UNIVERSITY OF AGDER

The impact of speculation in commodity futures on food prices

Modelling the impact of speculation using a generalized autoregressive conditional heteroscedasticity model (GARCH).

Siv Elisabeth Rinden

Supervisor

Jochen Jungeilges

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School of Business and Law

Department of Economics and Finance

“We learned about honesty and integrity - that the truth matters... that you don't take shortcuts or play by your own set of rules... and success doesn't count unless you earn it fair and square.”

(Michelle Obama)

“Hunger is a political question, not just a technical problem. We need markets, of course, but we also need a vision for the future that goes beyond short-term fixes. The global food system will always need firefighters. But what we need more urgently are architects to design a more fire-resistant system.”

(Olivier De Schutter, United Nations Human Rights Council)

“When billions of dollars of capital is put to work in small markets like agricultural commodities, it inevitably increases volatility and amplifies prices – and if financial flows amplify prices of food stuffs and energy, it's not like real estate and stocks. When food prices double, people starve."

(Mike Masters, Hedge fund manager)

Abstract

This thesis examine how speculative activities in the commodity futures market affect the commodity spot prices. The relationship between the commodity futures volume of contracts traded, open interest, speculative open interest and the commodity spot price are investigated. There is considerable disagreements about whether there exist a linkage here or not in the related literature. This study provides evidence that speculative activity do destabilize the commodity spot prices by increasing the volatility of the price process.

KEYWORDS: Speculation, agriculture, futures market, GARCH-model.
JEL-classification: G10, Q10.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Introduction

"Food inflation has attracted speculators for short term profit at the expense of people living a dignified life."

(Paul Polman, CEO of Unilever)

Food prices in the last decade have suffered from huge fluctuations, pushing millions of people, especially in developing countries, into poverty. Some people in the world spend more than half of their income on food, and some can actually spend up to 75 per cent on food and at the same time, they often rely heavily on food support[1]. This makes them very vulnerable to price and volatility fluctuations. The amount of undernourished people in the world topped 1 billion for the first time in 2009[2]. This indicates that the global food crisis observed in the recent years has definitely left its mark. From 2007 to 2008, the International Monetary Fund (IMF) price index of internationally traded food commodity rose by 56 per cent and by the end of 2008 the agricultural commodity prices had fallen by 50 per cent again[3]. There were enormous daily fluctuations in this period as well, and some reporters compared the fluctuations of the prices of corn and wheat in a single day in this period to be as large as the price fluctuations observed in a whole year back in the 1990s[4]. Unfortunately, the decline in the commodity prices at the end of 2008 turned out to be short-term. In 2010-2011 the prices rose rapidly again. Many researchers suggest that the price fluctuations observed derive from fundamental factors, such as supply and demand factors[5]. However, other researchers claim that the fundamental macro and microeconomic factors cannot fully explain the recent increase in commodity prices. One reason for this is that in the same period that the food prices fluctuated and reached all-time high levels, there has been remarkable structural changes in the commodity futures market. Trading volume and open interest have increased, and there have been some changes in the participants of the commodity markets[6]. Primarily the futures markets are associated with hedging purposes. Commodity futures can

[1] (Herman, Kelly, & Nash, 2011, p.2)
[2] (Clapp & Helleiner,2010, p.184)
[3] (Clapp & Helleiner,2010, p.184)
[4] (Clapp & Helleiner,2010, p.184)
[5] (Czech, 2013, p.11)
[6] (Czech, 2013, p.10)

be a tool for companies and other users (such as farmers) to reduce risk. Commodities are heterogeneous, and they often provide high transportation and storage costs. Because of this, it is normal to hedge a risk with a commodity contract that is imperfectly correlated with the risk being hedged[7]. Another participant in the futures market are the so-called speculators. A speculator uses futures contracts to make a profit from movements in the futures prices[8]. This is different from a hedger, because the hedger uses futures contracts mainly to protect against price movements, like an insurance. The observed increase of speculators in the commodity market has made the commodity markets more like financial markets in terms of motivations and participants. This observed change in the commodity markets refers to the "financialization" of commodity markets[9]. The main purpose of this thesis is to determine if there exist any linkage between agricultural commodity speculation and the price in the physical markets for food. Many researches have used a descriptive approach to analyze this linkage, but in this analysis, there will be a more empirical approach using a generalized autoregressive conditional heteroscedasticity model (GARCH). Other researchers have used similar models to try to identify this potential linkage, but in this analysis, the dataset is different in form of the length of the data and "outside shock" factors included in the conditional variance equation in the model.

1.1 Outline

The thesis has several sections. Section 1 and 2 describes the motivation for the issue of the thesis and what type of research and results that already exist regarding the phenomenon. In section 3 there will be a formal explanation of the behavior of the prices in the financial market, with focus on the derivative market. The purpose of this section is to explain how prices behave in theory and how the different participants of the markets play a role in the price settling process. Subsection 3.1 contains a presentation of the efficient market hypothesis, a well-known theory of how price patterns in the financial markets can be explained. In subsection 3.2, different terms and dynamics of the derivative market are described, involving the different participants of the market and some definitions of futures contract that are used in the empirical part of the thesis. The Spot-futures parity theorem is

[7] (McDonald, 2013, p.185)
[8] (Bodie, Kane & Marcus, 2011, p.675)
[9] (Clapp & Helleiner, 2010, p.189)

explained in subsection 3.3, and it shows how the price of the futures contract and the spot price of underlying product converge in time. Three different risk transfer hypothesis are discussed in subsection 3.4, and it shows how the futures contract price is equal to the expected future spot price of the asset. The purpose of including these theories is to give a presentation of how the futures contracts price dynamics are defined in theory. This is defined in an environment were all participant in the market are fully informed and there exists no uncertainties. This does not seem to fit with the situation of the real world, where there is a lot of information asymmetry and a lot of uncertainty. Could this uncertainty push up the prices of the futures contracts, and could this price increase affect the spot prices of the assets as well? Section 4 covers the agricultural commodity market and how the dynamics of the market has changed in the last decades. It starts with a description of the price movements observed in a given time period (subsection 4.1), followed by some information about the global food crisis the world has faced in this period (subsection 4.1.1). Many researchers claim that the fundamental supply and demand factors is to blame for this observed movement of the prices, hence there will be presented of a theory regarding general equilibrium in the commodity market (subsection 4.2) to show how these fundamental factors could create an equilibrium set of market prices. The issue of a potential linkage between speculation and higher food prices has been highlighted and discussed a lot in the recent years, resulting in a lot of theories and ideas of different factors, other than the fundamental supply and demand factors, that may contribute to the observed price increase. In subsection 4.3 there is presented some of the main factors that seems to have affected the food prices and which has some sort of consensus between the majorities of the researchers in the field. The effect of speculation is one of the factors mentioned and in subsection 4.4 this will be discussed further to motivate the empirical part of the thesis. Another important feature of the commodity market is the deregulation of the market observed since the millennium. Section 5 describes the de-regulative process observed in the U.S commodity market in the given time period. This process has resulted in a higher proportion of speculative participants in the market, thus motivating the possible linkage between speculative activity and high food prices. The increase of speculative activity in the commodity market give rise to the term "financialization of the commodity market", which is defined in subsection 5.2. The empirical part of the thesis starts in section 6. The testing procedure is presented, starting with a definition of the auto-correlation function in subsection 6.1, followed by another approach of testing the existence of autocorrelation known as the Ljung-Box test, and it is presented in subsection 6.2. Other important features such as normality and stationarity of the variables and residual of the model needs to be tested, and the testing procedures is described in subsection 6.3 (normality test) and 6.4 (test for stationarity). Akaike`s information criteria was used to select the proper order of the mean equation of the main model, and the criteria is described in subsection 6.5. If there are ARCH-effects in the residuals of the mean-stationary stochastic process selected by Akaike`s information criteria, we have a case of heteroskedasticity in the residuals and this is the motivation for the main model used to test the potential speculative linkage. The ARCH-effects testing procedure is described in subsection 6.6. The dataset used in the model is described in section 7, and the features and dynamics of the underlying processes are discussed and showcased in subsection 7.1. To analyze the phenomenon I have applied a general autoregressive conditional heteroskedasticity GARCH (1, 1) model, and in subsection 8.1 the methodology of the model is given. Subsection 8.2 contains the specific case I want to test, and the result of the model is presented. The discussion of my result compared to other findings is provided in subsection 8.3, followed by a conclusion in section 9. In subsection 9.1, some future research is suggested based on the empirical results provided from this thesis.

2. Literature review

With the rapid growth in commodity prices together with the observed financialization of the commodity futures market, many papers studies the co-movement between commodity futures and other assets, and how this may or may not affect the commodity price or the price volatility. Several papers also studies different types of traders, and how these different positions could be related to the observed price changes. The traders are often divided into two groups, the hedgers (also referred to as commercial traders) and the speculators (often referred as the non-commercial traders). Stoll & Whaley (2010) used 12 different commodity futures contracts from CFTC`s (U.S. Commodity Futures Trading Commission) supplemental report and two commodity indexes – the Standard and Poor`s Goldman Sachs Commodity Index (S&P-GSCI) and the Dow Jones UBS Commodity Index (DJ-UBSCI) to determine whether the rising phenomenon of commodity index investing is a disruptive force in the commodity futures market. They performed Granger-causality test on returns to determine the context. Their comprehensive study resulted in the conclusion that commodity index investing is not speculation, and it does not affect or destabilize the futures price[10]. Bohl & Stephan (2013) investigated the growing market share of futures speculators to see if they destabilize commodity spot prices. They used data from 6 agricultural and energy commodities and measured the returns of each asset. They used an autoregressive conditional heteroscedasticity (GARCH) model to analyze the phenomenon. They modeled the price changes as a first-order autoregressive (AR) process with a constant to account for possible return dependencies over time. The conditional volatility of the returns contained aggregate trading volume, aggregate open interest and speculative open interest. The basis of their main results provided evidence that speculators do not destabilize commodity spot prices in a large scale, and that financialization of raw material markets does not make them more volatile[11]. On the other side, Cooke & Robles (2009) performed a study with the purpose to try to find possible explanations for the movements in commodity prices observed form 2006-2008. They analyzed many possible factors that could explain the rise in agricultural prices, and one of the factors was the increased activity in the futures market. In the analysis, they looked at the price movements of 4 different agricultural commodities, and they used the volume of commodity futures, open interest of futures contracts and noncommercial to total trade ratio as a proxy of speculation. They used first difference models and granger causality tests to see if there exists any linkage. The study provides empirical evidence that financial activity and speculation in futures markets can help explain the behavior of the commodity prices in the period. In fact, in their findings, the financial activity in futures market and proxies for speculation were the only factor supported to have an effect on the rise in the commodity prices by the time series analysis, any other explanation were not well supported[12]. Varadi (2012) provided a study with the purpose to investigate for the evidence and impact of speculation on volatility of commodity prices in the Indian Commodity markets. The analysis mainly focused on the period of 2006-2010, to include the financial crisis that occurred in that period. Data from the Forward Markets Commission in India (FMC) were used and the econometric approach used was multivariate GARCH estimations and VAR Granger-causality tests. Volume of futures contracts, value of the contracts and open interest in the future contract market were used as a proxy for speculation. Varadi`s study provide empirical evidence for "speculation" during the crisis period which might be a cause for the excessive

[10] (Stoll & Whaley, 2010)
[11] (Bohl & Stephan, 2013)
[12] (Cooke & Robles, 2009)

volatility observed in the commodity markets in the given time period[13]. It shows that speculation can cause unreasonable price fluctuations. The idea of a possible linkage between speculative trading and increased food prices has engaged many researchers, and there exists big differences regarding the potential linkage. To provide a starting point to further investigate the linkage, it is important to have a basic understanding of how the financial market and physical market are interrelated. Different theories and dynamics of these markets will be provided in the two following sections.

3. Financial markets and theories

Financial markets in one way or another affects all people in the world. One example is when people invest their savings in mutual funds, they invest in stocks and bonds from companies all over the world. This means that they are not heavily exposed to one company only and this can reduce the risk of the investment. Another example is a company that wants to insure itself against certain risks. It could protect itself of currency changes, interest rate changes and commodity price changes that could give the company adverse consequences. This could be done through the global derivatives market. Risk sharing is definitely one of the most important functions of the financial markets[14]. In general, the financial markets can be defined as "a forum for the exchange of financial products, represented in some cases by a physical location, but in others by a common information system sharing data on prices and volume transacted, and where a number of professionals take an active part in the processes of the market"[15] (Fell, 2000, p.18).

The risk of an investment can be divided into two components: diversifiable and non-diversifiable risk[16]. Diversifiable risk is characterized by random events that are company-specific. This is also referred to as unsystematic risk, and this type of risk can be eliminated by diversification. Non-diversifiable risk attributes to more general forces that we cannot control. This type of risk does not vanish when spread across many investors like diversifiable risk do. The sum of these two components of risks is referred to as the total risk. The financial market serves two purposes[17]. It permits diversifiable risk to be shared all over the world; this

[13] (Varadi, 2012)
[14] (McDonald, 2013, p.10)
[15] (Fell, 2000, p.18)
[16] (Gitman, Joehnk, Smart, Jochau, Ross, & Wright, 2011, p.144)
[17] (McDonald, 2013, p.11)

makes it possible to vanish out this type of risk when it is widely shared. At the same time, non-diversifiable risk is permitted, but it does not vanish when widely shared, and can be held by those who are most willing to hold it. In theory, the fundamental economic idea is that risk-sharing mechanisms benefits everyone[18].

3.1 The efficient market hypothesis

In the 1950`s business cycle theorists traced the evolution of economic variables over time to (among other things) analyze the behavior of the stock market prices. Maurice Kendall was one of these theorists and in 1953, he discovered that there is no predictable pattern in the stock prices[19]. The price movements observed in the market seemed to evolve randomly, and it soon became apparent that the random price movements indicated a well-functioning market. This means that the prices do not follow any particular pattern, and they are as likely to increase as they are to decrease. Because of the random movement of the prices, there is no way of predicting the future prices based on the previous prices. Had it been the case that historical performance does affect the current price, investors could have made money very easily. They could all earn profits by investing in stocks that were predicted to increase and sell those stocks that are about to decrease. Because of this, it is said that any information that could be used to predict the stock performance is already included in the stock prices[20]. As soon as there exists any indication of an underpriced or overpriced stock that could provide some sort of profit for an investor, the investors flock to buy (or sell) the stock and this immediately bid up the price to a fair level. The price reaches its fair level, given all available information, in response to new information available. This new information is unpredictable, because if it could be predicted it would be a part of today`s information. The idea that stock prices reflect all available information is referred to as the efficient market hypothesis[21].

In general, the efficient market hypothesis consists of three versions: the weak, semistrong and strong form[22]. The main difference of these versions is the definition of the term "all information available". The weak-form involves information that can be derived from examining the market trading data only. The semistrong-form contains all public available information such as forecasted earnings, patents, management (and so on), including information of historical trading data involved in the weak-form. The strong-form contains the

[18] (McDonald, 2013, p.11)
[19] (Bodie, Kane, & Marcus, 2011, p.371)
[20] (Bodie, Kane, & Marcus, 2011, p.372)
[21] (Bodie, Kane, & Marcus, 2011, p.373)
[22] (Bodie, Kane, & Marcus, 2011, p.375)

same as the weak and semistrong-form, but it also includes available information from company insiders. This is an extreme version, and information from “insiders” is considered as illegal in most parts of the world. The semistrong-form is the most common because it states that the stock price reflect all information that is publicly known for all participants in the market.

