Volatility in the after crisis period – A literature review of recent empirical research

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ULYSSES project assess the literature on prices volatility of food, feed and non-food commodities. It attempt to determine the causes of markets' volatility, identifying the drivers and factors causing markets volatility. Projections for supply shocks, demand changes and climate change impacts on agricultural production are performed to assess the likelihood of more volatile markets. ULYSSES is concerned also about the impact of markets' volatility in the food supply chain in the EU and in developing countries, analysing traditional and new instruments to manage price risks. It also evaluates impacts on households in the EU and developing countries. Results will help the consortium draw policy-relevant conclusions that help the EU define market management strategies within the CAP after 2013 and inform EU’s standing in the international context. The project is led by Universidad Politécnica de Madrid.

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Abbreviations
FAO UN Food and Agriculture Organization
GARCH Generalised Autoregressive Conditional Heteroskedasticity
GJR-ARCH Glosten, Jagannathan, Runkle - GARCH
GARCH-X GARCH with explanatory variables
IFPRI International Food Policy Research Institute
OECD Organisation for Economic Cooperation and Development
OLS Ordinary Least Squares
TGARCH Threshold GARCH
VAR Vector Autoregressive
Executive summary

1. Price volatility has been a key concern for policy makers and scientists. Agricultural and food price level developments in the 2007/2008 food price crisis have triggered a substantial response in the published literature, although the perceived trend towards higher price volatility can only be robustly confirmed for cereals.

2. Volatility is unobservable and hence needs to be estimated. Since volatility refers to price changes which are unexpected, estimates of price volatility require modelling the price levels, too. Many conceptual choices have to be made in this exercise, with corresponding consequences for the interpretation of the resulting price volatility measure. This is not always as clearly documented as it should ideally be the case.

3. Empirical studies are often based either on futures or on spot prices; studies which look at the price volatility spillovers between the two price series are much less frequent. Price volatility is transmitted quickly between these markets only for sufficiently liquid futures and spot markets. For some policy concerns, the focus should be more on spot markets; for others, futures markets are the relevant scale.

4. Methods for price volatility are under continuous refinement. For agricultural markets, GARCH models are the main working tool. With increasing availability of high frequency trading data, realised volatility measures are used often in analyses for futures markets.

5. Policy measures can exert drastic influence on price volatility patterns. This holds obviously for direct price controls and similar agricultural price policies but also for export and import policies. In recent years, bioenergy policies are adding a new demand component which often is not adjusted in light of price changes, thus adding to price volatility.

6. Fundamental factors on supply and demand side explain a major part of price volatility in the past. They will most likely continue to be the most important factors for new episodes of inflated price volatility. However, the example of investment in agricultural productivity growth makes clear that fundamentals have also a role to play in curbing future price volatility. With sufficient productivity growth, price volatility due to bad harvests could be effectively mitigated.

7. Carry-over stocks normally play an important role for intertemporal price smoothing. If stocks are low (usually measured via stocks-to-use ratios), markets tend to show elevated price volatility in response to new information. Imprecise and vague knowledge about the magnitude of available carry-over stocks exacerbate the situation.

8. Price volatility is usually not affecting a single market but spillovers abound. For agricultural and food prices, input markets and fossil fuel markets are key volatility transmission channels. Among agricultural markets, substitution possibilities determine volatility linkages. Spillovers from other non-agricultural commodity markets are less important.
9. Speculation is seen as a driver of volatility, too. However, the establishment of causal links in this area is extremely challenging. Problems exist in the clear definition of what speculation exactly is (is the farmer who does not make use of a functioning futures market for hedging a speculator?), and how to exactly measure it (are all non-commercial investors in a given futures market speculating?). Furthermore, causality is generally difficult to assess in non-experimental settings. Most of the existing results (e.g., Granger causality type analyses) are merely assessing the predictive power of the history of one price series for the future development of another price series.

1 Introduction

Over the past years, price volatility on agricultural and food markets has become a major concern of policymakers worldwide. This increasing attention was triggered by the food price crisis of 2007/2008, when prices for major agricultural products were increasing at an accelerating pace, before quickly coming down again in the last year of the crisis. Price changes over this period were often viewed as excessive, raising the question which drivers were responsible for these patterns.

Scientists and market commentators responded to these concerns over the past few years so that there is now a rich body of literature available. However, most of the literature is more focused on price levels rather than on price volatility. There is a need for a clear distinction between these two aspects. Most internationally traded agricultural commodities are storable so that high price volatility is indeed more likely when prices are high (and stocks are low). Nevertheless, a qualified discussion of the drivers of price volatility requires careful distinction between drivers of price levels and drivers of price volatility.

Volatility relates to unexpected price changes. Hence, it is important to specify an explicit model for the expected price in order to be able to distinguish between expected price changes and unexpected price changes. In addition, there are a number of conceptual choices which have to be made in order to empirically assess price volatility, e.g., market definition, data frequency, time horizon, and methodological approach. The specific choices have repercussion on the interpretation of the generated price volatility measure. Therefore, we start our review with a chapter where we explore the consequences of the various possibilities with regard to these choices. We continue with an extensive review of the relevant literature on drivers of agricultural price volatility (broadly defined). The literature is categorized according to both methodological and topical criteria so that the most relevant strands of thought in the literature become clear. The current perceptions on the relative importance of the potential drivers of agricultural price volatility are the focus of the following chapter. We elicit the consensus for major drivers from the literature where possible, and highlight the areas where the literature provides no clear guidance whether a certain driver is relevant for price volatility on agricultural and food markets or not. The final section concludes, with a specific focus on the research gaps in the literature.

