{Cov}[\alpha_t, v_t]\text{Var}[v_t]^{-1}\text{Cov}[\alpha_t, v_t]' \\
&= P_t - M_t F_t^{-1} M_t'
\end{aligned}$$

and

$$\begin{aligned}
\text{Var}[\psi_t|Y_t] &= \text{Var}[\psi_t|Y_{t-1}, v_t] \\
&= \text{Var}[\psi_t|Y_{t-1}] - \text{Cov}[\psi_t, v_t]\text{Var}[v_t]^{-1}\text{Cov}[\psi_t, v_t]' \\
&= Q_t
\end{aligned}$$

filling this in in equation 16 we get

$$\begin{aligned}
\text{Var}[\alpha_{t+1}|Y_t] &= TP_t T' - TM_t F_t^{-1} M_t' T' + RQ_t R' \\
&= TP_t L_t' + RQ_t R' \\
L_t &= T - K_t Z \\
K_t &= TM_t F_t^{-1}
\end{aligned}$$

So we get the following KF equations:

$v_t = y_t - Za_t$	$L_t = T - K_t Z$
$F_t = ZP_t Z' + H_t$	$K_t = TP_t Z' F_t^{-1}$
$a_{t+1} = Ta_t + K_t v_t$	$P_{t+1} = TP_t L_t' + RQ_t R'$

6.3   C: Farmer interviews

Interview

Dennis Gallagher
address

Farmer: Dennis Gallagher

state: Iowa

Farmer since: 26 years

Acreage (ha.): 1800 acres

Average yield (bu. Or tons):

Products: corn and soy (~50/50)

---

1. Who do you sell corn to? How much of the yearly crop goes to export (%)?

Sells corn to cooperative elevator, as most farmers in Iowa do. This is a cooperation between farmers that combine the crop and sell it to large processors. Don't know what part of individual crop is sold to who or what.

2. How has your situation changed between 1988 (or before) and 2012 in terms of acreage, products that you cultivate, yearly corn yield, parties that you sell to?

Last 40 years it has been approximately 50/50 corn but last years bit more corn due to high prices. Since 1988 his acreage has increased approx 600 acres (from 1200 to 1800). Yields vary from year to year.

3. Has the way corn is cultivated changed between 1988 (or before) and 2012? In other words, would you do anything different in the corn cultivation process now than you would have done in 1988?

More corn is planted without tillage (no cultivation, ploegen). This is possible because tillage is used to get rid of weeds, which nowadays is done more with chemicals. The advantages of no-till production is that there is less chance of erosion, the soil retains more moisture.

4. What is the effect of different planting days? Why was corn planted earlier in 2012? How does yield increase with early planting?

Planting as early as weather conditions allow. For corn the soil temperature should be 50 degrees F or higher (and 10-15 day weather forecast should be good). The most important reason for these conditions is that corn should come out of the ground as fast and even as possible. Corn that come out of the ground at different times will overshadow each other.

2012 planting was 15-20 days earlier than in 1988 because weather conditions allowed (high temp).

5. How does corn respond to drought, and what do you think is the point that major crop losses are incurred (What does it take to kill a corn crop)? Has this changed over the years (more resistance now)?

Most important phase is the pollination, which is most stressed by drought. And afterwards when the ear and kernels need to grow it needs a lot of water, nutrition and fertilizers. Nowadays corn is more resistant to drought due to better genetics in the corn seeds. These genetics have improved both in bug and drought resistance. The bug resistance leads to stronger plants that will by itself be less stressed by drought.

6. Is there any difference between the drought in 1988 and 2012? (soil moisture or humidity or the course of the drought)

The big difference is that the plants were stronger (healthier) in 2012. He remembers that 1988 did not start out as hot. Another important factor is that corn was planted earlier in 2012.

7. In what way do you use weather forecasts during the cultivation process? Are there any adjustments made based on weather forecasts?

Weather forecasts are only used for determining planting date. The rest of the production process is not determined by weather forecasts.

8. Do you have any irrigation system? Do you think this has helped or would this have helped during the drought? Have these systems improved or become more affordable since 1988?

He has no irrigation system. Western Iowa has more farms with these systems. They are expensive, but with high corn prices become more and more affordable and many farmers start to buy such systems.