The efficient market hypothesis has been widely discussed among portfolio managers, because it basically states that they are wasting their time trying to earn abnormal returns in a market that provides no arbitrage opportunities. Is the market as efficient as the hypothesis claims? There exists many different opinions on this, and there are some factors that trigger these disagreements. Two examples of such factors are the magnitude issue, and the selection bias issue[23]. The magnitude issue derives from the fact that even though the prices are close to fair prices, a very small performance could provide huge annual earnings for large investments. This small contribution of the investment will be swamped by the yearly volatility of the market and there is no way of measuring this single contribution. So if the market is meant to be efficient, how efficient is it really? This challenges the basic concept of the efficient market hypothesis. Another issue is the selection bias issue. This derives from the fact that if you contain valuable information about an investment that could result in huge profit earnings, would you share this information to achieve some sort of public recognition, or would you keep the secret and take the profit yourself? If any investor chooses the second statement, this would violate the assumption of information available in the efficient market hypothesis. There is a lot of research done in this field, and there are some that find evidence of abnormal returns, but because of the high competition in the market, only superior information or insight has a potential of earning money[24]. In general, the conclusion is that the markets are efficient from a large point of view, but there exists some rewards to the intelligent or creative investors in the market.

3.2 Derivatives

Derivatives play a large role in the financial markets. Derivative securities, or derivatives, are securities that are determined by (or derived from) the prices of other securities[25]. The payoffs

[23] (Bodie, Kane, & Marcus, 2011, p.384)
[24] (Bodie, Kane, & Marcus, 2011, p.401)
[25] (Bodie, Kane, & Marcus, 2011, p.576)

depend on the value of other securities, and this makes them powerful tools for both hedging, speculation, and reducing transaction costs. When a person or a company enter some sort of derivative contract with the intention of reducing risk that they are disposed to, this is referred to as hedging[26]. Speculation is another side of the story, because here the main purpose of investing in derivatives is to make profit. Investing in derivatives can sometime provide a lower cost way to conduct a particular financial transaction. One of the reasons for this is that you construct contracts in forms of "bets" that could provide you a high gain or loss compared to the initial cost of making the bet. This could be a way of reducing transaction cost. Even though the derivative market is mainly used to hedging purposes, speculation is a necessary part of the derivative market. Without it, hedging pressure could create stochastic markets and this could disable the risk transfer capacity[27]. The different risk transfer hypothesis is further discussed in section 3.4.

A participant in the derivative market is said to have a long position if he/she or it buys a security (commodity, stock, currency) with the intention of selling it in the future to gain from a possible price increase. The opposite story is called short-sale. If a participant of the market expects that the security price will fall, he/she or it can borrow the security from an owner, sell it, receive the cash, and when the prices fall, buy the security back and return it back to the lender. Put in a simpler way, selling something you do not own is referred to as short-sale.

There are many reasons to use derivatives, and it seems to have an increasingly important role in today's volatile financial markets. In general, derivatives provide an alternative to a simple sale or purchase, and this increase the investment possibilities in the market. However, because of the high level of uncertainty in some markets, hedging may be more desirable than arbitrage opportunities in the market. McDonald (2013) defines three distinctive perspectives on derivatives: the end-user perspective, the market-maker perspective and the economic observer. The end-users is defined as the corporations, investment managers and other investors that enter into derivative contracts to manage risk, speculate, reduce costs, or avoid some sort of regulation or rule. An end-user care about how a derivative contract can help achieve some sort of goal he/she/it may have. The market-makers are the intermediaries. They are traders that buy derivatives from customers that want to sell, and sell to the customers that want to buy. The way to do this is to make a spread, you buy at a low price and when the price is high, you sell. The activity of an economic observer is to look at the use of the

[26] (McDonald, 2013, p.11)
[27] (Berg, 2011, p.269)

derivatives, the activities of the market-makers, the organizations and the logic pricing models and to try to make sense of it all. This is to consider actions such as regulation of certain activities and how to construct such regulations.

Futures contracts are a type of derivative product. A future contract is a contract between two parties that carries out the obligation to buy or sell an asset for a price determined today with delivery and payment at a future point, the delivery date[28]. Futures markets have their roots in commodities and agricultural products, but there also exists financial futures such as those based on stocks indexes and government bonds. Hedging and speculation are typical intensives to use futures contracts. There are different theories regarding the price dynamics of these futures contracts, and to give a perception of the dynamics, some of these theories are described in the following sections.

3.3 Spot-futures parity theorem

Futures contract can be used to hedge against changes in the value of any underlying asset. For example, a firm planning to sell oil might be exposed to periods of high market volatility and in order to protect against this the firm can use futures contracts. To do this the oil firm engage in a "short-hedge", taking a short futures position to hedge against risk in the sales price. A "long-hedge" refers to a position where someone wants to eliminate the risk of an uncertain purchase price. Using the oil example again, this applies to a power supplier that buys oil and needs to hedge against the potential risk of high oil prices. In the futures market, the convergence property implies that $F_T - P_T = 0$. This means that on the maturity date of a contract, the basis risk between the futures price and the spot price is equal to zero[29]. The futures market convergence is the process were futures market and spot market prices come together (converge) at the futures market expiration[30]. Convergence occurs at every futures contract expiration because of arbitrage. If the spot prices are lower than the futures prices, a market participant could by in the spot market and sell in the futures market, thus making a risk-free profit. The same holds in the opposite case, when the spot price is above the futures price, a market participant could buy in the futures market, take delivery and sell in the spot market, thus earning a risk-free profit. However, if a futures contract is liquidated before

[28] (Bodie, Kane, & Marcus, 2011, p.664)
[29] (Bodie, Kane, & Marcus, 2011, p.677)
[30] (Seamon, 2010, p.2)

maturity, the hedger bears basis risk, because the spot- and futures price has not converged yet. Because of this convergence property, a portfolio containing both assets and futures has no risk, and the hedged position provides a rate of return equal to other risk-free investments. If this is not the case, arbitrage opportunities will be exploited until the prices are brought back into line. This is the main insight of the spot-futures parity theorem. The theorem provides the theoretically correct relationship between futures and spot prices. It states that a total investment of a current stock price (S_0) grows to a final value of $F_0 + D$, where D is the dividend payout of the portfolio. According to the theorem, the futures price must be[31]:

$$F_0 = S_0(1 + r_f - d) \qquad (3.3.1)$$

where d is the dividend yield on a stock portfolio, S_0 is the current stock price and r_f is the risk-free rate. Because of this, the rate of return of a perfectly hedged stock portfolio is essentially riskless.

3.4 Expectation-, Normal Backwardation- and Contango Hypothesis

Theories of futures pricing in this subsection are all based on Keynes way of defining the nature of risk and returns. Keynes (1930) proposed that the speculative participants of the commodity futures market earn a risk premium as their reward for absorbing the hedger's risk[32]. The theories is referred to as the risk transfer hypothesis, and it is assumed that the hedgers are net short, and speculators net long[33].

The expectation hypothesis is considered as one of the simplest theories of futures pricing. The hypothesis states that the futures price is an unbiased estimate of the expected future spot price of the asset[34]: $F_0 = E(P_T)$. The hypothesis relies on the assumption of risk neutrality, because if all investors are risk neutral, they should be able to agree on a futures price that provides an expected profit of zero to all participants. The market is assumed to be efficient, and this result in a market with no uncertainty and all the prices are currently known and available. Because of this, the futures price will be equal the currently known future spot price for any given maturity. This theory ignores the fact that spot prices can be uncertain, thus ignores the risk premium that should be added to the futures prices.

[31] (Bodie, Kane, & Marcus, 2011, p.680)
[32] (Goss, 2013, p.119)
[33] (Goss, 2013, p.3)
[34] (Eyedeland & Wolyniec, 2003, p.66)

The theory of normal backwardation derives from the assumption that for most commodities there are natural hedgers who wishes to shred risk[35]. For example a farmer that wants to hedge against the risk of uncertain wheat prices. This could be done by taking short positions to deliver wheat in the future at a settled future price, thus short-hedging the risk. Speculators could enter the long side of these contracts if the futures price is below the expected spot price of wheat, thus getting an expected profit of $E(P_T) – F_0$. This is the farmers expected loss that this individual is willing to bear in order to protect against potential losses due to uncertain wheat prices. According to Bodie, Kane & Marcus (2011) "the theory of normal backwardation thus suggest that the futures price will be bid down to a level below the expected spot price and will rise over the life of the contract until the maturity date, at which point $F_T = P_T$" (Bodie, Kane & Marcus, 2011, p.686). This theory includes risk premiums in the futures market, but it is based on variabilities rather than on systematic risk. This could result in an inappropriate risk premium.

The Contango hypothesis deals with the opposite situation where the natural hedgers are the purchasers of a commodity, rather than the suppliers. It states that the purchasers are willing to pay a premium to lock down the price that they must pay for the commodity. The purchasers hedge by taking a long position in the futures market, in other words, they are long-hedgers and the buyer are short-hedgers. The long-hedgers will agree to pay high futures prices to avoid risk, and the speculators must be paid a premium to enter the opposite (short) position, the Contango theory states that F_0 must exceed $E(P_T)$[36]. The basic movements of the three theories are shown in figure 3.1.

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[35] (Bodie, Kane, & Marcus, 2011, p.685)
[36] (Bodie, Kane, & Marcus, 2011, p.686)

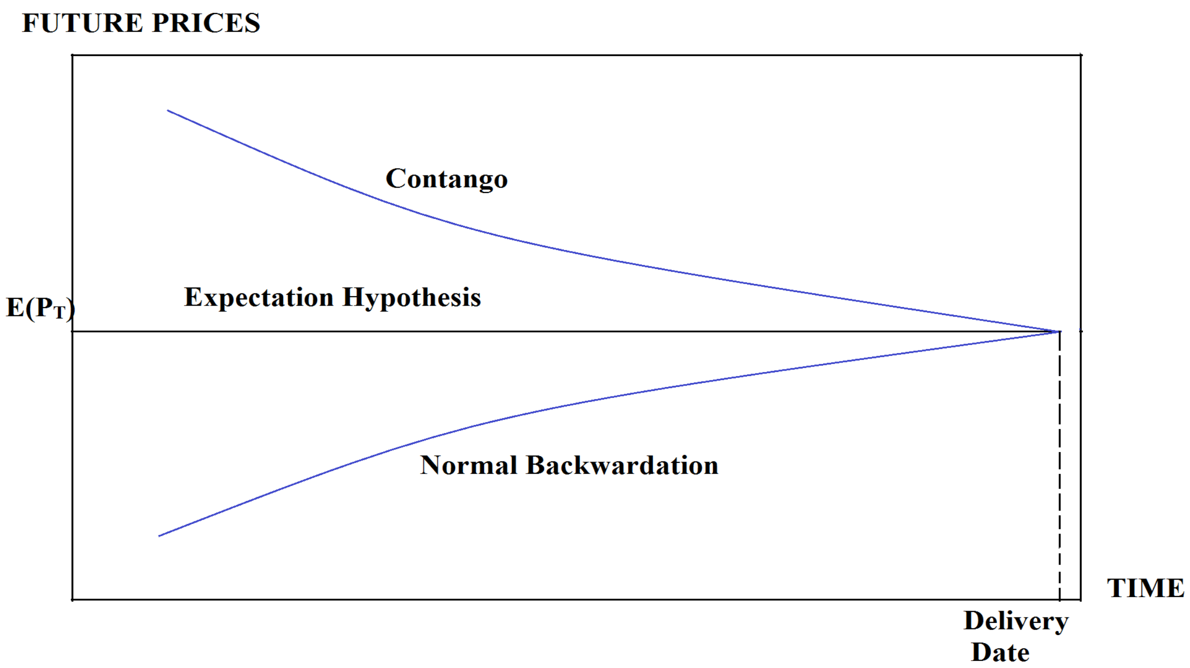

Figure 3.1 Futures prices over time when the expected spot price remains unchanged.

All these traditional hypotheses have been widely criticized, and the main criticism is that it seems to be far away from what is observed in the real world. One of the reasons for this is that it is in a way assumed that all participants in the market live in a static world with typical transactions and predictable behaviors[37]. The situation in the real world is not very predictable and it consists of high fluctuation and shocks that is hard (if not impossible) to predict. It is also the case that in real world, not all participants have the same access to full information, so their expectations are often based on different criteria, which again challenges the efficient market hypothesis.

The question is, could this uncertainty push up the prices of the futures contracts, and will this price increase affect the spot prices of the underlying assets as well? It is clear that speculative activity is an important factor that contributes to the price convergence in time, but what if the proportion of these participants surpasses the participants that needs to reduce risk? This is what seem to happen in today's commodity markets, and some researchers claim that this increases the volatility of the returns, thus affecting the hedgers that need to use these contracts to hedge against potential risk factors they are facing. Increased prices due to increased volatility could give these participants huge negative consequences such as not being able to enter these contracts simply because they cannot afford it. These observations and statements should encourage institutional parties to investigate the possible linkage

[37] (Mikolajek-Gocejna, 2014, p.38)

between the increasing speculative activities and the higher futures and food prices observed in the market.

4. Price dynamics of global agricultural commodities

The agricultural commodity prices have suffered from huge fluctuations in the recent years, affecting many people in the world. The price of maize raised as much as 93 per cent in the United States (not inflation adjusted) from 2009-2012 (figure 4.1). In the same period the price of soybeans increased by 50 per cent and the price of wheat increased by around 60 per cent[38] (figure 4.2). There exist similar patterns for the commodities in other parts of the world as well. There are several factors that have contributed to the increase in the commodity prices, some reflects trends of slower growth in production and some reflects the rapid growth in demand. Figure 4.3 shows a monthly price index for food commodities that are considered as the basis for human consumption of staple foods. The prices seems to have been stable in the period from 1990-2006 with some short periods where the prices rose from the previous year. In 1996, the prices reached a high peak compared to the previous years, but in 1997, it quickly declined to its previous level. After this the prices were stable in the following years, but in 2005 the prices slowly started to rise again, and in 2007-2008 the prices increased drastically, and reached an unusual high level compared to the previous years. In fact, the prices increased around 25 per cent from 2007-2008, and 58 per cent from 2006-2008[39]. Luckily, this huge increase did not last long, and in 2009, the prices decreased again. Unfortunately, the price level of 2009 were not to last, the prices started rising again, and in 2011 the prices reached even higher levels than before. Prices increased as much as 43 per cent from 2009-2011. It seems like the prices has declined a bit since 2011, but it has maintained high levels compared to the whole period shown in the figure. In the recent year, there has been some declining tendency, and the current prices are similar to the levels of 2009. Why do these spikes and fluctuations occur? Will the prices suddenly raise again reaching new all-time high levels? These types of questions derive from these observed price movements, seeing as these movements affect all consumers in the world. This uncertainty especially influence people that already spend a huge amount of their income on food, because they cannot afford a similar price increases in the future.