2 Volatility concepts and measurement

This review article mainly focuses on the literature that contributes to the understanding of volatility drivers. Any attempt, however, to identify factors that govern volatility in agricultural
commodity markets depends on the volatility concept which is applied. In particular, any empirical analysis of volatility and its drivers requires a definition of volatility that is specific enough to make the empirical measurement of volatility operational. Therefore, this section of the report sets the ground by dealing with the concept of volatility itself, i.e., the quantity to be explained, and not with its driving factors, i.e., the variables that explain volatility.

Almost all papers reviewed in this report base their analysis of volatility on the following definition: Volatility is the standard deviation of relative price changes (log-returns).\(^1\) This simple definition has several important implications. (i) Since the standard deviation is the square root of the expected squared deviation between the actual (relative) price change and the expected price change, such a volatility concept clearly distinguishes between expected price changes and unexpected price changes. Stated in the words of Andersen et al. (2010), p. 69, volatility according to this definition is „the component of a given price increment that represents a return innovation as opposed to an expected price movement“. (ii) Since volatility expresses the magnitude of deviations from the expected price movement, any attempt to measure volatility empirically requires in addition the modelling of the price process, e.g., by modelling trends, seasonality, or cyclical components. Such trend models are often not discussed explicitly in the literature on volatility but they are always present. For example, the popular assumptions of zero expected returns, or expected returns that are constant over time imply the absence of any trend, or a simple linear trend, respectively. These simple trend models may be perfectly appropriate for short time intervals like a minute or a day. However, for longer time intervals it is important to deal both with long-term trends and cycles as well as with seasonalties according to harvest cycles. If these were ignored, the corresponding expected price changes would be mistaken for volatility. (iii) Since volatility addresses potential price changes, it inevitably refers to a period (over which a price change can happen) and not only to a single point in time. (iv) According to the above definition, volatility is not a directly observable quantity, like a price, but has to be estimated.

Although the literature largely agrees on the above definition of volatility, the concrete measurement or estimation of volatility based on this definition still involves many choices. Because different choices could lead to different volatility estimates which in turn could lead to different conclusions about volatility drivers and policy implications, we briefly discuss these choices.

Time horizon: Volatility always refers to a time period. The end of this time period defines the time horizon. Selection of an appropriate time horizon is a major decision one has to make for the analysis of volatility and this decision clearly depends on the goal of the analysis. For example, for an understanding of the effects of volatility on producers and consumers a time horizon of at least one month seems appropriate, but it may also be much longer. It is important to note that the time horizon does not necessarily coincide with the frequency of the data which is used to estimate volatility. On the contrary, some estimation methods require that data is available at a higher frequency than the time horizon under study. However, several studies considered in this literature review do not explicitly discuss the time horizon they are focussing on. Moreover, the time horizon should also not be confused with the data period that defines the total period of historical data that is available for volatility estimation.

\(^1\)The only alternative concept that is used in some papers is the coefficient of variation, however, this measure contains the standard deviation in the numerator.
Markets considered: Another central issue is the choice of markets to be considered in a study. The goal of the analysis should in principle determine which commodities and which regions are investigated. In practice, however, it can be a difficult task. Even if one is interested in a single commodity and a specific region, connections between markets and spill over effects might require an analysis of several markets to obtain a clear understanding of the factors that drive the volatility of the commodity of interest. Another important aspect concerning the choice of markets is the use of spot data versus futures data. Even if one is interested in the spot price volatility, futures markets are frequently used because of data availability and data quality. It is important to note, however, that volatilities obtained from futures data can be quite different from the corresponding spot price volatilities. For example, Schwartz (1997) provides a theoretical and empirical analysis of this issue. He shows that spot volatilities tend to be higher than futures volatilities, an observation that can be explained by the dependence between spot prices and convenience yields.

Ex-post measurement versus ex-ante prediction: It is important to clearly distinguish between ex-post volatility and ex-ante volatility. In general, ex-post measurement of volatility can use all available information, including the price changes that occurred in the time period of interest (see the discussion on the time horizon above), and even price changes that occurred later. In contrast, measurement of ex-ante volatility is entirely based on information up to the beginning of the time period. This distinction has several implications: (i) The preferred approach depends on the objectives of the volatility assessment. Ex-post volatility is most useful in an analysis that aims to explain what has driven volatility in the past, whereas ex-ante volatility helps us to understand expectations about future volatility. Both perspectives are economically relevant. In terms of policy implications, the ex-post analysis can be used to guide longer-term reforms, whereas ex-ante measures could provide an early warning system that may indicate the need for immediate action. (ii) Ex-post volatility can be interpreted as an in-sample volatility whereas ex-ante volatility can be seen as a forward-looking out-of-sample volatility. Ex-ante approaches hence require that the estimated volatility model continues to be valid for the time horizon outside the observation sample. (iii) Different estimation methods are available for ex-post volatility and ex-ante volatility. In particular, implied volatilities based on the expectations of options markets participants can be used as measures of ex-ante volatility.