9. Do you consider the WASDE reports to be important for any decisions that you make? Are there any other reports that you keep track of? What are the most important aspects in these reports?

Yes, he checks the supply and demand with the price forecasts, which caused him to produce a little more corn last couple of years.

10. Do you have any crop insurance policy, and how does that work? Has this changed between 1988 and 2012?

Most farmers now have insurance. Over 90% in 2012 vs less than half in 1988, because more affordable and the price of production has gone up. This means that farmers want to insure themselves to cover these expenses. Many farmers started to get insurance around 1990-1995.

Insurance policies cover 70-85% of the yield, with higher premiums for higher coverage (of course). Any yield that falls below your coverage level will be paid out by the insurance company according to the spring or fall price. This is an option for the farmer, where they pay higher premium if they want to get the fall price (as it is more uncertain).

11. Do you (or any farmer you know) use any kind of financial products like future contracts to hedge against falling corn prices? And in what way do you use them? Has the market changed between 1988 and 2012, changing your hedging behavior?

He doesn't use futures, but uses local future contracts with the cooperative elevator. Which means he sells his crop before harvesting for a agreed upon price.

12. Has the ethanol production from corn changed the way corn is cultivated in any way? Has it changed the amount of carryover? Or is there another reason the carryover was so different in 1988 and 2012?

More acres are now planted with corn due to the higher demands. But there is no distinction of corn for different end products. He thinks just a small part of his corn is sold for ethanol production due to price convenience (easier to sell it for other purposes), but his neighbor on the other hand could be selling half of his crop for ethanol production.

13. Finally, do you have any ideas, from your vision as a farmer, as to why the future prices moved up earlier in 1988 than in 2012, both years that had a very dry growing season?

The reasons for the higher corn prices after the jump were a good supply in 1988 and more usage in 2012. Spring 2012 farmers did not think that crop failure could place at all. A drought was never foreseen and the genetics were believed to be strong, acreage was really high. So everybody was expecting high corn production. 25 years no drought.

Other questions through mail?

yes

Interview

Farmer: Paul Jeschke

state: Illinois

Farmer since: 1975

Acreage (ha.): now 5000 Acres (1988 1400Acres, 2012 4400 Acres).

Products: Corn and Soy (2/3, 1/3)

1. How has your situation changed between 1988 (or before) and 2012 in terms of acreage, products that you cultivate, yearly corn yield, parties that you sell to?

In 1988 , 60-40% (Corn-Soy) to 2/3-1/3 today.

Crash in the mid 80's causing land prices to fall. Fall 1978 bought land for 4010 USD/acre. 1985 fell to 1500USD/acre. Farmers were weak in the 80' due to the crisis, huge leverage. High Debt/Equity ratio due to low land prices (low equity).

2012 a huge crop was expected, record planted acres, early planting!!

2. Has the way corn is cultivated changed between 1988 (or before) and 2012? In other words, would you do anything different in the corn cultivation process now than you would have done in 1988?

Nowadays more rootworm resistant species, means less pesticides.

A trend is seen of earlier planting as farmers discover that yields increase with earlier planting.

Not much further difference.

3. How does corn respond to drought, and what do you think is the point that major crop losses are incurred (What does it take to kill a corn crop)?

A corn plant will always try to reproduce. Drought causes limited roots, but as long as the plant can regenerate roots it will.

Pollinating begin-late July. If no pollination occurs then the kernels will not grow.

After pollination, the amount of water determines the size of the kernels and thus ultimate yield. A dry spring is welcome, as too much moisture is not good for recently planted crops.

4. Do you think corn nowadays is more resistant to drought, due to stronger hybrids?

Yes, corn is now able to tolerate higher temperatures.

The rootworm resistance is better in 2012, meaning less pesticides that need water to get into the soil. 80% of his crop is rootworm resistant.

Both indicate that the drought in 2012 was less severe as the crop is more resistant to the drought. He said that with the 1988 crop planted today, yields would be 25% lower.

5. Is there any difference between the drought in 1988 and 2012 in terms of soil moisture or humidity or the course of the drought?

1988 was hotter than 2012, but was more moist.

Paul thinks the lack of moisture is worse than high temperatures. Plenty of moisture decreases the temperatures through evapotranspiration.

6. What is the effect of different planting days? Why was corn planted earlier in 2012? How does yield increase with early planting?