[38] (Food and agriculture organization of the United States STATISTIC DIVISION (FAOSTAT), 2015)
[39] (Food and agriculture organization of the United States STATISTIC DIVISION (FAOSTAT), 2015)

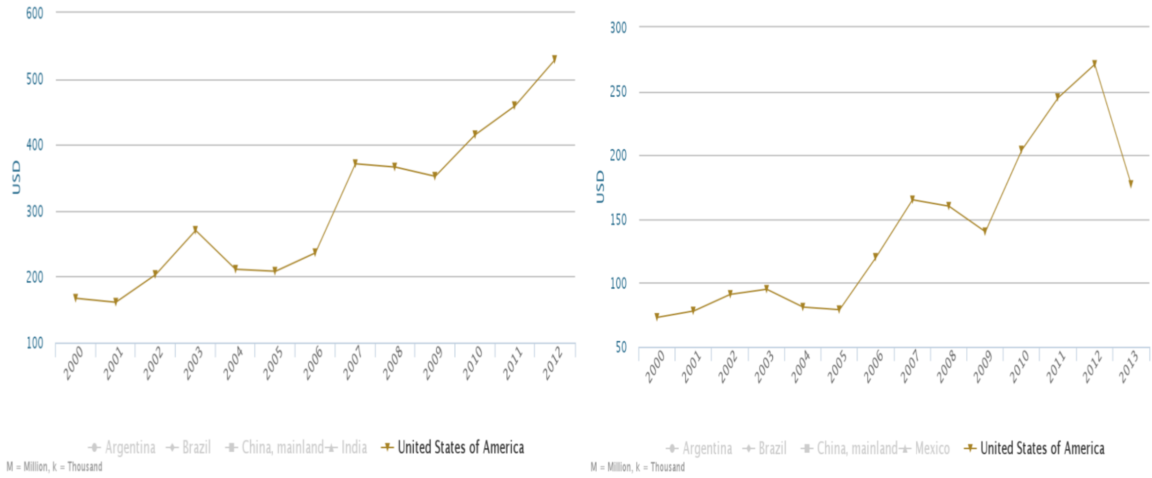

Figure 4.1 Annual maize and soybean price in United States (retrieved from FAOSTAT).

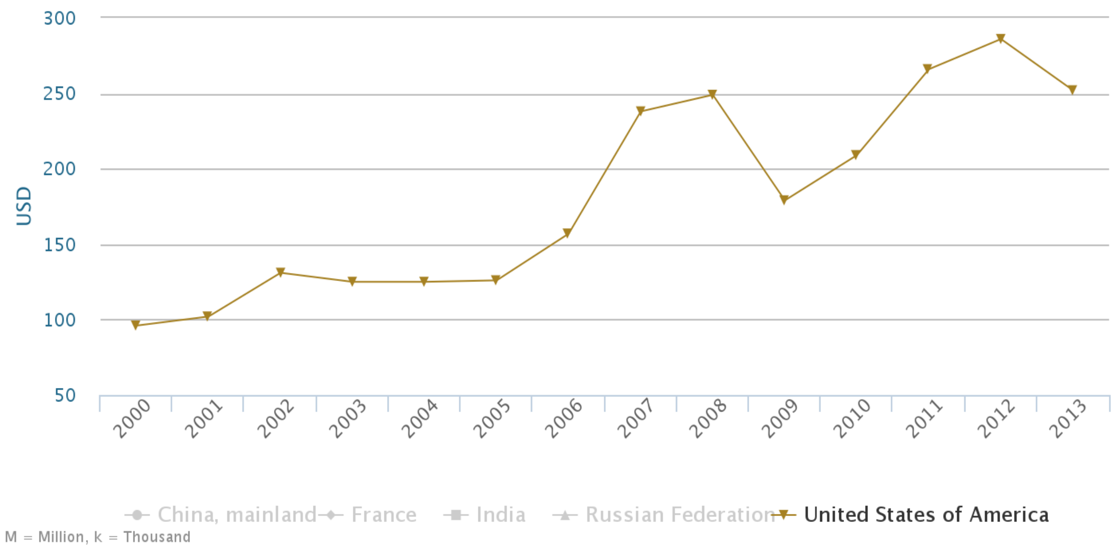

Figure 4.2 Annual wheat price in the United States (retrieved from FAOSTAT).

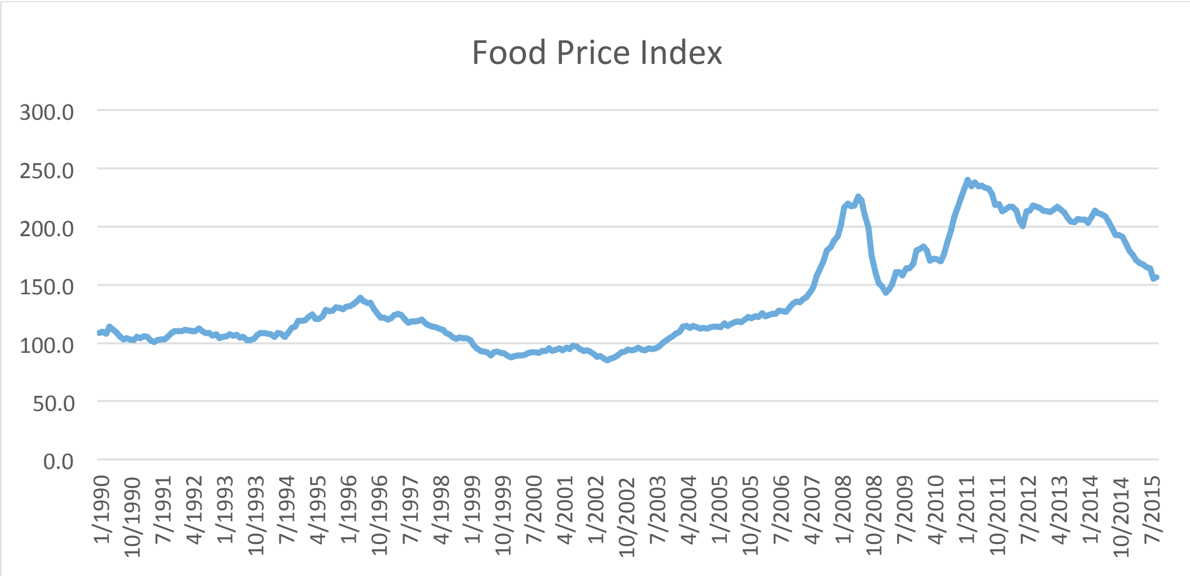

Figure 4.3. The FAO food price index (measured as monthly change in international prices of the average of 5 commodity groups of food commodities, weighted with the average export shares of each of the groups). Retrieved from FAOSTAT.

4.1 Global food crisis

From the development observed the last decade, it seems that high food prices are the new normal. The high prices have forced many disadvantaged families to remove their children out of school and to eat cheaper and less nutritious food. This could potentially serve life-long effects on the well-being of human beings worldwide[40]. In fact, these price developments has pushed millions of people into the category of "food insecure" and in 2009 the total number of undernourished people on the planet topped 1 billion, marking a drastic setback for the UN goal of reducing the number of hungry people to 420 million by 2015[41]. According to the Food and Agriculture Organization of the United Nations (FAOSTAT), the number of undernourished people in the world today is around 793 million[42]. Even though the number has decreased compared to the levels of 2009, it is still far away from the goal set by the UN.

The crisis commenced in 2006 when several of the commodity prices started to rise, and many analysts attributed it to be a mixture of factors affecting the demand and supply for

[40] (The World Bank, 2015)
[41] (Clapp & Helleiner, 2012, p.184)
[42] (Food and agriculture organization of the United States (FAO), 2015)

food. However, the role of speculation also attracted some of the attention because of the indication that the "fundamental" factors did not seem to explain the observed level of volatility in the market alone. They questioned whether long-term supply and demand forces could lead to the sudden price increases. One reason for this doubt was the observation of the futures prices for wheat and the spot price for maize in 2008. According to FAO, the futures price of March 2000 for wheat were 60 per cent higher than the expected level derived from market fundamentals of supply and demand, and the maize prices in April 2008 were 30 per cent beyond their expected underlying value in the same period[43]. This observation highlighted the rapid growth in financial investment in agricultural futures in the U.S. market during the years before the crisis.

4.2 General equilibrium theory

As stated several times before, fundamental supply and demand factors has been claimed to be the dominated forces behind the observed food price movements. The purpose of this section is to provide an overview of some of the concepts regarding commodity price movements. There exist many theories regarding general competitive equilibrium in the market of individuals and firms. The main purpose of these theories is to determine under which conditions there could be some sort of harmony between the actors in the market. To be able to discuss these theories, three fundamental elements of the economy are defined and assumed[44]:

- Households have given preferences represented by utility functions
  U^h , $h = 1,2,\ldots\ldots,n_h$
- Firms have specific technologies described in production functions
  Φ^f , $f = 1,2,\ldots..,n_f$
- Resource stocks R_i of the commodities $i = 1,2,\ldots.,n$. In addition, it is assumed that there exists markets in all commodities and all agents are perfectly informed about what is going on in the economy. It is also assumed that the agents usually act like price takers in each of the markets.

[43] (Clapp & Helleiner, 2012, p.185)
[44] (Cowell, 2005, p.145)

The reason for the approach of trying to find an equilibrium derives from questions such as: where do the prices observed in the market come from? Why do people act as price takers? What mechanism drives the economy towards an equilibrium? To be able to give a reasonable (and general) answer to these questions some further assumptions of the state of the economy is assumed[45]:

- Information about what is going on in every household and in every firm at a particular moment in time are public and available to all agents in the market. Hence the competitive allocation in an economy can be described as

  $$\mathbf{a} = ([\mathbf{x}], [\mathbf{q}], \mathbf{p})$$

  where $\mathbf{x}^h$ is the utility maximizing consumption bundles for household h = 1,2,….n_h, and $\mathbf{q}^f$ is the profit maximizing net output for firm f = 1,2,…,n_f at prices **p**.
- All goods are purely private goods and joint consumption is not permitted.
- There are no externalities in the production, thus if $\mathbf{q}^1$ is technologically feasible for firm 1 and $\mathbf{q}^2$ is technologically feasible for firm 2 and the combined net output vector $\mathbf{q}^1 + \mathbf{q}^2$ is also feasible.

These assumptions are very simplified, and it is referred to as the simple aggregation property[46]. If this property holds, the generalized materials balance condition for any commodity *i* is[47]:

$$\sum_{h=1}^{nh} \mathrm{x}i\hat{}h \leq \sum_{f=1}^{nf} \mathrm{q}i\hat{}f + \sum_{h=1}^{nh} \mathrm{R}i\hat{}h, \qquad (4.2.1)$$

or represented in vector form: $\mathbf{x} \leq \mathbf{q} + \mathbf{R}$. On the basis of this Cowell (2005) states that " if an allocation is to be feasible, demand cannot exceed supply, where "supply" of any commodity covers the aggregate of all net outputs of the firm plus the aggregate of all pre-existing stocks" (Cowell, 2005, p.147). From this we get the definition of the competitive equilibrium; it is a competitive allocation $\mathbf{a}^* := ([\mathbf{x}^*], [\mathbf{q}^*], \mathbf{p})$ were the materials balance condition holds. This competitive equilibrium is divided into two components, the price-taking maximizing behavior of the agents and a feasibility condition incorporated in the generalized material balance condition. Together with the assumption that price taking is the representing behavior of all rational economic agents in a "core" equilibrium, this could be used to define another

[45] (Cowell, 2005, p.146)
[46] (Cowell, 2005, p.147)
[47] (Cowell, 2005, p.147)

useful economic device; the excess demand function for each commodity i. This tool can give an indication of where the prices come from.

4.2.1 The excess-demand approach

The excess-demand function is said to contain information about the aggregate demand and the aggregate supply for a particular good at some given set of market prices. It is defined as a function of $E_i(\mathbf{.})$ such that[48]:

$$E_i(\mathbf{p}) := x_i(\mathbf{p}) - q_i(\mathbf{p}) - R_i \quad (4.2.2)$$

We subtract the net output $q_i(\mathbf{p})$ and resource stock R_i of each commodity from the aggregate demand function $x_i(\mathbf{p})$ for each commodity (given as a function of prices **p**). According to Walras`s law, for any price vector p, the set of n excess demand functions must satisfy[49]:

$$\sum_{i=1}^{n} piEi(\mathbf{p}) = 0 \quad (4.2.3)$$

given that each excess-demand function are homogenous of degree zero and that all agents in a private ownership economy are fully informed and rational. In other words, the price of any good i is the equilibrium price if the value of the excess demand function is equal to zero. This relationship between the market demand from consumers, resource stocks, net output from the firms and excess demand for any commodity i, give rise to the conditions for the equilibrium price in terms of the excess demand function:

$$E_i(p^*) \leq 0, \quad (4.2.4)$$

$$p^*_i \geq 0, \quad (4.2.5)$$

$$p^*_i \ E_i(p^*) = 0 \quad (4.2.6)$$

From this, it is claimed that in equilibrium there cannot be excess demand, and for any good that there exist excess supply, this must be a free good[50]. Because of these properties of the excess demand functions, it is possible to find E_n if you know $E_1,\ldots,E_{n-1}$ from the following formula[51]:

$$E_n(\mathbf{p}) = -\frac{1}{pn} \sum_{i=1}^{n-1} piEi(\mathbf{p}) \quad (4.2.7)$$

48 (Cowell, 2005, p.157)
49 (Cowell, 2005, p.159)
50 (Cowell, 2005, p.158)
51 (Cowell, 2005, p.160)

Because of the restrictions in (4.2.4-6), it is possible to find the equilibrium price vector in any economy were there are *n* commodities, *n* prices and *n* excess demands. Although this sounds trivial, it contains some issues regarding the existence-, the uniqueness and the stability of the possible equilibrium. There exists conditions that eliminates these issues, but I will present these in detail in this thesis. It is not always the case that there exist an equilibrium price vector **p***, given a set of some specific excess demand functions E such that the conditions of the equilibrium prices holds. If an excess demand function contains "holes" it may jump from positive to negative without ever being zero, and the price will never reach equilibrium[52]. Another issue regarding the excess demand functions is that they could consist of functions that provides several equilibriums because of several turning points around zero. There exists conditions that eliminates these issues, but I will present these in detail in this thesis. However, some of the weaknesses of the approach is mentioned below.

The excess-demand approach described above provides a general overview of which factors and behaviors that could provide a general competitive equilibrium in the economy. It provides a tool for all agents in the market for analyzing the properties of the equilibrium price vectors. The approach holds all the information about the price taking responses by aggregating the relationship between the demand and supply functions over all agents. The system will yield a unique equilibrium price vector **p*** under given reasonable conditions discussed in this section. Although excess demand functions are helpful tools for getting results, some weaknesses should be mentioned. The assumption of continuity may be demanding. In reality, it is not always the case that we have continuity in the excess demand functions, and if we assume that these functions are continuous, the approach could provide an inaccurate picture of how the factors in the economy actually work. Another problem with the theory is the normalization of the prices. Even though normalized prices do provide nice properties such as convex and compact prices, non-convex properties may exist in the real world. This could also provide an absence of equilibrium in the excess demand functions because of discontinuity in the function. Even though there exists some deficiencies in this theoretical approach, the theory is widely used and in fact, most macroeconomic models are general-equilibrium models as well[53].

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[52] (Cowell, 2005, p.162)
[53] (Cowell, 2005, p.167)

4.3 Macroeconomic factors

As mentioned in section 4.1, there are several factors that could affect the agricultural commodities price dynamics, and in section 4.2 the fundamental factors of general equilibrium prices were discussed. There are many assumptions and properties involved in such a theoretical approach, and often these do not reflect a realistic view of the reality. In fact, all citizens in the world would live in perfect harmony, and the prices would always reflect the "correct" price given by the demand and supply in the market. Even though the prices would differentiate from the equilibrium level in some periods, it will always move towards the equilibrium price again because of the stability condition given in the theory. According to the recent observations, this does not always seem to be the case, and this gives rise to the current discussion of other possible factors that could be affecting the price processes. In this section, there will be presented some concrete macroeconomic factors that possibly could affect the commodity price processes supported by the existing literature of the phenomenon.