Estimation method: Given all the choices mentioned above, the concrete selection of the estimation method still allows for a great number of decisions to take, which could also have a large impact on the resulting volatility estimate. The most common approach is to use a parametric volatility model and to estimate it with historical data. Models of the GARCH class and stochastic volatility models are the major approaches here. A GARCH model explains (squared) volatility by past return innovations and past (squared) volatilities (plus potentially some exogenous explanatory variables (GARCH-X)). A stochastic volatility model treats volatility as a random variable and models its evolution via a stochastic process. GARCH models are the most common choice for the analysis of volatility in agricultural commodity markets. Model specification in this context involves several specific choices: (i)

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2 The approach dates back to the seminal work by Engle (1982) and Bollerslev (1986).
3 An early example of a model that treats volatility itself as stochastic is Clark (1973). A very popular stochastic volatility model is the one by Heston (1993). For a review paper that covers both GARCH models and stochastic volatility models see Andersen et al. (2010).
To obtain the return innovations, a model for the expected price change has to be specified (see discussion above). In the discussion to follow, we concentrate, however, on the volatility part of the model. (ii) Some general specification issues involve the questions whether a univariate GARCH model is applied to each market under consideration or several markets are treated simultaneously via a multivariate (vector) GARCH model, the integration property of the volatility (stationary, integrated or fractionally integrated GARCH models), and the question whether the volatility response to past return innovations is asymmetric (GJR-GARCH) or depends on certain thresholds (TGARCH). For storable agricultural commodities, the fact that demand for storage tends to become more and more elastic at low price levels suggests that asymmetry or threshold effects are likely present. (iii) One has to select the number of lagged return innovations and the number of lagged volatilities to be included, i.e., the order of the GARCH model. (iv) The data frequency to be used for the estimations has to be chosen. (v) The historical data period has to be selected, e.g. the ten years period between 2002 and 2012. One disadvantage of the parametric approach followed by GARCH models is the assumption that the structure of the model remains constant over the whole data period, including any possible forecast horizon.

An alternative to parametric volatility models is a nonparametric approach often called “realised volatility”. The basic idea is that the volatility of a certain time period can be estimated from data of this period only, which is available, however, on a higher frequency. For example, the volatility referring to a certain month is estimated from the daily price changes within this month. The major advantage of this approach is that it does not require the assumption of a fixed model structure over a quite long period of time (the data period used for GARCH models usually contains several years). One disadvantage of the approach is its need for price data measured at relatively high frequencies, which might not be available. Moreover, the issue of how volatility scales over different frequencies appears. For example, if daily data is used to estimate the volatility for a time horizon of one month, we have to convert the daily volatility into a monthly one. Simple scaling rules for the volatility, like the square root of time rule, might not work very well because of dependencies in the daily price changes.

Parametric and nonparametric methods based on historical price data can in principle be used both for the ex-post measurement of volatility and for ex-ante predictions. Prediction is rather straightforward with the parametric models. Given the parameter estimates, volatility forecasts for different time horizons are often easily obtained from the model, e.g., for the standard GARCH model. The nonparametric approach delivers a time series of “realised volatilities” that can build the basis for out-of-sample predictions of volatilities. The specification of the concrete prediction model, however, is an additional task that again entails many choices to be made by the researcher. A completely different approach to ex-ante volatility prediction is the use of options data to back out the volatility expectations of market participants. This leads to the concept of implied volatility. This concept relies on the idea that volatility is an input variable in standard option pricing models. Given observed market prices for options, the corresponding pricing formula can be inverted to obtain a volatility estimate that is in line with observed market prices. A drawback of this approach is its reliance on a particular option pricing model. For example, a standard approach uses Black’s (1976) model.

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1 This approach was first introduced and applied by French et al. (1987), Schwert (1989, 1990a, 1990b), and Schwert and Seguin (1990). It was later formalized by Andersen and Bollerslev (1998).

for options on futures or a corresponding discrete-time approximation. Alternatively, model-free approaches to estimate implied volatilities have been developed by Britten-Jones and Neuberger (2000) and Bakshi et al. (2003). These are computationally more complex but do not require the assumption of any specific pricing model. The major advantage of the implied approach to volatility estimation in general is that it does not require any historical data, which might no longer be representative for the future, but relies only on current option prices. It can therefore exploit the most recent information available to market participants in derivatives markets and often leads to better predictions than alternative methods based on historical price data.\(^6\)

As a brief illustration of at least some of the approaches and choices one can make to measure volatility, consider the following examples for the wheat market, as presented in Figure 1 and Table 1. We choose a common time horizon of one month and present three different ex-post measures of wheat price volatility and two different approaches to ex-ante volatility prediction. The total data period for the ex-post measures is March 1982 to April 2012. The ex-ante approaches deliver predictions for each month between February 1987 and April 2012. All numbers refer to annualized values.