Early planting is done to get more growing days, i.e. More sunlight, bigger kernels, higher yield.

There exists a trend that farmers are more and more aggressive to get the highest yield possible. You can see through the years that planting happens earlier and earlier, more risk is taken as it turns out earlier planting causes higher yields despite the risk of early frost.

7. Do you consider the WASDE reports to be important for any decisions that you make? Are there any other reports that you keep track of?

All the USDA reports to keep track of the total picture. "If I am the only farmer with a bad crop the USDA doesn't care much, and I will have to make adjustments."

8. Do you (or any farmer you know) use any kind of financial products like future contracts to hedge against falling corn prices? And in what way do you use them? Has the market changed between 1988 and 2012, changing your hedging behavior?

Hedge about 2/3 of the planted crop before planting. In the 80's this number was a lot lower, he also used mini contracts back then. Back in the 80's he didn't have the capital and knowledge to invest in future contracts.

In 2012 with the drought he bought out of his future contracts as there was an uncertainty that he could meet the conditions. So to be sure he bought back all the future contracts.

He thinks all information is included in the future markets. He talked about the example of the Brazilian dock workers that decided to go on strike, which was immediately seen in the soy been future prices. Where just a moment later this strike was less severe and price went down again. This illustrates in his view how future markets very rapidly respond to thing that happen nowadays. And there is no indication that future markets are less efficient than before. On the contrary, with the faster information distribution markets respond faster than before.

9. Do you have any crop insurance policy, and how does that work? Has this changed between 1988 and 2012?

1988 Crop insurance was expensive. In Illinois less than 15% of the fields were insured.

With the drought of 88, the government helped with payments to save the farmers, as most of them were not insured. This lead to the government forced to improve these policies to make them appealing to all farmers.

In 2012 the insurance policies have been greatly improved. There is a much greater variety in policies that cover up to 85% of the acres, which means that up to 85% of the lost crop is covered. The government even subsidizes in the insurance premium (about 46% for the high coverage policies).

10. Has the ethanol production from corn changed the way corn is cultivated in any way? Has it changed the amount of carryover? Or is there another reason the carryover was so different in 1988 and 2012?

All corn for different purposes is the same, there is no distinction in corn species for different end-products.

Much more demand due to ethanol production. People say this caused the corn price to rise, but with almost twice as much corn production as in 1989 this should not be the only reason that corn prices have risen.

China buys a lot of the residual product from ethanol production which is called DDG and used for animal feed.

In 1988 the bottom price of the corn was determined by the government rate on the loans that farmer has on its ground. Nowadays farmers check the marketplace.

Carryover is much lower due to the high demand, which is party caused by the ethanol production. Must keep in mind that total production nowadays is approximately twice as high as in '88.

11. In what way do you use weather forecasts during the cultivation process? Are there any adjustments made based on weather forecasts?

Weather forecasts are only used on a short term basis. "Check if it will rain this afternoon to decide on planting". Check if it will rain tomorrow to decide whether to apply pesticides (rain = no pesticides). This sort of decisions.

Long term decision are not based on the weather analysis, as they are not reliable enough. For instance, when in September a drought in the next summer is foreseen, the farmer will not adjust the hybrid of corn seeds he buys.

There is a 10% shift possible in the corn-soy ratio based on weather and crop reports.

12. Do you have any irrigation system? Do you think this has helped or would this have helped during the drought? Have these systems improved or become more affordable since 1988?

No irrigation systems. Only economically feasible when surface water is nearby. In illinois water is deep in the ground.

Just a small part of the Corn belt is irrigated.

Seed production is usually done on irrigated field, as the quality of the seeds is very important. Irrigated field almost always produce high yields.

13. Do you produce any corn for export, and how much of the yearly crop (%)?

Export around 2bln bu., this year only 900 mln bu. But this number doesn't count the DDG.

14. Finally, could you think of any reason why in 1988 the future prices moved up earlier than in 2012, both years that had a very dry growing season?

More uncertainty in 1988 for farmers: insurance, high debt/equity. Farmers buy back their future contracts earlier, causing the price to rise earlier.

In 2012: insurance policies keep farmers covered, first action comes from the long side of the contract.

In 1988: Lot of uncertainty from farmers, causing them to buy back the contracts.

Other questions through mail?

Yes or cellphone.

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