It is definitely not an easy task to identify all the potential causes of the price movements observed in recent years. One of the reasons for this could be that it is not always easy to differentiate the factors affecting the prices as endogenous or exogenous causes. If endogenous factor are creating price spikes, this cannot be considered as a primary driver[54]. The reason for this is that endogenous variables are claimed to be affected by individual's internal responses to an external state of affairs[55]. The exogenous variables are said to have some sort of value given by nature, hence it cannot be affected by any theorist's variable of interest. Because of this conflict of determining which factors that could be considered as possible valid drivers of agricultural food prices, Braun and Tadesse (2012) differentiates possible food price drivers as root, intermediate and immediate causes. The result is provided in table 4.1.

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[54] (Braun & Tadesse, 2012, p.16)
[55] (Economics Stack Exchange, 2015)

Root causes	Intermediate causes	Immediate causes	Effects
Extreme weather events	Concentrations of world food production in some areas. Few exporters. Lack of information on world food.	Export restrictions Aggressive food imports.	Increase in prices
Increasing biofuel demand	Economic growth in emerging markets	Decline in world food reserves	Volatility
Increasing volume of futures trading in commodity markets			Spikes

Table 4.1 Possible Food Price Drivers

The basis for Braun and Tadesse (2012) division of possible food drivers is the empirical and theoretical research done on the phenomenon that suggests that climate change from the supply side, biofuel production from the demand side and speculation in commodity futures from the market side are the three most important root causes of the observed price spikes and volatility. Even though the total grain production has not shown any significant change over the past 10 years, it continues to be volatile and less predictable as a result of extreme weather conditions in some part of the world. One example of this is the drastic drought in Ukraine and Russia that occurred in 2010[56]. This event reduced the wheat supplies in that period. Another example is the drought in southern China that resulted into small food storages and this forced the country to turn to large scale imports. Flooding events is another factor that has devastated millions of wheat and rice fields, thereby contributed to pushing up the global food price.

Another factor that is considered to affect the prices of certain commodities is the demand for biofuel feedstock. The cause for this increased demand has its roots in the increased oil price and biofuel mandates in European Union, the United States, and other developing countries[57]. Agricultural resources such as land and labor are being used to produce this biofuel feedstock.

[56] (Braun & Tadesse, 2012, p.17)
[57] (Braun & Tadesse, 2012, p.19)

In fact, as much as a third of the U.S. corn yields have been allocated to the production of ethanol, and it continues to grow[58]. Actually, corn used for ethanol rose from around 1 million bushels in 2002/2003 to around 3.1 billion bushels in the crop year of 2007/2008[59]. If this growth exaggerates, this could increase the price of biofuel feedstock such as maize, corn and oilseeds. Non-biofuel feedstock crops such as wheat could also be affected because of the resource allocation and substitution observed in the field. The increase in the crop prices derived from biofuel feedstock could potentially contribute to world starvation (especially in developing countries), and at the same time it could accelerate the climate change present in the world. Other demand-factors that could affect the commodity prices are high energy costs, decelerated productivity growth in agriculture, trade policies, and population growth[60].

The factors that could affect the commodity prices discussed so far derives from fundamental supply/ demand factors. As mentioned before, many researchers claim that the price movements of the commodity prices are due to these fundamental factors, and there exists a lot of academic research supporting this linkage. However, the resent price spikes have opened a debate of whether other factors, such as speculation in the derivative market, could affect the commodity prices as well. The reason for this is the observed increase in the volume of futures traded (alongside with the other features of the market mentioned above) in the commodity market. Speculation in the commodity markets is considered to be conceptually and empirically ambiguous, and there exist little evidence that speculation drives commodity prices beyond fundamental levels[61]. However, there are some researchers that claims to have provided evidence of this linkage, hence it should not immediately be rejected as a possible influencing factor.

4.4 The effect of speculation

As mentioned in section 4.1 and 4.3, speculation has received many researchers attention when trying to explain the observed price movements of several commodities in the commodity market in recent years. However, agricultural commodities have always in a way been volatile because of the risk of possible events such as natural disasters (shocks) are always present. This makes the prices very vulnerable and difficult to predict, but in the recent

[58] (Prewitt, 2008, p.90)
[59] (Trostle, 2008, p.16)
[60] (Czech, 2013, p.12)
[61] (Czech, 2013, p.12)

years, the slopes in the price changes are so steep and the peaks so high that there seems to be an extraordinary phenomenon in the commodity markets. This has motivated researchers to take a closer look on the linkage between speculation and price changes. To further investigate the price changes, Braun and Tadesse (2012) distinguishes the different terms used when referring to price changes: price movements can be descried as spikes, trends or volatility. They state that "a price trend is the smooth, long-term average movement of prices over time; it shows the general tendency of prices for a certain period of time" (Braun & Tadesse, 2012, p.3). A price spike "refers to a change in price levels over a shorter period of time, usually between two consecutive observations" (Braun & Tadesse, 2012, p.3), and volatility is defined as "the dispersion of a price series from a mean" (Braun & Tadesse, 2012, p.3). The volatility is said to measure the risk of the prices, it does not measure any direction (trend) of the price changes. Volatility can further be divided into high-frequency and low-frequency volatility, high-frequency volatility refers to natural shocks that last for a season or less, and low-frequency volatility refers to variability that persist for more than one season[62]. High short-term spikes in the commodity prices are often related to high-frequency volatility, and this type of risk is possible to manage by providing insurance to protect against potential losses deriving from such a shock. Low-frequency volatility is more difficult to manage, and it is important to figure out which effects this volatility has on both consumers and producers. Price volatility affect both consumers and producers, and risk-averse agent`s will be affected because of the risk introduced by the volatility. The question is what causes high volatility? Volatility can derive from fundamental factors such as supply and demand factors, but market manipulation and even high prices itself can create periods with high volatility. The relationship between an increase in prices and an increase in the volatility is not well defined in the literature, but the high price levels observed in 2008 and 2011 have been linked to high price volatility. One of the reasons for this is that it seems to be a tendency of volatility clustering in the prices, figure 4.4 shows the price changes in the prices of wheat, maize and soybeans in U.S the last 15 years.

[62] (Braun & Tadesse, 2012, p.3)

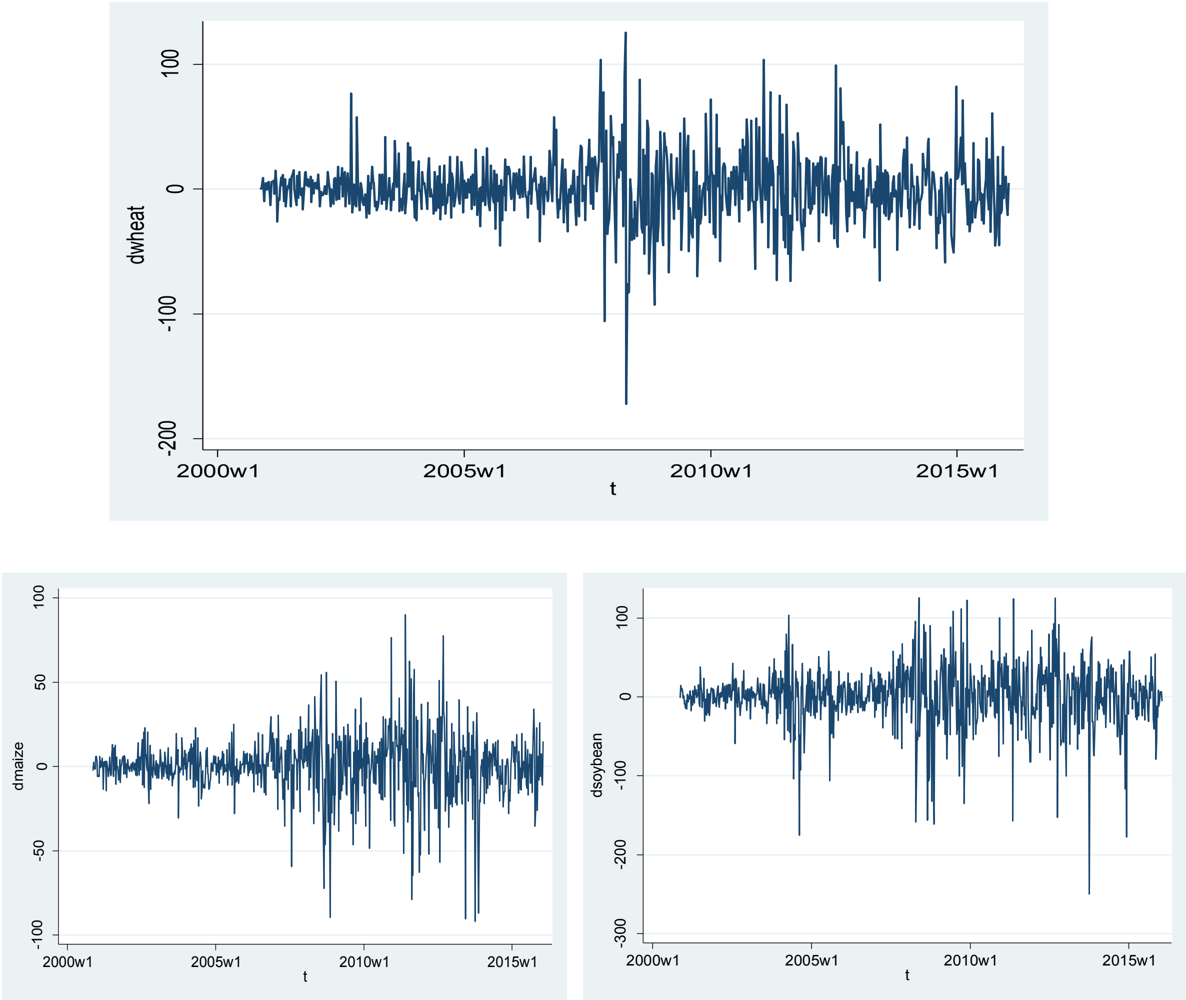
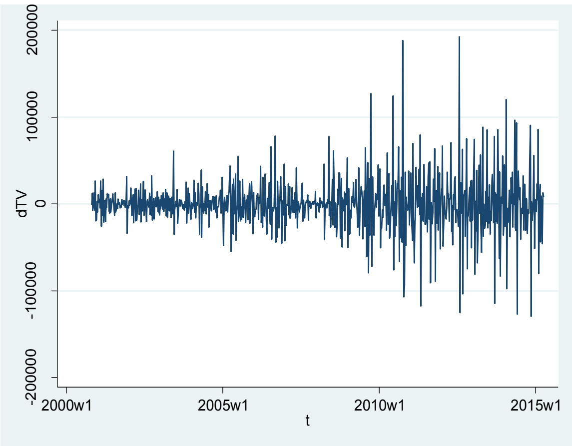
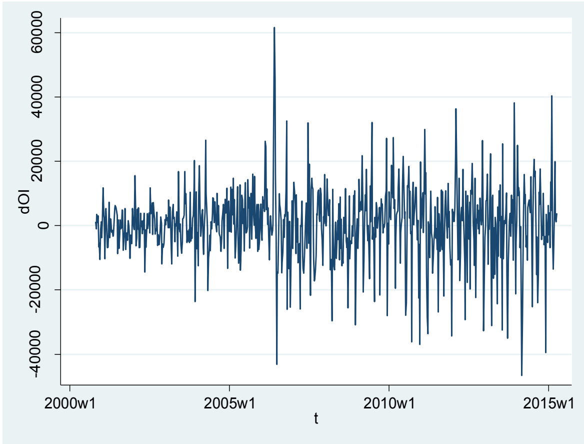


Figure 4.4 Weekly spot price changes in the price of wheat, maize and soybean in the U.S (retrieved from the U.S Department of Agriculture). Source: Thomson Reuters Datastream.

In these figures, it is clear that there are some periods were there are many large positive and large negative changes. This can indicate that the current level for volatility depends on the volatility level derived from the immediately preceding period. In other words it looks like the volatility of the price process occurs in bursts. In the wheat price case this is specially observed in the period from 2006-2009, but there seems to be some tendency also after 2010. In the period before 2006, this market seemed to be relatively tranquil. Similar patterns are observed in the prices of maize and soybeans; maize has huge weekly fluctuations, especially in the period of 2007-2013. The price of soybeans seems to have some tendency of volatility clustering some time before 2006 as well, but the size of the changes increases a lot in the later years, especially from 2008-2013. In the same period of these observations there have been some significant changes in the agriculture commodity market as well. Figure 4.5 shows the changes in the settlement prices, volume traded and open interest of wheat futures on the CBOT exchange.





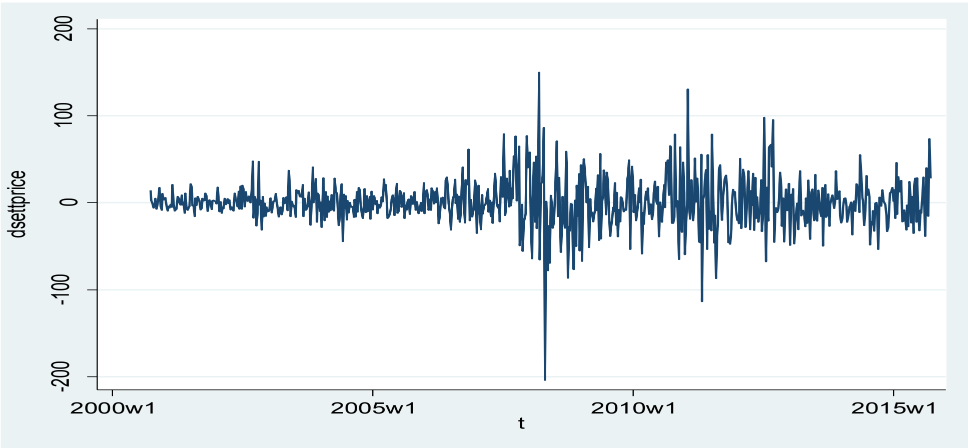


Figure 4.5 Weekly changes in wheat futures trading volume, open interest and settlement price (retrieved from CBOT and the U.S Commodity Futures Trading Commission (CFTC)). Source: Thomson Reuters Datastream.

The open interest, trading volume- and settlement price processes of the wheat futures seems to contain some tendency of volatility clustering, especially from around 2008 to current time. The amount of futures contracts traded has increased a lot in this period as well. Could there be a linkage between these aspects of the markets? This is the fundamental motivation for the empirical work, and the linkage is tested in section 8.

5 Deregulation of the commodity market in U.S

Trading of agricultural derivatives are definitely not a new phenomenon, but there exists some major differences in the futures market today compared to earlier years. Historically, starting with the Grain Futures Act of 1922, the U.S agriculture futures market was highly regulated[63].

[63] (Clapp & Helleiner, 2012, p.186)

There were established position limits on traders (speculators) that were not hedgers to prevent market manipulation and exaggeration that could create chaotic situations for farmers, food producers and consumers. The purpose of these regulations was never to prevent speculation, because the price discovery function of speculation has long been recognized. The objective of the Act in 1936 speaks of "eliminating "excessive speculation" that causes sudden or unreasonable fluctuations or unwarranted changes in commodity prices" (Clapp & Helleiner, 2010, p.186). This shows that the discussion of the possibility that exaggerate speculation in commodity markets could affect the spot prices have long been recognized, and therefore there has been regulations in the market to avoid this. So what have been the incentives of the de-regulative activities observed in the commodity market the last decades? Who are the winners and who are the losers of these deregulatory events?