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\[^6\] See Poon and Granger (2003, 2005) and Christoffersen et al. (2012) for survey articles that document the excellent predictive performance of implied methods for many different markets. This result still hold despite the fact that implied estimates can be biased due to risk premia.
Figure 1: All graphs show the annualized standard deviations of logarithmic price changes of wheat (annualized volatility). The futures used for the estimation are the ones traded at CME (soft red winter), the spot prices refer to their underlying (WHEATSF from Datastream). The time series of futures prices is constructed by using the futures contract with the shortest time to maturity and rolling it over to the second shortest contract when there are less than five trading days for the shortest contract. The realised volatilities for the futures and spot markets refer to a period starting on the 20th calendar day or the next trading day (if there is no trading on the 20th) of each month using the following 20 daily (logarithmic) price changes. The full data period is March 1982 to April 2012. For the ex-post and ex-ante GARCH estimation, a GARCH(1,1)-model is selected and estimated with monthly spot market returns. The data period for the ex-post GARCH estimation is also March 1982 to April 2012. The first GARCH-based ex-ante prediction is made in January 1987 for the next month’s volatility, using monthly returns from April 1982 to January 1987 for the estimation of model parameters. The following predictions use a successively extended estimation window up to March 2012. Implied volatilities are calculated based on a discrete version of Black’s (1976) option pricing model that can handle American-style options. For the calculation, at-the-money options on wheat futures traded at CME between January 1987 and March 2012 with times to maturity between 29 and 32 calendar days are used.

Source: Own elaboration.

Table 1: Summary statistics of the volatilities shown in Figure 1.

<table>
<thead>
<tr>
<th></th>
<th>Realised Futures</th>
<th>Realised Spot</th>
<th>GARCH (ex post)</th>
<th>GARCH (ex ante)</th>
<th>Implied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Volatility</td>
<td>24.92 %</td>
<td>29.75 %</td>
<td>29.65 %</td>
<td>27.90 %</td>
<td>29.28 %</td>
</tr>
<tr>
<td>S.D. of Volatility</td>
<td>11.00 %</td>
<td>15.49 %</td>
<td>5.10 %</td>
<td>4.91 %</td>
<td>9.27 %</td>
</tr>
<tr>
<td>Maximum</td>
<td>89.12 %</td>
<td>132.11 %</td>
<td>50.27 %</td>
<td>51.45 %</td>
<td>70.30 %</td>
</tr>
<tr>
<td>Minimum</td>
<td>8.44 %</td>
<td>9.78%</td>
<td>22.73 %</td>
<td>20.96 %</td>
<td>11.82 %</td>
</tr>
</tbody>
</table>

Source: Own elaboration.

Note: The summary statistics (Average, Standard Deviation, Maximum, and Minimum) of the volatility measures are calculated from 362 observations for the ex-post measures (Realized Futures, Realized Spot, GARCH (ex post)) and 303 observations for the ex-ante predictions (GARCH (ex ante), Implied).
A first distinction that we make is the one between futures markets and spot markets. As the upper two graphs of Figure 1 and the first two columns of Table 1 show, realised volatilities (using on a daily data frequency) obtained from futures and spot markets can be rather different. Our example confirms previous results from the literature (e.g., Schwartz (1997)), that futures returns show a lower volatility than spot returns. Although we use the futures with the shortest maturity available, the difference is quite substantial. On average, the spot volatility is about 5 percentage points higher than the futures volatility (29.75% versus 24.92%). Moreover, spot volatilities are clearly less stable over time. A second distinction is the one between the non-parametric realised volatility and the volatility resulting from a parametric GARCH(1,1) model. The second and third graphs of Figure 1 show the corresponding results. Both approaches use spot price data for volatility estimation. As we see, the main difference between the two approaches is not the general level of volatility they deliver (29.75% versus 29.65%), but how volatility fluctuates over time. The GARCH model clearly leads to a much more stable evolution of volatility than the realised volatility does, showing up in a much lower standard deviation of volatility (5.10% versus 15.49%). As a third aspect, note that ex-post and ex-ante volatilities can be rather different, even if they are based on the same model (GARCH(1,1)). In particular, the series of ex-ante volatilities shown in Figure 1 is clearly smoother than the corresponding series of ex-post volatilities over the period between 1987 and 2006. Finally, a comparison between the GARCH volatility predictions and the implied volatilities reveals that the options-based values fluctuate much more over time.

The discussion of this section and the examples for the wheat market have shown the wide range of volatility concepts and measurement approaches as well as some of the consequences they have for the volatility one finally obtains. The many different choices that any empirical study of volatility in agricultural commodity markets has to make should be explicitly recognised and should also be transparently documented in the publication of the results. This would certainly facilitate the understanding and interpretation of the many results that are already reported in the literature and are reviewed in this report.