5.1 Development of the U.S Commodity markets

In 1972, financial futures were introduced and the Chicago Mercantile Exchange launched several currency futures contracts to enable trade between the United States Dollar foreign currencies including British Pound, Deutsche Mark and Swiss Franc[64]. Other exchange traded financial futures started to rise and because of this innovation, the Commodity Futures Trading Commission (CFTC) was born in 1974[65]. The American congress at that time gave the CFTC the authority to approve positions limits and to define the specifications of all futures contracts listed on United States exchanges to make sure that any form of market manipulation were avoided[66]. (This fits well with the objectives of the Act from 1936). However, in the beginning of the 1980s, the first important deregulatory initiative related to the activities in the derivative market emerged: over-the-counter (OTC) swaps[67]. These swaps were offered to clients that were seeking exposure to commodity price movements, or clients that wanted to balance their investment portfolios. However, this was not all that the OTC swaps offered. The swaps also offered clients the opportunity to invest with the main purpose to speculate in the commodity price movements, and from the early 1990s, banks also started to sell swaps based on indices of commodity prices (including agricultural commodities)[68]. The reason that these contracts indicated a shift in the commodity markets was that the OTC

[64] (Berg, 2011, p.264)
[65] (Berg, 2011, p.264)
[66] (Berg, 2011, p.265)
[67] (Clapp & Helleiner, 2010, p.187)
[68] (Clapp & Helleiner, 2010, p.187)

contracts were (and is currently) not traded on formal exchanges, thus they are not subject to any regulations. Already in the middle of the 1990s, the OTC swap market was in full swing, topping 10 trillion in notional amounts of outstanding contracts[69]. Even though there were periodic initiatives to extend the CFTC`s regulatory reach to the OTC derivatives market in both the 1980s and the 1990s, this was wildly resisted by the financial industry and the free-market oriented policymakers[70]. Under pressure from these groups together with the pressure from other powerful organizations like the International Swaps and Derivatives Association (ISDA)[71], the U.S congress passed the Commodity Futures Modernization Act in 2000 which according to Clapp and Helleiner (2010) "explicitly *prevented* the CFTC from regulating OTC derivatives" (Clapp & Helleiner, 2010, p.187). This Act removed essential safeguards that had protected the agricultural derivatives from misuse in many decades. According to a report provided by Oxfam International in 2011, Wallace Darneille, the chief executive of the Plains Cotton Cooperative Association quoted in the New York times that "the market is broken … It no longer serves its purpose" (Herman, Kelly, & Nash, 2011, p.4).

In the beginning of this section there were questioned why these deregulatory events observed in the last decades has emerged. From an investors point of view, the deregulation were highly preferable because investment in financial instruments tied to commodity prices appeared to give more lucrative and stable returns compared to stocks. In fact, investments linked to commodity prices could also provide protection against inflation, and when the subprime mortgage crisis broke out in 2007, investment in commodities raised further since the commodity markets seemed to offer some protection against financial instability[72]. At the same time that all these different events occurred, the spot prices of the underlying commodities increased rapidly as shown in section 4.1. As mentioned several times before, it is hard to provide empirical evidence of a linkage between these observations, but there seems to be some sort of "unwillingness" to actually trying to figure this out, especially seen from the financial institutions point of view. But who can blame them for this? Berg (2011) claims that "the commodity index retail fund might be viewed as one of the most ingenious innovations ever sold" (Berg, 2011, p.267). The reason for this is that these financial products oblige the customer to pay a 100 per cent deposit to purchase a basket of commodity futures. Because of this, the customer cover 100 per cent of the potential losses derived from events

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[69] (Berg, 2011, p.266)
[70] (Clapp & Helleiner, 2010, p.187)
[71] (Herman, Kelly & Nash, 2011, p.4)
[72] (Clapp & Helleiner, 2010, p.188)

such as declining commodity prices, and if the commodity price increases, the customer must share the profits with the sales firm. This actually makes the sales firms in a way immune to possible counterparties or default risk. This implies that the true winners of the deregulations observed in the commodity markets are banks and funds that cashes in huge profits from this new asset class.

It is reasonable to imagine that in a situation where there exists winners, there also exists losers. Who are the potential losers of this "game"? In section 4.1 there was provided some explanations of how the high food prices observed in the recent years affect the world's poorest population, but the "rule of the game" may also affect other participants in the market. Food producers (especially in developing countries) may also be influenced of this increased speculative trading in the commodity markets[73]. If a food producer wants to protect herself from a particular risky event, she might want to hedge against the risk that she is disposed too. This could be done by buying a suitable derivative product from a financial broker in return of a fixed premium. However, if the prices are too unstable and the premium to high, she may not be able to provide enough cash up front because it is simply too expensive for her. This should give the supervisory institutions motivation and incentives to further investigate this phenomenon in order to consider new regulations to provide such situations to occur.

5.2 Financialization of the commodity market

The steep rise of institutional inflows from financial parties into the commodity market explained in section 5.1 gives rise to the term "financialization of commodity markets"[74]. The increased speculative activity in the commodity market have made these markets more like financial markets in terms of motivations and participants, and this has led to a definition of this phenomenon. Financialization can be defined as the "increasing role of financial motives, financial markets, financial actors and financial institutions in the operation of the domestic and international economics"[75] (Fuchs, Hamenstadt, & Meyer-Eppler, 2013, p.221). The problem with financialization of agricultural derivatives is that they are no longer working as initially intended[76]. Some would say that the intention of agricultural derivatives is to help food producers, processors and other end users to deal with plausible risk factors of the

[73] (Herman, Kelly & Nash, 2011, p.8)
[74] (Berg, 2011, p. 269)
[75] (Fuchs, Hamenstadt & Meyer-Eppler, 2013, p.221)
[76] (Herman, Kelly & Nash, 2011, p.2)

physical markets, but as described in section 5.1, this do not seem to reflect what is really going on in the markets. From the definitions provided above, financialization could also be referred to the increasing speculative activity provided by agents who do not have any interest in the physical commodity traded. The main purpose of trading seems to be to place bets on their future prices in order to profit from their price movements. According to the risk transfer hypothesis described in section 3.4, the efficient price that speculation helps to find should accurately reflect the market situation. However, this does not seem to be the case when looking at the commodity spot prices in the last decades. In fact, the UNCTAD study finds that in the recent years, the commodity spot prices has not reflected the real world situation[77]. This type of observations has given rise to several economic studies related to the phenomenon. Many of these studies focus on the restricted form of financilization, which produces changes in correlations and rises in open interest and trading volume, but whether these increases is due to speculative behavior is still unclear[78]. However, the fact that the financialization of the commodity markets observed in the recent years is due to the deregulatory and market pressures seems to have some consensus among the researchers in this field. The consequences of the financialization in the commodity markets is another story, here there exists many different suggestions, and this has been a part of the main motivations for the empirical work of this thesis.

6 Testing procedure

To test whether speculation in the commodity markets affect the underlying commodity spot price, I used the statistical software STATA. The model used to study the phenomenon is a general autoregressive conditional heteroscedasticity (GARCH) model. The parameters of the model are estimated using a maximum likelihood function. Given the estimates from the model, there will be performed parametric tests to check their significance. The result of the model is only valid if the underlying assumption of the model holds. The residual of the model has to be normally distributed and it should not be serial-correlated. The Akaike`s information criteria (AIC) was used to identify the proper process of the mean equation of the model. In order to use a GARCH model there should be ARCH-effects in the residuals

[77] (Gross, 2011, p.1)
[78] (Aid, Ludkovski, & Sircar, 2015, p.4)

derived from the mean equation of the model, meaning that the variance of the current error term is related to the size of the previous period error term.

6.1 The auto-correlation function (ACF)

One of the assumptions of the model is that there should not exist any serial-correlation in the residuals derived from the model. If the volatility clustering observed in the wheat price series is properly explained by the model, then there should not be autocorrelation in the residuals. An auto-correlation function (acf) could be derived from a given stochastic process and this could provide important properties of the process. This can also be helpful when trying to identify the data generating process. The correlation between two elements of a stochastic process separated by lag *k* is defined as[79]:

$$\tau_k = \frac{\sum[(X_t - \mu_t)(X_{t+k} - \mu_t)]}{\sqrt{E[(X_t - \mu_t)^2]E[(X_{t+k} - \mu_t)^2]}} \quad (6.1.1)$$

For a stationary process (E[X_t] = 0 and V[X_t] = σ^2) the expression (6.1.1) reduces to:

$$\tau_k = \frac{C(X_t, X_{t+k})}{\sigma^2} \quad (6.1.2)$$

If τ_k is plotted against k = 0,1,…, T-1, the auto-correlation function is obtained. The values of τ_k lie in the interval (-1,1), and the estimate plot of the acf could be a helpful tool when trying to identify a stochastic process which could serve as a model for the underlying process. If for a given *k* the estimate $\hat{\tau}_k$ lie outside the Bartlett band:

$$\left(-\left|z_1 - \frac{\alpha}{2}\right|\frac{1}{\sqrt{T}}; +\left|z_1 - \frac{\alpha}{2}\right|\frac{1}{\sqrt{T}}\right)$$

Then we can reject the null hypothesis. The null- and alternative hypothesis of the test are:

H0: $\tau_k = 0$ H1: $\tau_k \neq 0$

If we are able to reject the null hypothesis, there should exist a proper stochastic process that could serve as a model for the underlying process.

[79] (Jungeilges, 2015)

6.2 Test for Serial-Correlation

Another way of testing for autocorrelation in the residuals is by using a Ljung-Box test. The test is designed to test the joint hypothesis that all m of the τ_k correlation coefficients are simultaneously equal to zero using the modified Q-statistics known as the Ljung-Box statistic (1978)[80]:

$$Q = T(T+2)\sum_{k=1}^{m}\frac{\hat{\tau}_k^2}{T-k} \sim \chi_m^2 \qquad (6.2.1)$$

The null- and alternative hypothesis of the test are:

$$H0: \tau_k = 0 \qquad\qquad H1: \tau_k \neq 0$$

Under the null hypothesis, we want to test if all *m* autocorrelation coefficients are zero. If the p-value < 0.05 (5% significance level) and $Q \geq \omega_{1-\alpha}$ we can reject H0 (with $\omega_{1-\alpha}$ denoting the relevant percentage level). If we fail to reject HO, then there exists no autocorrelation in the residuals of the model. In order to use this hypothesis test, the residuals derived from the model has to be normally distributed. This assumption makes it possible to assume that the sample autocorrelation coefficients are close to normally distributed:

$$\hat{\tau}_s \sim \text{approx.. } N(0, \tfrac{1}{T})$$

Where T represents the sample size and $\hat{\tau}_s$ represents the autocorrelation coefficient at lag *s* estimated from the sample. This is required in order to conduct significance tests.

6.3 Test for Normality

There exists many ways of determining if we have normality in the residuals or in the sample data itself. One possibility is to check the skewness and kurtosis of the data. These factors represent the third and fourth moment of the specific distribution we are dealing with[81]. Brooks (2008) state that "skewness measures the extent to which a distribution is not symmetric about its mean value and kurtosis measures how fat the tails of the distributions are" (Brooks, 2008, p.161). A normal distribution is not skewed and it contains a kurtosis coefficient of 3.

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[80] (Brooks, 2008, p.210)
[81] (Brooks, 2008, p.161)

There are other more formal tests to test for normality such as the Shapiro-Wilk test. Shapiro and Wilk (1965) proposed a test that tests whether a random sample comes from a normal distribution. The test statistics is[82]:

$$W = \frac{\left(\sum_{i=1}^{n} a_i x_{(i)}\right)^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \qquad (6.3.1)$$

where $x_{(i)}$ are the ordered sample values and a_i are constants generated from the mean, variance and covariance of the order statistics, and n is the sample size. The test statistics can be presented as:

$$H0: x \sim N(0,\sigma^2) \qquad H1: x \nsim N(0, \sigma^2)$$

were the null hypothesis states that the sample data is normally distributed. The null hypothesis can be rejected if the p-value is less than the chosen alpha level (p-value < $\alpha_{(0.01,0.05,0.1)}$.)

[82] (Shapiro & Wilk, 1965, p.592)

6.4 Test for Stationarity

It is not always easy to conclude that a particular process is stationary just by looking at the autocorrelation plot, especially if we are dealing with a random walk process. The acf of such a process will often not show a very persistent decay toward zero, this can result in false conclusions of the underlying process if we don't use other stationary tests as well. If a non-stationary series must be differenced d times to become stationary, then it is said that it is integrated of order d[83]. When a series is differenced once this may have removed one of the unit roots, but there may still exist a unit root in the new differenced variable. So to be sure

that a process is stationary there could be performed an augmented Dickey-Fuller (ADF) test, which is a testing procedure that test whether a series is characterized by a unit root or not.

Dickey and Fuller (1976 & 1979) develop the test, and the objective of the test is to examine the null hypothesis that φ=1 in:

$$y_t = \varphi y_{t-1} + u_t \qquad (6.4.1)$$

against $\varphi < 1$[84], where u_t is a white noise disturbance term with $E(u_t) = 0$ and $V(u_t) = \sigma^2$.

The test-hypothesis is:

HO: series contains a unit root H1: series are stationary

The test can also be written as:

$$\Delta y_t = \Psi y_{t-1} + \sum_{i=1}^{p} \alpha i \, \Delta \, y_{t-1} + u_t \,, \qquad (6.4.2)$$

and the test statistics is $\hat{\Psi}/SE(\hat{\Psi})$. Reject HO if $p < \alpha_{(0,01/0,05/0,10)}$ and $Z < (-3.43,-2.86,-2.57)$. If we fail to reject the null hypothesis, the underlying process contains a unit root, and the process is not stationary.

6.5 Model selection

Another issue with the auto-correlation function is that even though the process is stationary, the order of the underlying process needs to be selected. Deciding on the appropriate order

[83] (Brooks, 2008, p.326)
[84] (Brooks, 2008, p.327)

from the ACF could be very difficult. Therefore, to be able to identify the proper order of the process we can use an information criterion to decide the model order. The objective of this approach is to select the number of parameters which minimizes the value of the information criteria. The information criteria used in this thesis is Akaike`s (1974) information criterion (AIC). Algebraically, the expression looks like this[85]:

$$\text{AIC} = \ln(\hat{\sigma}^2) + \frac{2k}{T} \quad (6.5.1)$$

where $\hat{\sigma}$^2 is the residual variance, k= p+q+1 is the total numbers of parameters and T is the size of the sample[86]. The information criteria is minimized subject to $p \leq \bar{p}$, $q \leq \bar{q}$ and an upper limit is specified on the number of moving average and autoregressive terms that will be considered.

6.6 Test for Heteroscedasticity

To test for heteroscedasticity in the residuals of the mean equation of the model, a test for the presence of ARCH-effect is used. The estimated residuals $\hat{\varepsilon}_t$ form the mean equation is obtained as well as their squares $\hat{\varepsilon}_t^2$. To test for first order ARCH, a regression of $\hat{\varepsilon}_t^2$ on the squared residuals lagged $\hat{\varepsilon}_{t-1}^2$ is performed[87]:

$$\hat{\varepsilon}_t^2 = \beta_0 + \beta_1 \hat{\varepsilon}_{t-1}^2 + v_t \quad (6.6.1)$$

where $v_t \sim N(0,1)$. The null and alternative hypotheses are:

HO: $\beta_0 = 0$ H1: $\beta_0 \neq 0$

If $\beta_0 = 0$ then there are no ARCH effects. The test statistics is $(T-q)R^2$ were T is the sample size, q is the number of $\hat{\varepsilon}_{t-j}^2$ on the right hand side of the regression equation, and R^2 is the coefficient of determination. If $(T-q)R^2 \geq \chi^2_{(1-\alpha,q)}$ then we can reject the null hypothesis and conclude that there are ARCH effects present in the residuals.