3 Literature review on food price volatility

3.1 Introduction

In this section we present a comprehensive literature review of the agricultural and food price volatility patterns as observed over the last decade. We focus on studies published in peer reviewed journals but also include a selected number of working papers, policy briefs, and discussion papers (‘grey literature’) from international organisations or research institutes. This literature is categorised and analysed from different dimensions in this section. We divide the literature according to its methodological approach into theoretical, descriptive, empirical statistics, and modelling categories. Besides these categories, we further added another dimension regarding the contribution of the papers to the theory behind volatility, its drivers, spillover effects, changes in volatility patterns and summary papers. We present these papers based on different statistical methods which are used to analyse the volatility phenomenon in food and agricultural prices.
3.2 Studies on price volatility

Food price volatility is a major focus of research and policy advising of many international organizations or research institutes such as FAO, IFPRI, NBER, IMF, World Bank, etc., in particular since the food price crisis of 2007/08 brought the issue of food price development back to the top of the international political agenda. In the book edited by Prakash (2011), a comprehensive overview of food price volatility, its drivers, consequences and case studies are presented. This book partially presents FAO’s view on food price volatility. Other international organisations with an interest in food and agricultural markets were active in this research area, too. For instance, IFPRI conducted empirical researches on food price volatility (e.g. Pietola et al., 2010) or policy briefings are presented on this topic (e.g. Robles et al., 2009). There are also publications which represent the shared vision of different development organizations (e.g. FAO et al., 2011). Similar policy papers can be found by other organisations. The main focus of these types of policy briefings is to present the drivers of food price volatility or to give policy recommendations to deal with this problem. The focus of this section is to review the established body of literature on food price volatility with a methodological and analytical background. The above discussion on volatility concepts illustrates that extracting the main drivers of recent food price volatility trends from the existing literature requires such a methodological and analytical focus because of the important role of conceptual choices for the findings and implications of any empirical study on food price volatility.

In general the food price volatility literature can be categorized in studies aiming at:

- Volatility levels
- Theoretical aspects of price volatility analysis
- Empirical analysis of price volatility drivers
- Volatility spillover effects
- Interaction between spot and futures price volatility
- Price formation in futures markets

In the following we will present the detailed information of empirical studies in each of the above mentioned categories.

3.2.1 Volatility levels

The after crisis period has shown in general high price volatility for many agricultural commodities, however if compared to the 70s it seems that recent volatility spikes remains below their historical levels for most of the commodities. Gilbert & Morgan (2010) conclude that the volatility for agricultural products is lower over the past two decades than in the 70s and 80s with the exception of rice, and although volatility is high over the 2007-2009 period for many foodstuffs, in the case of groundnut oil, soybeans and soybean oil their conditional variances increase significantly. Despite there is no increasing tendency on food volatility during recent years, volatility of the main grains does increase. Gilbert & Prakash in Prakash (2011) argue that the periods of extreme volatility in agricultural markets are seldom. They distinguish the '73 – '74 episode as a ‘crisis’ with extreme high price levels and volatility on commodity markets, whereas the recent '06 – '07 -despite showing relative high price levels and volatility- is not comparable in size and effects (ca. five million malnutrition related deaths) to the former one. Huchet-Bourdon (2011) finds from the analysis of ten products (1957 – 2010) that agricultural price volatility is on average low for beef and sugar. She also arrives to the conclusion that volatility is higher in the last decade than in the 90s but not higher than in the 70s. However, same as Gilbert & Morgan (2010), she finds that recent volatility is higher than in
the 70s only for cereals. Ocran & Biekpe (2007) ascertain whether the long-run price volatility and trend change over the past four decades for 18 main Sub-Saharan Africa's commodities. Their findings reveal that the volatility does not show any significant change over the considered period for aluminium, beef, cocoa, groundnut oil, crude oil, palm oil, rubber, timber and tobacco. For gold, sisal, shrimps, groundnuts and sugar the volatility decreases while for copper, coffee, cotton and tea it increases. Crude oil price exhibits the highest level of volatility persistence followed by sugar, aluminium and coffee.

3.2.2 Theoretical aspects of price volatility analysis

There are few papers on the comparison and review of the models and studies in the area of price volatility. In this type of papers, models, empirical studies or both in the field of price volatility are reviewed. Poon & Granger (2003) and Granger & Poon (2005) are two major papers in the area of forecasting volatility in financial markets. In these papers, they review different understandings of price volatility; empirical models to estimate the volatility; and some empirical studies. We could not find any similar reviews in the area of agricultural and food price volatility. Gouel (2012) is an exception. He presents a review over the major theoretical studies on the issue of agricultural price volatility.

The reviewed papers in this section use empirical statistical methods to shed light on various theoretical aspects of measuring volatility in agricultural commodity markets. Jin & Kim (2012), using real prices on rice, red pepper, onion and sesame for South Korea, test regime switches techniques. They, suggest a new type of measurement using a model which incorporates multiple structural changes in the unconditional mean to overcome the problem of amplified variance. They prove that this method performs better than others when the regime switches are given a form of parallel mean shift. However if the series are more dominated by trends than by mean shifts this method is not suitable. Fong & See (2001) examine issues in modelling the conditional variance of futures returns considering regime switches in volatility. Using daily settlement prices of the Goldman Sachs Commodity spot Index and futures, they find that the simple GARCH model is not adequate in the presence of regime shifts since this characteristic dominates the GARCH effects.