85 (Akaike, 1974, p.720)
86 (Brooks, 2008, p.233)
87 (Engle, 1982, p.1000)

7 Data

I used Wheat No.2, Soft Red Cts/Bu from U.S Department of Agriculture to measure the price movements. The commodity is quoted in US cents per bushel. To measure the effect of speculation I used wheat futures contracts from the Chicago Board of trade (CBOT) exchange. Data on open interest and trading volume were collected from the Thomson Reuters Datastream[88]. Information on closing open interest can also be found in the weekly Commitment of Traders (COT) report issued by the Commodity Futures Trading Commission (CFTC)[89]. In this report the outstanding futures contracts are split into commercial and non-commercial traders, as well as reportable and non-reportable traders. I have used this report to collect data on the non-commercial trading activity[90]. A trading activity is classified as commercial if the trader uses future contracts in that particular commodity for hedging purposes[91] . Non-commercial traders just hold positions in futures contracts, but they do not own the underlying asset. Another way of describing non-commercial traders is that they do not invest in futures contracts with the purpose of reducing risk; they only want to make a profit. The non-reportable positions are the number of traders left after subtracting total long and short “reportable positions” from the total open interest. According to CFTC`s explanatory notes (2015), the reportable traders are clearing members, futures commission merchants and foreign brokers[92]. Unfortunately, the commercial/non-commercial classification of traders involved in the non-reportable positions is unknown. This could make the measure of the noncommercial participant a bit inaccurate. In the empirical analysis, I used volume of contracts traded, the open interest and the non-commercial open interest positions as a proxy for speculative behavior. These factors can be defined as outside shocks of the model. Since the dataset from the COT report is weekly compounded, all the other datasets has been transformed into weekly returns. The COT report is widely used in academic research, but there exist some shortcomings. The data provided are weekly compounded which can result in a high degree of aggregation, and the trader classifications

[88] (Thomson Reuters Datastream, 2015)
[89] (Bohl & Stephan, 2013, p.600)
[90] (Quandl, 2015)
[91] (U.S. Commodity Futures Trading Commission, 2015)
[92] (U.S. Commodity Futures Trading Commission, 2015)

could not be as accurate as we want it to be. It is important to keep this in mind before drawing any conclusions.

7.1 Characteristics of the wheat market

Figure 7.1 displays the price movements of wheat in the last 15 years. Here we can see that the price has been quite stable from 2000-2006, but around 2006 it started to get abnormally high compared to levels observed in previous periods. This abnormal increase did not seem to stop and around 2007-2008 the price rose drastically, followed by a dramatically decrease at the end of 2008. The price increased heavily again from end2009-2011, and the price level has been relative high in the period after, but it has decreased a lot this year again. This observation could imply that the movement of the wheat price process seems to exhibit periods of long swings away from its mean value. This pattern represents the whole period, especially the period after 2006. This indicates that the price process of wheat could be a random walk process, thus the process seems to be non-stationary.

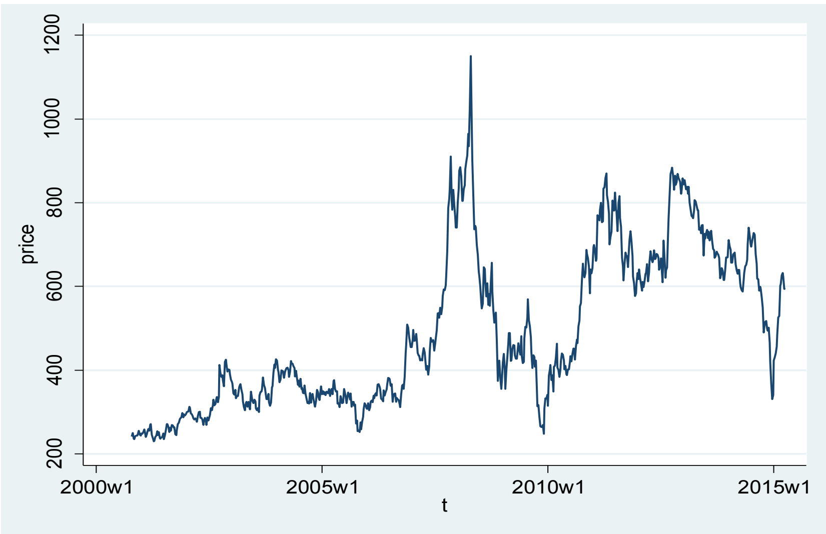

Figure 7.1 Weekly wheat prices from 2000-2015 (provided by the U.S Department of Agriculture). Source: Thomson Reuters Datastream.

Figure 7.2 shows the first difference plot of the wheat price, and this differenced process cross the mean value very rapidly, thus indicating that the wheat price process is a difference-stationary process, and the process seems to be at least mean stationary. This transformation property could indicate that the wheat price process could be described as a random walk process with drift. A more formal description of random walk processes is given in Appendix A3.

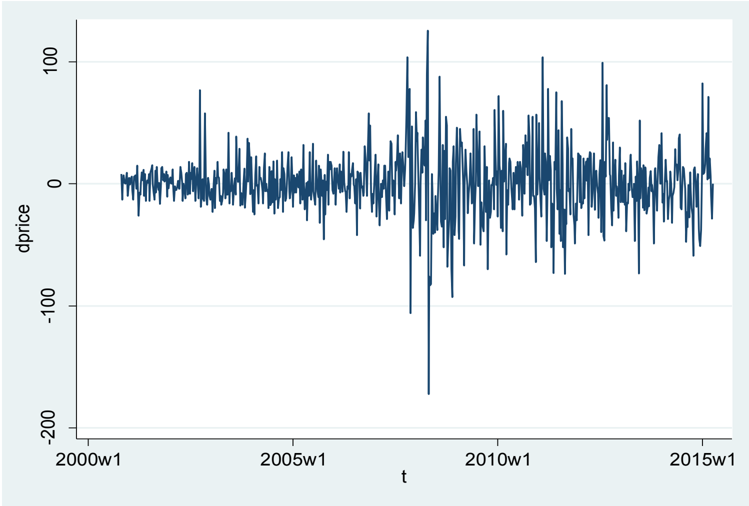

Figure 7.2 First difference plot of the weekly wheat prices.

However, as described in section 4.4, there seems to be some tendency of volatility clustering in the difference plot. This could indicate that the wheat price process is a non-linear process. Figure 7.3 shows the histogram of the wheat price process, and there seems to be leptokurtosis present in the price changes because of the high peakedness in the mean.

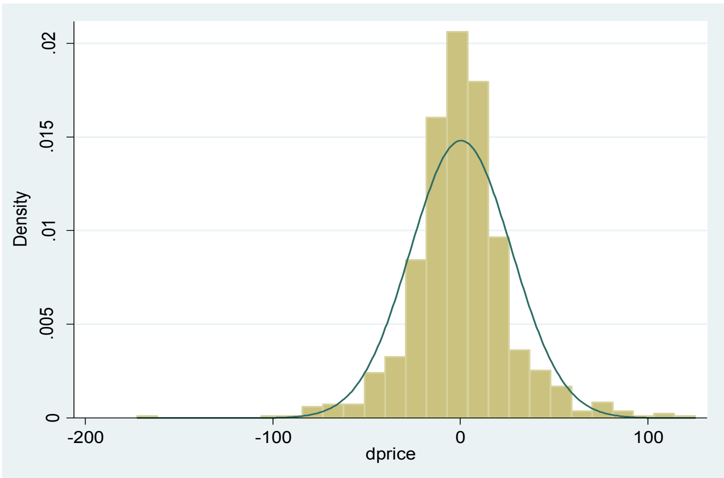

Figure 7.3 Histogram Wheat Price Changes.

Linear models are not able to explain these important features of the data so it is important to recognize whether this process is as a non-linear process or not, and because of the presence of volatility clustering and leptokurtosis we are in this case dealing with a non-linear process. To make sure that the price changes (measured as first differences) are in fact stationary an augmented Dickey-Fuller (ADF) test will be performed. The test is also applied on the trading volume, open interest and speculative open interest dataset to make sure that we do not use non-stationary variables in the main model. Table 7.1 shows the result of the ADF test. The test has been performed with different number of lags to be sure that we have an unbiased result.

	Wheat Price	**TV - wheat futures contracts CBOT**	**OI - wheat futures contracts CBOT**	**SpecOI - derived from CFTC COT report**
Raw data	-2.125 (0.2242)	-11.280 (0.000)	-1.281 (0.6377)	-1.797 (0.3822)
Differences	-25.018 (0.000)	-38.423 (0.000)	-21.572 (0.000)	-22.028 (0.000)

Table 7.1 Augmented Dickey-Fuller Test Results.

After the wheat price process was differenced once, the process becomes stationary. As mentioned above there are other features of the differenced process that are present and this implies that even though the price process is stationary it looks like the variance of the process is not constant and that we have a case of heteroscedasticity.

Other descriptive statistics is provided in table 7.2, and it contains information regarding all the variables that are used in the main model.

	Mean	Maximum	Minimum	Standard Deviation	Skewness	Kurtosis	Shapiro-Wilk
Wheat Price	489.1	1150	229.5	187.9	0.51	2.25	0.92076 (0.000)
Wheat Price first difference	0.4688	125.5	-172.5	26.962	-0.05	7.347	0.94557 (0.000)
ΔOI_t	373.52	61519	-46585	11324.05	-0.128	6.05	0.95441 (0.000)
ΔTV_t	59.22	192435	-129710	31439.76	0.441	9.067	0.90537 (0.000)
$\Delta SpecOI_t$	36.76	10287	-9646	2372.982	0.087	5	0.96920 (0.000)

Table 7.2 Descriptive Statistics.

The changes in the futures trading volume, open interest and speculative open interest are also measured as weekly differences. All the variables has a kurtosis significantly higher than the required level of normality. The result of the formal Shapiro-Wilk test for normality is also included in the table. All p-values are zero, thus the null hypothesis which states that the data is normally distributed is rejected and we have a case of non-normality in the series. This is very typical for financial datasets. The most important issue regarding the dataset is to determine if the processes are stationary, and as shown above, all the variables above are stationary after some transformations were implemented. Using non-stationary data can provide undesirable outcomes, and this is further describen in Appendix A2. Non-normality does not necessesarily make the parameter estimates less consistent if the mean and variance equations of the main model are correctly specified[93]. However, the usual standard error estimates will be inappropriate in the context of non-normality, and therfore a different variance-covariance matrix estimator that is robust to non-normality should be used in the analysis[94].

[93] (Brooks, 2008, p.399)
[94] (Brooks, 2008, p.399)

8 Testing speculative effects in the wheat spot price

In this section, the purpose is to assess whether these price movements observed in the commodity markets the two last decades may be related to speculative activity in the futures market. I studied the price of wheat during two last decades, with the sample period starting in 2000 up to 2015. The base of this empirical approach is inspired by the paper " Does Futures Speculation Destabilize Spot Prices? New Evidence for Commodity Markets" by Bohl and Stephan (2013), and the extension of the conditional volatility equation of the GARCH model used in this thesis derive from their research.

8.1 Methodology

To analyze the phenomenon I have applied a general autoregressive conditional heteroscedasticity GARCH (1, 1) model, and the process of the model is given by[95]:

$$\varepsilon_t \,|\psi_{t-1} \sim N(0, h_t) \qquad (8.1.1)$$

$$h_t = \alpha_0\ \alpha_1\ \varepsilon_{t-1}^2 + \beta_1 h_{t-1}\ , \qquad \alpha_0 > 0,\ \alpha_1 \geq 0,\ \beta_1 \geq 0 \qquad (8.1.2)$$

were ε_t is a real valued discrete time stochastic process and ψ_t is the information set of all information through time *t*. According to Bollerslev (1986) the GARCH (1, 1) process is "wide-sense stationary with $E(\varepsilon_t) = 0$, $var(\varepsilon_t) = \alpha_0(1 - A(1) - B(1))^{-1}$ and cov $(\varepsilon_t, \varepsilon_s) = 0$ for $t \neq s$ if and only if $A(1) + B(1) < 1$" (Bollerslev, 1986, p.310). This indicates that even though the conditional variance is changing, the unconditional variance of ε_t is constant and given by

$$var(\varepsilon_t) = \frac{\alpha 0}{1-(\alpha 1 + \beta)} \qquad (8.3.3)$$

as long as $\alpha_1 + \beta < 1$. If this is not the case, the unconditional variance of ε_t is not defined and there would exist non-stationarity in the variance. For a GARCH(1, 1) process there exists a necessary condition for the existence of the 2*m*th moment, and it derives from the fact that any GARCH(p, q) process can be interpreted as an autoregressive moving average process in ε_t^2 of orders *m* = max(Aïd, Ludkovski, & Sircar, 2015) and *p*[96], thus the process can be given by:

[95] (Bollerslev, 1986, p.311)
[96] (Bollerslev, 1986, p.310)

$$\varepsilon_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha i\ \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j\ \ \varepsilon_{t-j}^2 - \sum_{j=1}^{p} \beta_j\ v_{t-j} + v_t\ , \qquad (8.3.4)$$

and

$$v_t = \varepsilon_t^2 - h_t = (\ \eta_t^2 - 1\ )h_t\ , \qquad (8.3.5)$$

where

$$\eta_t \sim N(0,\ 1)$$

From the GARCH (1,1) process given by (8.3.1) and (8.3.4) the sufficient condition for the existence of the $2m$th moment is[97]:

$$\mu\ (\ \alpha_1,\ \beta_1,\ m\ ) = \sum_{j=0}^{m} \binom{m}{j} a_j \alpha_1^j \beta_1^{m-j} < 1\ , \qquad (8.3.6)$$

where

$$a_0 = 1, \qquad a_j = \prod_{i=1}^{j} (2j-1)\ , \qquad j = 1\ldots\ldots \qquad (8.3.7)$$

Given these conditions, the $2m$th moment can be expressed by the recursive formula[98]:

$$E(\varepsilon_t^{2m}) = a_m\ \left[\sum_{n=0}^{m-1} a_n^{-1}\ E(\varepsilon_t^{2n}) \alpha_0^{m-n} \binom{m}{m-n} \mu(\alpha_1, \beta_1, n)\right]\ \times [1 - \ \mu(\alpha_1, \beta_1, m]^{-1} \qquad (8.3.8)$$

According to Bollerslev (1986) the GARCH(1,1) process is leptokurtic, meaning that it is heavily tailed[99].

The parameters of the model are estimated through the maximum likelihood (ML) technique, and the log likelihood function for a sample of T observations is (apart from some constant)[100]:

$$L = \frac{1}{T} \sum_{t=1}^{T} (\ -\frac{1}{2} \log(ht) - \frac{1}{2} \frac{\varepsilon_t^2}{ht}\ ) \qquad (8.3.9)$$

The GARCH model allows the conditional variance to depend upon precious own lags, and this makes it possible to interpret the current variance h_t (8.1.2) as a function of long term average (dependent on α_0), information about the volatility during last period ($\alpha_1\ \varepsilon_{t-1}^2$), and the fitted variance from the model during the last period ($\beta_1 h_{t-1}$). If $\alpha_1 > 0$ and significant, then previous information about the phenomenon under investigation will affect the current

[97] (Bollerslev, 1986, p.311)
[98] (Bollerslev, 1986, p.311)
[99] (Bollerslev, 1986, p.313)
[100] (Bollerslev, 1986, p.315)

volatility of the phenomenon. If $\beta_1 > 0$ and significant, then previous volatility of the phenomenon affect the current volatility of the phenomenon.

8.2 Results

The purpose of this empirical approach is to assess whether the price movements observed in the recent years may be related to speculative activity in the futures market. The wheat price changes are modeled as a mixed autoregressive moving average ARMA (1, 1) with GARCH error term.

The conditional volatility equation consists of internal shocks (arch and garch effects) and external shocks. Like Bohl and Stephan (2013) the external shocks are aggregate trading volume, aggregate open interest and speculative open interest. The GARCH (1,1) model thus reads:

(1) $r_t = C1r_{t-1} + e_t + C2e_{t-1} \quad e_t = v_t\sqrt{ht}$, $\quad v_t \sim N(0, 1)$

(2) $h_t = C3 + C4e^2_{t-1} + C5h^2_{t-1} + C6\Delta TV_{t-1} + C7\Delta OI_{t-1} + C8\Delta SpecOI_{t-1}$

were r_t is the weekly price returns measured as the difference in week t from t-1, and e_t is the unexpected return (error term). The conditional variance equation h_t consists of one arch term and one garch term, as well as one period lagged change in trading volume (ΔTV_{t-1}), open interest (ΔOI_{t-1}) and the speculative open interest ($\Delta SpecOI_{t-1}$). If C6, C7 or C8 are statistically significant then there is evidence that changes in these variables may increase the conditional volatility of the wheat price, and this could affect the physical price of the commodity as well. The model parameters are estimated through the maximum likelihood (ML) technique, and the properties of the estimators are given in Appendix A4.

The price return process of wheat is stationary according to the ADF-test (result given in table 7.1 above). To test if the assumption of a white noise error term in the ARMA model holds, a Q-test were applied. The result of the Q-test is given in table 8.1.

Portmanteau test for white noise	
Portmanteau Q-statistic	45.352
Prob > chi2(40)	0.2587

Table 8.1 Q-test result of the ARMA(1,1) error-term.

We fail to reject HO thus the residual derived from the ARMA(1,1) in is in fact a white noise process as acquired. A test for ARCH-effects was also used to make sure that we have a case of autoregressive conditional heteroscedasticity. The result of the test is given in table 8.2.

Testing for ARCH effects	
β0	473.927 (0.000)
β1	0.331 (0.000)

Table 8.2 Result ARCH-effect test of the ARMA(1,1) error-term.

The null (H0) hypothesis that represent the case of no ARCH effects can be rejected, which implies that we have a case of volatility clustering. Another possible way to describe this is that "the volatility is auto-correlated".

The result of the GARCH(1,1) model is presented in table 8.3.

	WHEAT	**Standard error**	**p-value**
Constant (C3)	1.79	0.434	0.000
Residual^2 (C4)	0.101	0.018	0.000
Volatility (C5)	0.879	0.020	0.000
ΔTV (C6)	0.0000226	0.00000502	0.000
ΔOI (C7)	-0.0000704	0.0000135	0.000
ΔSpecOI (C8)	0.0003911	0.000104	0.000

Table 8.3 Result of the GARCH (1,1) model.

The results of the main model are derived from a Gaussian distribution and weekly data. The $Residual^2$ is the squared residual from the return equation. Volatility is the conditional volatility. ΔTV, ΔOI and ΔSpecOI represent the weekly returns given as the weekly changes in number of contract in units. All the variables are lagged by one period, and they are all statistically significant at the 1% level. The time span is from October 2000 to January 2015. The constant term represent the time-invariant level of conditional volatility[101]. The squared lagged residuals from the return equation and the lagged volatility represent a positive influence on the present conditional volatility, given everything else in the model. This means that the information about previous week returns do affect the volatility of this week`s return and it is statistically significant. The previous week volatility of the returns also affect the current volatility of the wheat return and this estimate is also statistically significant. The previous period change in aggregate trading volume has a small positive effect on the conditional volatility. This means that huge sudden changes in the trading volume may influence the current conditional price return volatility. Aggregate changes in the open interest have a small negative effect on the conditional volatility. This means that large changes in the open interest generally lead to a reduction in the conditional volatility. This is similar to the result of Bohl and Stephan (2013). Finally, speculative open interest has a statistically significant positive effect on the conditional volatility. This indicates that an increase in the speculative participants in the futures market do increase the conditional volatility of the wheat price return.

Figure 8.1 show the conditional variance of the model. From this plot it is clear that the degree of price fluctuations is not constant over time. There are periods of high and low volatility, emphasizing the fact that this is a price process consisting of conditional heteroskedasticity. The volatility was particularly high around 2008, in the same period the world faced a huge food crisis with all time high prices, described in section 4.1. In fact, in mid-2008 the prices of wheat, corn, rise and soybeans were more than two times the observed levels in 2006[102].

[101] (Bohl & Stephan, 2013, p.603)
[102] (Cooke & Robles, 2009, p.1)

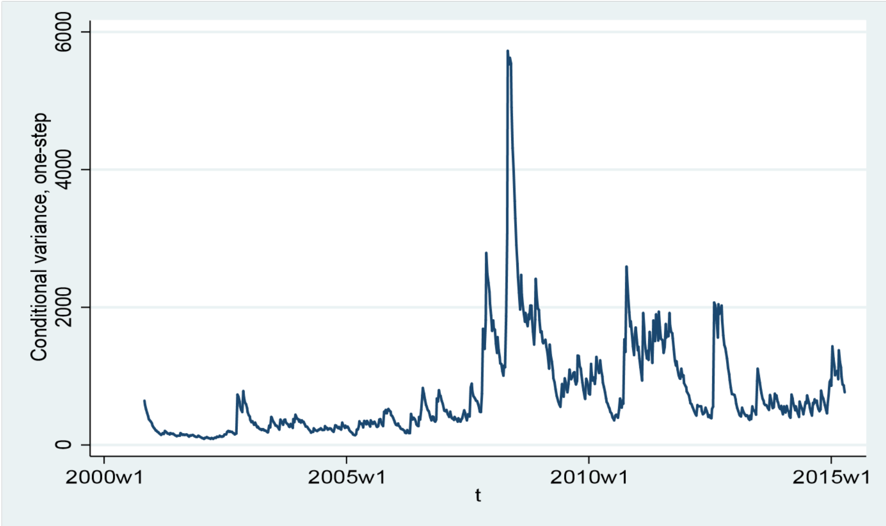

Figure 8.1 The conditional volatility plot of the wheat price changes.

At the same time, several aspects of the commodity market also experienced huge changes such as an increase in the number of futures traded, and in the volume of open interest contracts, as shown in section 4.4. This observation together with the empirical evidence from this thesis and other qualitative investigations in the field, could give an indication of the need to regulate this market. Destabilization of the commodity market affects many of the world citizens, both financially and physically, and it should receive more attention than it does today.

8.3 Discussion

The majority of the research on this phenomenon provides evidence against the linkage between commodity futures speculation and the commodity spot price. Bohl and Stephan (2013) got similar result for aggregate trading volume and open interest as the result from this analysis, but they found no statistical significant effect of the speculative open interest. Kim (2015) did not find any evidence that speculators destabilize the commodity spot market, in fact the presented findings show that speculators contributes to lower the price volatility[103]. Algieri (2012) had a slightly different measure on the speculative activity in the commodity markets. The quantitative analysis provided evidence that excessive speculation drives price volatility[104]. Excessive speculation occurs when the price of the derivatives do not reflect the physical market pricing. This is more similar to the findings from the quantitative analysis in

[103] (Kim, 2015)
[104] (Algieri, 2012)

this paper, were it seems to exist a small linkage. Even though its small, one should not totally reject that there could exist some kind of link here. The problem is that it is not as easy as we want it to be to gather the right information to a possible analysis. CFTC`s COT report is not very transparent and it is not perfectly accurate. The reason for this is that companies have to report their positions to the CFTC themselves, and we cannot be completely certain that this is the accurate information. It is definitely clear that there needs to be more research on the phenomenon to be able to provide more evidence that there could be or not be a linkage.

9 Conclusion

In this paper, the purpose was to assess whether speculative activity in the commodity futures market affect the commodity spot prices. In the first sections, different theories and dynamics of the financial and the agricultural commodity market were presented to, and political/institutional features of the market was also discussed to illustrate the huge changes that have been implemented since the millennium especially. The price of wheat was further investigated, as well as the observed changes in wheat futures trading volume, open interest and the so-called speculative open interest. The time period studied in this paper consist of the last 15 years. In this period there where periods were the wheat price rose and fell substantially. There is applied an general autoregressive conditional heteroskedasticity (GARCH) model to investigate if the observed changes in the commodity futures market affect the volatility of the wheat price return process, which may affect the spot price itself. This paper provides evidence that speculators in the futures market could contribute to increasing the spot price volatility. The result supports the literature that future speculation destabilizes the spot markets. Wheat futures trading volume provides a positive effect, meaning that it increases the conditional volatility of the wheat price process. The open interest in the wheat futures commodity market provides a negative effect, implying that it decreases the conditional volatility, and the speculative open interest defined in the paper provides a positive effect, which again means that it increases the conditional volatility of the wheat price process, and this holds given everything else in the model. Weekly data were used in the quantitative analysis because of the information available in the time of the study.

9.1 Future research

Financialization is a way of describing the institutional changes in the market, but the consequence of this change is widely debated and it needs further investigation. The result of this investigation can affect millions of people, especially in developing countries. If the majority of researchers provide significant evidence that the observed financialization of the commodity market do affect the commodity spot prices, regulations should be introduced to protect those who are most vulnerable to these price changes. Future research should involve bigger datasets, including (for example) daily data to catch up the daily fluctuations in the price processes as well. This could provide better volatility estimates for the GARCH-model. The CFTC`s COT report only include weekly data, so the majority of researchers in the field has used weekly datasets as used in this thesis. Another issue that should be emphasized is the presence of non-normality in the residuals of the model. Even though the GARCH model was able to capture some of the leptokurtosis in the unconditional distribution of the wheat price changes, it could not capture all of it, and hence the residual is not normally distributed. Because of this, a different variance-covariance matrix estimator that is robust to non-normality should be used in future research regarding the phenomenon. Such a procedure is developed by Bollerslev and Wooldridge (1992), and is known as the quasi-maximum likelihood (QML)[105].

[105] (Brooks, 2008, p.399)

10 Acknowledgements

I have learned a lot through this paper production facing challenges including new processes and not knowing where to start. I also needed to learn some new skills and techniques to be able to analyze the desired issue of the paper.

I would like to express my sincere and deepest gratitude to my advisor Professor Jochen Jungeilges for his support and his vast knowledge and for helping me find motivation by constructing an issue consisting of my professional interests. His way of conveying his knowledge is unique, and I think that this distinguishes him from other lecturers/professors I have met during my courses of study.

I will also like to thank Henry Langseth, one of the University librarians, for helping me obtain parts of the dataset used in the quantitative part of the paper and for giving me advice of where to ask and look if we didn't find it out together. This has really helped me a lot.

A APPENDIX

A1 More details about the wheat price process

As stated in section 7.1, the wheat price process seems to be non-stationary, but after differencing the price process once, it becomes stationary. Figure A1.1 shows the autocorrelation plot of the raw wheat prices and the price changes.

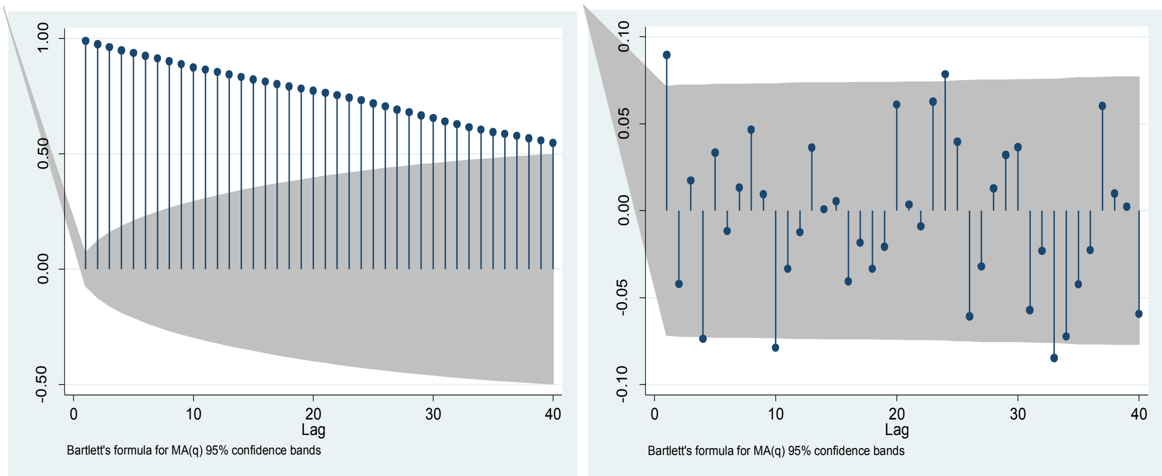

Figure A1.1 The autocorrelation plot of the weekly wheat price and the weekly wheat price changes.

There seems to be some decay towards zero in the first plot containing the raw data, but to determine if the process is stationary or not, an augmented Dickey-Fuller test was performed (result provided in table A1.1). The null hypothesis (which states that the process contains a unit root) could not be rejected; hence the process is not stationary. In the second plot, the process movement is quite different. It seems to fluctuate around zero, but it does not show a clear decay towards zero. A conclusion regarding the stationarity of the process could not be based only on this plot, so an augmented Dickey-Fuller test was performed here as well (result provided in table A1.2). In the weekly wheat price changes case, the null hypothesis were rejected, hence the process became stationary after it was differenced once.

Augmented Dickey-Fuller test wheat price				
	Test	1% Critical	5% Critical	10% Critical
	Statistic	Value	Value	Value
Z(t)	-2.152	-3.430	-2.860	-2.570
MacKinnon approximate p-value for Z(t) = 0.2242				

Table A1.1 Augmented Dickey-Fuller test result of the what price process.

Augmented Dickey-Fuller test wheat price changes				
	Test	1% Critical	5% Critical	10% Critical
	Statistic	Value	Value	Value
Z(t)	-25.018	-3.430	-2.860	-2.570
MacKinnon approximate p-value for Z(t) = 0.0000				

Table A1.2 Augmented Dickey-Fuller test result of the wheat price changes.

Another issue with the dataset is the distribution. Figure A1.2 shows the histogram plot of the weekly wheat prices and the weekly wheat price changes measured as first differences. The transformation of the data results in a stationary process, but the process is not normally distributed. The process contains high peakedness in the mean as mentioned in section 7.1. Table A1.3 shows the result of the normality test of the weekly wheat price changes.

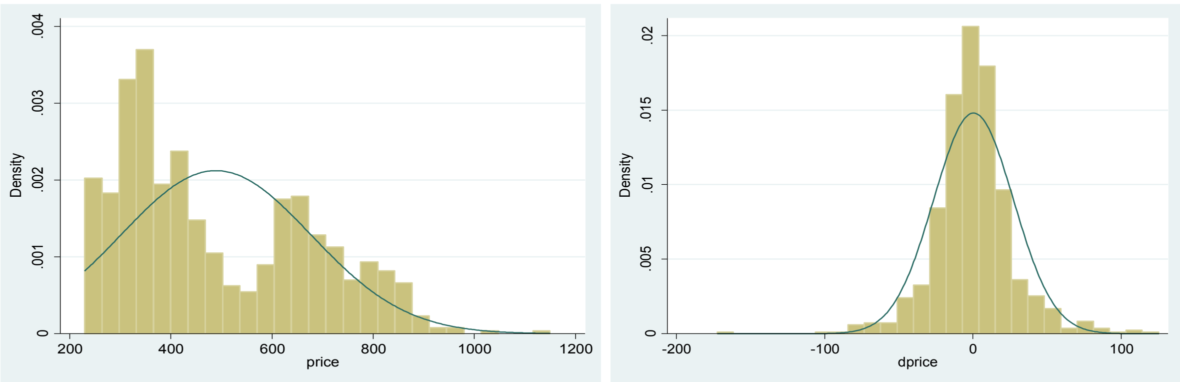

Figure A1.2 Histogram plot weekly wheat price raw data and weekly wheat price changes.