Symeonidis et al., (2012) analyze the relation between stock levels and the shape of the forward curve. They use daily futures prices on grains and livestock for the US market. As predicted by the theory of storage they demonstrate that low (high) inventory is related to curves in backwardation (contango) and price volatility is a decreasing function of stock levels for most of the considered commodities. Karali et al. (2011), using weekly data for soybean, corn and wheat in the US futures market, apply a Stochastic Volatility (SV) and Bayesian Seemingly Unrelated Regression (SUR) method to prove whether modelling volatility as a stochastic instead of a deterministic variable leads to improved inference about its relationship with seasonality, storage, and time to delivery, the latter also known as the Samuelson effect (Samuelson, 1965). The results show that volatility decreases the closer the time to delivery for soybeans and for wheat and increases for corn. This study provides limited support for the theory of storage and for Samuelson's maturity hypothesis. Black & Tonks (2000) use a multi-period futures model to test whether price volatility increases or decreases as the maturity date of the futures contract approaches (Samuelson effect). They find that if output uncertainty is resolved before the maturity of the contract, and if the retrade market (the market that appears after some new information arrives between the beginning and the maturity
of the contract) is informationally efficient, then the Samuelson hypothesis of increasing volatility before maturity will not occur.

Smith (2005) develops a Partially Overlapping Time Series (POTS) framework to model jointly volatility dynamics of traded futures contracts with different delivery dates. This model incorporates time-to-delivery, storability, seasonality and GARCH effects. Using US corn futures the author shows the dynamic structure of the data and reveals substantial inefficiency on the contract delivery. His results also provide evidence in favour of both the theory of storage and the relevance of the Samuelson effect. Lence & Hayes (2002) consider a ‘Rational Expectations Storage model’ to uncover the potential effects of the FAIR Act on the US markets for corn and soybeans. The results suggest that the price volatility that has been evident in the grain markets since the FAIR Act enactment was due to an unusual sequence of events that took place in the 1995 crop year. Yang et al. (2001) investigate the effects of the market-oriented US FAIR act 1996 on agricultural price volatility, using GARCH models for corn, oat, soybeans, wheat and cotton daily futures prices. The results show that agricultural liberalization policy causes: an increase in price volatility for the three major commodities (corn, soybean and wheat); a little change for oats; and a decrease for cotton.

Onour & Sergi (2011) compare the performance of models, when considering a normal instead of a t-distribution to capture volatility in food commodity prices. They use monthly prices for wheat, rice, sugar, beef, coffee, and groundnut and conclude that the t-distribution model is superior to the normal distribution one. This implies that the normality assumption of the residuals may lead to unreliable volatility results. Ramírez & Fadiga (2003) use soybean, sorghum and wheat deflated farm gate prices, in order to evaluate the performance of an asymmetric error A-GARCH model. They find that this type of model is a viable alternative for forecasting time-series where the conditional probability distribution of the dependent variable is asymmetric. With leptokurtic but not skewed errors, either the t-GARCH or the A-GARCH models are suggested. If there is positive kurtosis and right or left skewness then the Exponential Generalized Beta 2-GARCH or the A-GARCH are appropriate choices.

Long memory or long dependence processes in agricultural futures prices is considered by Jin & Frechette (2004). They find that a FIGARCH approach can be a better way to model long dependence inside the volatility by allowing for fractional integration in the variance equation. Elder & Jin (2007) argue that wavelet methodology can explain long memory processes in agricultural commodity futures better than the FIGARCH. Sephton (2009) develops the fractional integration idea by considering the leverage effect for the same dataset as Jin & Frechette (2004). He finds that FIAPARCH explains the long dependence in futures prices for some of the crops better than FIGARCH as some agricultural commodities futures display asymmetric leverage effects. Power & Turvey (2010) assess the presence of the long-memory phenomenon in the volatility of energy and agricultural commodity prices using the improved Hurst coefficient estimator in a wavelet-based R/S analysis. Using daily futures prices for coffee, cotton, sugar, cocoa, orange juice, wheat, live cattle, lean hogs, corn and soybeans, they find evidence of long memory and non-constant Hurst parameter in most of the considered commodities.

Egelkraut & García (2006) investigate the predictive accuracy of implied forward volatility for agricultural commodities with different seasonality. They use daily futures prices for corn, soybeans, soybean meal, wheat, and hogs and their results indicate that the implied forward volatility has better predictive power for commodities whose uncertainty resolution is concen-
trated in space and time. Giot (2003) evaluates the information content of the implied volatility for options on futures contracts of cacao, coffee and sugar. It is shown that lagged squared returns slightly improve the information content provided by the lagged implied volatility in a GARCH framework. Moreover, he shows that Value at Risk models that rely on past implied volatility perform as well as with ARCH type modelled conditional variance, concluding that implied volatility for the considered commodities has high information content.

Westerhoff & Reitz (2005) and Reitz & Westerhoff (2007) develop a simple commodity market model which explains the cyclical nature of commodity prices by considering the behaviour of two types of heterogeneous agents, the fundamentalists and the technical traders. They use commodity (agricultural and non-agricultural) monthly data in a Smooth Transition Autoregressive STAR-GARCH model. The results show that technical traders progressively enter the market as price deviates from its long run equilibrium. This trend-following pattern initially enforces market’s mispricing. At the same time fundamentalists become more active, forcing the price back to its fundamental value and leading to cyclical motions. Voituriez (2001) uses the ‘Trader Behaviour model’ for the palm oil market to test the hypothesis that the overlapping of the operators’ expectations (short versus long term expectation horizon) is triggering volatility changes. Using monthly prices he finds that volatility can increase as long as operators with a short term expectations horizon superimposes on the long term expectations trade, precluding the argument that larger markets reduce volatility.

Taylor (2004) compares the performance of the Periodic PGARCH with alternative Periodic Conditional Volatility (PCV) models using 5-minute high frequency data of cocoa futures. When considering high-frequency commodity futures returns, the periodicity in conditional return volatility is a key issue. He argues that not considering adequately the periodicities in high frequency data could lead to poor forecasts of future return volatility. Moreover he concludes that return volatility forecasts, obtained by the Spline PGARCH model, are shown to be less accurate than those generated by PCV models, but if used in a Value at Risk framework, the Spline model produces accurate and consistent VaR measures.

3.2.3 Empirical analysis of price volatility drivers

The literature on volatility drivers can broadly be classified as descriptive; based on modeling approaches; and based on empirical statistics.

There are some studies which, despite based on empirical results, do not present explicitly quantitative estimates. For instance Gilbert & Morgan (2010) recognize that the volatility levels during the recent crisis period are not as high as in the 70s (except for the rice), nevertheless they argue that factors like the global warming related climate shocks; oil price volatility transmitted via the biofuel production; and the relative large investment in index funds of futures markets may permanently increase volatility, especially in grain markets. Anderson & Nelgen (2012), using annual prices for rice, wheat, maize, soybean, sugar, cotton, coconut, coffee, beef, pork and poultry, assess the trade responses of 75 countries to provide empirical evidence on how governments, both in developing and developed countries, reacted during the past price spikes. The responses of agricultural-importing and agricultural-exporting
countries are offsetting and therefore the domestic price-stabilizing effect of their interventions was ineffective.

Nissanke (2012) states that the financialisation of commodity markets served as a transmission channel of the financial crisis from the developed to the developing world. He proposes more regulation and transparency for futures markets, minimal stockholding of essential commodities and innovative market oriented stabilization mechanisms like virtual reserve holdings or multi-tier transaction taxes. Jennifer Clapp (2009) considers agricultural commodities on different periods. She argues that the falling value of the US dollar; increasing speculation activities in commodity futures market; and trade measures have an important influence on food price volatility. Wright (2011) identifies as a major cause of food volatility the low grain stock levels due to mandated diversions for biofuels. He concludes that accumulated shocks such as the long drought in Australia and further biofuels boost due to oil price spike would have caused panic leading to a cascade of export bans and taxes. Chandrasekhar (2012) find that for the case of India the 2008 - 2010 food crises was driven mainly by food inflation and to a lesser extent by an increase in food price volatility.

Another group of literature uses mathematical modelling approaches to explain food price volatility. Babcock (2012) uses a ‘Stochastic Partial Equilibrium model’ to analyze the price volatility in US soybean, maize and wheat markets in order to assess the impact of US biofuel policies on agricultural price levels and volatility. He finds that US ethanol policy modestly increased maize prices from 2006-2009, but under tighter market conditions like in 2010-2011 the impacts on prices were larger. Moreover, US biofuel policy increases price volatility especially on the upside when demand for feedstocks is high or supply is short. Miao et al. (2011) model the ‘Herd Behaviour Theory’ to test the risk and regulation of price volatility of non-staple agricultural commodities in China. They find that the speculation and price manipulation, originated from asymmetries of information, bring about herd like behaviour. This phenomenon has pervasive and difficult to control consequences that affect especially the farmers and consumers.

The last group of selected literature uses different statistical methods to examine the food price volatility drivers. Zheng et al., (2008) apply an E-GARCH model to examine whether unexpected news affects food price volatility. They use monthly prices for 45 foodstuffs in the US. The results confirm that the amplifying effect of the news is present only in one third of the products. They argue that the increasing concentration of the distribution and retailing of food on large firms is absorbing the price volatility. Hayo et al. (2012) measure with a GARCH model the impact of the US monetary policy on the price volatility of different commodities (agricultural, livestock, energy and metals). They arrive at the conclusion that expected target interest rate changes and communications do decrease volatility, whereas unexpected interest rate movements and innovative measures do increase it. Roache (2010) runs a Spline-GARCH model on US maize, palm oil, rice, soybeans, sugar and wheat monthly spot prices to explain what drives low frequency volatility. He finds that the slow-moving component of spot price volatility is positively correlated across the different commodities, showing that there are common factors affecting the low frequency volatility. He proves that the variables with the largest effect on this type of volatility -since the mid 90s- are US inflation and US dollar exchange rate volatilities.

Du et al. (2011), use a model of ‘Stochastic Volatility with Merton Jump’ in returns (SVMJ) to investigate the role of speculation on crude oil price variability; and to what extent the volatil-
ity in oil price transmits to agricultural commodity markets. Using weekly futures prices on oil, corn and wheat they conclude that scalping\(^7\), speculation and petroleum inventories explain crude oil price volatility. Oil price shocks appear to trigger sharp price changes in agricultural commodities, especially on the corn and wheat markets, arguably because of the tightening interconnection between the energy and food markets.