Shapiro-Wilk W test for normal data					
Variable |	Obs	W	V	z	Prob>z
dprice |	752	0.94557	26.488	8.019	0.00000

Table A1.3 Result of the Shapiro-Wilk test of the weekly wheat price changes

The null hypothesis is rejected in the normality test, and this underpins the fact that the weekly wheat price changes are not normally distributed. This is important to keep in mind when interpreting the result of the model. This implies that the GARCH(1,1) model probably will provide inappropriate standard error estimates, because they are estimated under a normality assumption when they in fact are not, but the parameters estimates will still be consistent if the mean and variance is correctly specified[106].

A2 More about Stationarity

The stationarity or non-stationarity of a series strongly influences its properties and behavior. The classification of the series differs in many ways, and one of the main differences is the way a model containing the underlying series reacts to a change or an unexpected change in the series or in the error term during a particular period[107]. If a series is stationary, the shocks to the system will gradually die away. If a series in non-stationary, the persistence of shocks will always be infinite, and the effect of the shocks will not have a smaller effect through time. Another problem with using non-stationary variables in a model is that the standard assumptions for asymptotic analysis will not be valid. The t-ratios will not follow a t-distribution and the F-statistics will not follow an F-distribution[108]. This makes it impossible to use hypothesis tests about the regression parameters regarding its validity if the data is non-stationary. There are many ways of defining stationarity, Tsay (2010) state that a time series "is said to be strictly stationary if the joint distribution of $(r_{t1},\ldots,r_{tk})$ is identical to that of $(r_{t1+t},\ldots,r_{tk+t})$ for all *t,* where *k* is an arbitrary positive integer and $(t_1,\ldots,t_k)$ is a collection of *k* positive integers" (Tsay, 2010, p.30). A more analytical presentation can be presented by focusing on two elements of a process, the random variable at time X_t, and a random variable that is associated with a future (or past) point in time t-τ where $\tau \in \mathbb{N}$. Set $\tau < 0$, then we are looking at an instance in the future relative to X_t. The auto-covariance of this process can be defined as[109]:

$$C[X_t, X_{t-\tau}] = E[(X_t - E[X_t])(X_{t-\tau} - E[X_{t-\tau}])] \quad \text{(A2.1)}$$

The expected value at each point in time equals μ, $E[X_t] = \mu$ for $t \in T = \{1,2,\ldots,T\}$ and thus the expression in (A2.1) simplifies to:

$$C[X_t, X_{t-\tau}] = E[(X_t - \mu)(X_{t-\tau} - \mu)] \quad \text{(A2.2)}$$

106 (Brooks, 2008, p.399)
107 (Brooks, 2008, p. 319)
108 (Brooks, 2008, p. 320)
109 (Jungeilges, 2015)

which is the same as

$$C[X_t, X_{t-\tau}] = E[X_tX_{t-\tau} – \mu(X_{t-\tau} + X_t) + \mu^2] \qquad (A2.3)$$

The expected value is a linear operator and the expected value of a constant is the constant itself, (A3.3) can be represented as

$$C[X_t, X_{t-\tau}] = E[X_tX_{t-\tau}] – \mu E[X_{t-\tau} + X_t] + \mu^2 \qquad (A2.4)$$

If we have a case of two stochastically independent random variables X and Y, one can establish E[XY]=E[X]E[Y], therefore

$$C[X_t, X_{t-\tau}] = E[X_t]E[X_{t-\tau}] – \mu(E[X_{t-\tau}] + E[X_t]) + \mu^2 \qquad (A2.5)$$

$$= \mu^2 – \mu(2\mu) + \mu^2 \qquad (A2.6)$$

$$= 2\,\mu^2 - 2\,\mu^2 = 0 \qquad (A2.7)$$

The auto-covariance function equals zero for any lag $\tau \neq 0$, and for $\tau = 0$ the expression $E[(X_t – E[X_t])(X_{t-\tau} – E[X_{t-\tau}])]$ reduces to $E[(X_t – E[X_t])(X_t - E[X_t])]$ which is equal to $E[(X_t - E[X_t])^2]$ which represents the variance of the random variable X_t and its equal to σ^2. Therefore, when the auto-correlation function of a process equals zero for all *t* and all values of τ, the process is both mean and variance stationary according to the specification given above, and this process is referred to as a white noise process. This is an example of a strictly stationary process.

The form of stationarity described above is often hard to verify empirically, so a weaker from of stationarity is often assumed. Tsay (2010) states that "a time-series $\{r_t\}$ is weakly stationary if both the mean of r_t and the covariance between r_t and r_{t-k} are time invariant, were *k* is an arbitrary integer"[110] (Tsay, 2010, p.30). If a series satisfies:

$$E(X_t) = \mu \qquad (A2.8)$$

$$E(X_t – \mu)(X_t – \mu) = \sigma^2 < \infty \qquad (A2.9)$$

$$E(Xt_1 – \mu)(Xt_2 – \mu) = C(Xt_1,Xt_2) – C(Xt,Xt_1) = \gamma_{t2-t1} \qquad (A2.10)$$

then the series is said to be weakly stationary[111]. This can also be referred to as a covariance stationary process because the covariance between two observations only depends on the

[110] (Tsay, 2010, p.30)
[111] (Brooks, 2008, p.208)

length of time separating the observations[112]. Most economic series are trended, and the concept of trend-stationarity allows for deterministic trends, and it is further described in appendix A3.

A3 Random Walk definition

Random walk processes are non-stationary processes. They are often referred to as a random walk with drift or a trend-stationary process[113]. A more formal definition is[114]:

$$X_t = f(t) + X_{t-1} + e_t \qquad (A3.1)$$

were t = {0,1,….,∞}, f is any function such that f : ℝ and an i.i.d variable e_t for which $E[e_t] = 0$ and $V[e_t] = \sigma_e^2 < \infty$ exist. Assume $X_0 = x_0 \in \mathbb{R}$, then (A3.1) constitutes a random walk process. Many trending financial time series can be characterized by a trend stationary process or a random walk with drift, and the formal description of these processes is given by[115]:

$$y_t = \gamma_0 + \gamma_1 t + u_t \quad \text{(Trend-Stationary)} \qquad (A3.2)$$

$$y_t = \delta_1 + y_{t-1} + u_t \quad \text{(Random walk with drift)} \qquad (A3.3)$$

were u_t is a white noise process, which means that $E[u_t] = 0$ and $V[u_t] = \sigma^2$. If a non-stationary series must be differenced *n* times before it becomes stationary, then it is said to be integrated of order n: I(*n*)[116]. An I(0) process is a stationary process, while a I(1) process contains a unit root. A I(1) process must be differenced once in order to get stationary. (A3.2) and (A3.3) are processes that is integrated of order one, denoted by I(1). In order to choose the right process to describe the dynamics of the underlying data, a test for the presence of unit roots can be performed. One way of testing this is nest both cases into a general model with specification[117]:

$$y_t = \gamma_0 + \gamma_1 t + \alpha[y_{t-1} - \gamma_0 - \gamma_1(t-1)] + u_t \qquad (A3.4)$$

[112] (Pesaran, 2015, p.268)
[113] (Brooks, 2008, p.320)
[114] (Jungeilges, 2015)
[115] (Patterson, 2011)
[116] (Brooks, 2008, p.326)
[117] (Patterson, 2011)

if $|\alpha| = 1$ we have a case of random walk with drift specification, and if $\alpha < 1$ we have a trend-stationary specified process. To be able to construct a proper way of testing this, some re-parametrization is performed:

$$y_t = \beta_0 + \beta_1 t + \alpha y_{t-1} + u_t, \quad \text{(A3.5)}$$

$$\beta_0 = \gamma_0(1 - \alpha) + \gamma_1\alpha;$$

$$\beta_1 = \gamma 1(1 - \alpha).$$

Subtracting y_{t-1} from both sides:

$$\Delta y_t = \beta_0 + \beta_1 t + (\alpha - 1) y_{t-1} + u_t, \quad \text{(A3.6)}$$

if $\alpha < 1$ we have a case of a trend-stationary process and if $\alpha = 1$ we are facing a random walk with drift. The test statistics of unit roots are:

$$H0: (\alpha - 1) = 0 \qquad H1: (\alpha - 1) < 0$$

If $\alpha = 1$, the underlying series under investigation is non-stationary.

A4 Properties of ML estimators

The parameters of the ARMA(1,1)-GARCH(1,1) model are estimated by maximum likelihood (ML) estimation. This estimation technique provides optimal properties for the estimators produced by this approach. One of the relevant properties is the invariance property[118]:

1. "Let g denote continuous function. If $\hat{\theta}$ is a MLE for θ then $g(\hat{\theta})$ is a MLE for g(θ)" (Jungeilges, 2015, lec.2 p.6)

For large samples, the ML estimators are the minimum variance unbiased estimator of θ. In the small sample case, the ML estimators are not always unbiased or minimum variance estimators, because unbiasedness means that $E[\hat{\theta}] = \theta_t$ where $\hat{\theta}$ is an estimator of θ (were θ_t is its true value) and E[.] is the expectation operator and the ML estimator $\hat{\theta}$ takes the true value with minimum variance in the limit as the size of the sample increase to infinity. This can also be referred to as the property of consistency[119].

[118] (Jungeilges, 2015)
[119] (Lam, Wong & Lo, 2009, p.46)

2. "Let $\hat{\theta}_n$ denote a ML estimator of the parameter θ based on a random sample of size n from $f_X(X, \theta)$. Then $\hat{\theta}_n \sim N(\theta, \xi_n)$ where

$$\xi_n = \frac{1}{-nE[\frac{\partial^2 \ln f_X(X;\theta)}{\partial \theta^2}]}$$

the sequence of ML estimators $\hat{\theta}_n$ is the best asymptotically normal (BAN)" (Jungeilges, 2015, lec.2 p.7).

These properties makes the ML estimators asymptotic efficient and asymptotic normal[120]. The variance of the estimators is determined by the Rao-Cramer lower bund. Because of the features described above, the ML estimators are asymptotically normally distributed in the limit of large samples, and this makes it possible to use standard statistical tests.

A5 Testing the result of the main model

For the result of the test to be as valid and as optimal as possible, there should not exist serial-correlation in the residuals of the model, and the residual should be normally distributed. Figure A5.1 displays a histogram plot of the residuals of the result of the main model, and table A5.1 shows the result of the normality test.

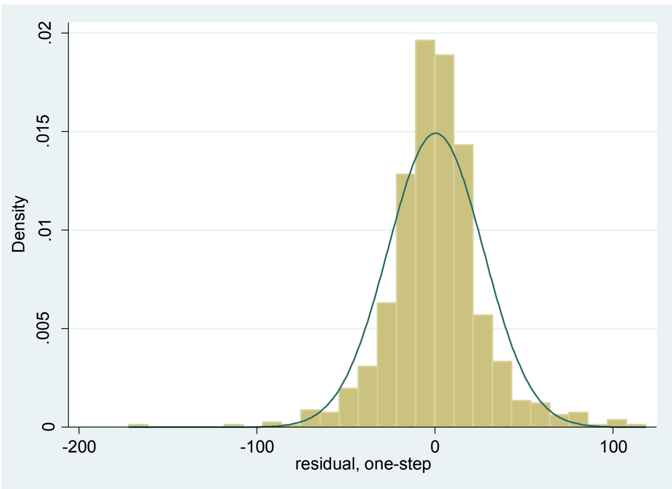

Figure A5.1 Histogram plot of the residuals of the ARMA(1,1)-GARCH(1,1) model.

[120] (Lam, Wong & Lo, 2009, p.46)

Shapiro-Wilk W test for normal data					
Variable |	Obs	W	V	z	Prob>z
resgarch |	752	0.94626	26.155	7.988	0.00000

Table A5.1 Result Shapiro-Wilk test of the residuals of the ARMA(1,1)-GARCH(1,1) model.

According to the Shapiro-Wilk test, the residual of the model is not normally distributed. The histogram plot shows that we have a more leptokurtic distribution rather than a normal distribution. This is very normal for financial data, and this does not necessarily make the result of the main model invalid, but other alternative probability density functions for the conditional returns should be tested to see if they capture the fat tails and asymmetry better than the method used in this thesis. Verhoeven and McAleer (2004) examined different probability density functions and the result of their study show that GARCH-models that are estimated using asymmetric leptokurtic distributions are better than those estimated under normality in terms of capturing skewness and leptokurtosis and when estimating the maximum likelihood values.[121]

Another important feature of the residual of the model is presence of serial-correlation. The residual should not be serial-correlated in order for the result to be valid. Table A5.2 shows the result of the Q-test.

Portmanteau test for white noise	
Portmanteau (Q) statistic =	52.6712
Prob > chi2(40) =	0.0865

Table A5.2 Result of the Portmanteau test of the residuals of the ARMA(1,1)-GARCH(1,1) model.

According to the test for serial-correlation provided in table A5.2, we fail to reject the null hypothesis that states that there is no serial-correlation; hence the residual is not serial-correlated. It should be mentioned that this result is at a 5 per cent significance level. The null hypothesis can be rejected at a 10 per cent level. So even though the conclusion is that there is no serial-correlation in the residual, it is not as robust as desired. However, this means that in this analysis, the residual is not serial-correlated; hence this underpins the validity of the result of the model.

[121] (Verhoeven & McAleer, 2004, p.351)

A6 DO-FILE STATA

import excel "\\uia.no\Student\KRS\u07$\serind10\Desktop\STATAklar-sett2long (2).xlsx", sheet("Ark1") firstrow
generate DATE=date(date,"DMY")
format %tw DATE
generate t=tw(2000w41)+_n-1
format t %tw
tsset t
tsline price
tsline OI
tsline TV
tsline SpecOI
ac price
wntestq price
dfuller price
generate dprice=price-L1.price
tsline dprice
ac dprice
pac dprice
wntestq dprice
dfuller dprice
generate wrprice=(price-L1.price)/L1.price
tsline wrprice
ac wrprice
wntestq wrprice
dfuller wrprice
histogram dprice, normal
swilk dprice
histogram wrprice, normal

swilk wrprice
arima dprice, arima(1,0,0)
arima dprice, noconstant arima(1,0,0)
predict res, residual
gen res2=res*res
regress res2 L1.res2
histogram res
tsline res
wntestq res
arima dprice, noconstant arima(1,0,1)
estat ic
arima dprice, noconstant arima(1,0,1)
predict resarma, residual
gen resarma2=resarma*resarma
regress resarma2 L1.resarma2
wntestq resarma
tsline resarma
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arima dprice, noconstant arima(2,0,2)
estat ic
histogram dprice, normal
histogram price, normal
summarize price, detail
summarize dprice, detail
swilk dprice
swilk price
generate dOI=OI-L1.OI

generate dTV=TV-L1.TV
generate dspecOI=SpecOI-L1.SpecOI
dfuller dOI
dfuller dTV
dfuller dspecOI
arch dprice, noconstant arch(1/1) garch(1/1) het(dTV dOI dspecOI)
arch dprice, noconstant ar(1) ma(1) arch(1/1) garch(1/1) het(L1.dTV L1.dOI L1.dspecOI)
predict resgarch, residual
histogram resgarch, normal
wntestq resgarch
corrgram resgarch
wntestq resgarch, lags(40)
wntestq resgarch, lags(100)
wntestq resgarch, lags(1)
swilk resgarch
summarize resgarch, detail
predict garch, variance
tsline garch

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