In a study by IFPRI, Pietola et al. (2010) assess the empirical relationship between US weekly wheat prices, inventories, and volatility. They use a ‘Co-integrated vector-autoregressive’ model, and add price volatility in the form of the estimated variance to the basic model. The price movements and inventories have a significant negative relationship in the very short run, but this relation levels off over time. Thus, in the short run, increasing wheat prices coincide with decreasing inventories. Decreasing prices imply either inventory build-ups or postponement of inventory withdrawals.

Ghosh et al. (2010) employ GARCH, GARCH-dummy, EGARCH-M and OLS models to examine the price volatility and supply response for rice, jowar, bajra, maize, groundnut and cotton. Using annual prices, they check whether trade liberalization indeed exacerbates volatility of agricultural products in India. The results show that the prices of major agricultural products become more unstable in India the period after the signing of the WTO agreement. Swaray (2007) uses an Exponential E-GARCH and a Threshold T-GARCH model to assess the impact of the suspension of international commodity agreements on the asymmetry and persistency of the volatility. They employ monthly prices for cocoa, coffee, rubber, sugar and tin. The results demonstrate a rise in the asymmetry but a decrease in the persistence of the shocks.

3.2.4 Volatility spillover effects
A considerable share of the literature on food price volatility is on volatility spillover effects. Bivariate or multivariate GARCH models are the main statistical models for this group of research studies. However, based on the causality test results, other methods or a mixture of methods are also considered for this group of studies. Spot price or price indices are mainly used in the reviewed literature in this section. The spillover studies have different focuses. The volatility spillover effect can be recognised between commodities and macroeconomic variables, in the supply chain or inside the commodity markets.

3.2.4.1 Macroeconomic factors
The interaction among food commodity prices and macroeconomic variables has been an important area of research on food price volatility. The theory of Dutch Disease Syndrome is considered as theoretical framework for analysing the effects of oil price fluctuations on food price volatility in Nigeria by Udoh & Egwaikhide (2012). They employ GARCH, VAR, and OLS models to 1970-2008 domestic food prices for this study. They conclude that oil price volatility has a complementary relation with domestic inflation in food prices of Nigeria.

The conditional correlations between commodity futures and traditional asset classes in periods of high equity and bond volatility is the focus of Oleg (2011). He uses Bivariate GARCH model. The dataset consists of Shanghai Stock Index (SSI), China 10 year government bond

\(^7\) Scalping refers to a trading strategy that opens and closes contract positions within a very short period of time to realize small gains.
index, and a set of commodities such as corn, cotton, oats, soybean meal, soybean oil, soybeans, sugar, copper and aluminium, and heating oil for the period 2006 to 2010. The conditional correlation between commodity futures and the Shanghai Stock Index (SSI) rises in period of recession when market risk rises. The negative correlation between treasury bonds and commodity futures rises with the bond volatility, suggesting that a bond and commodity portfolio should not be tilted more towards commodity futures in periods of high bond volatility.

Busse et al. (2011) analyse the behaviour of price volatility of the EU biofuel markets during and after the 2006 - 2008 event and investigate the correlation in price volatility of different commodities and their evolution over time. They use ARMA-GARCH(1,1) and dynamic conditional correlation Model (DCC) (categorised as MGARCH model) with rapeseed futures price of “Marché à Terme International de France (MATIF)” in Paris, soybean spot price from Brazil, rapeseed oil prices and soybean oil prices from Rotterdam in Netherlands, and Brent crude oil one month forward prices. The results show a relatively high persistency in volatility in all series. They mention that the model neither allows for conclusions about causal mechanisms of volatility spillovers nor is it able to capture the magnitude of influence of one market on the other. They found a non-stable and increasing correlation between the returns of rapeseed in MATIF and crude oil prices. They concluded that the correlations of rapeseed price returns with vegetable oil and soybean price returns on the spot market are much lower than these with crude oil.

Short run deviations from the relationship between food prices and macroeconomic factors drive volatility is studied by Apergis & Rezitis (2011). They use GARCH-X with data from Greece on food index, money supply, income per capita, real exchange rate, and budget deficit/surplus during 1985 – 2007. They find cointegration between relative food prices and macroeconomic variables (real public deficit, real money supply, real exchange rate and per capita income) and all macroeconomic variables exerted an effect on relative food prices. Moreover, results are valid with and without the presence of a structural break (1992 CAP restructuring).

Apergis & Rezitis (2003b) employ a multivariate GARCH model including the Greece food price index. Macroeconomic variables such as money supply, income per capita, real exchange rate, budget deficit/surplus during 1985–1999 are used in order to investigate the volatility spillovers effects between food and macroeconomic fundamentals. They find that additional to the effect of the volatility of food prices on its own volatility, significant and positive effects of macroeconomic volatility on food prices volatility can be recognised.

3.2.4.2 Volatility spillovers through supply chain
Another area of spillover effect volatility is the volatility transfer inside the supply chain. The interaction among input prices, retail prices and output prices is one of the focuses of the volatility studies.

Khaligh et al. (2012) is one of the recent studies on this issue. They used ECVAR and MVGARCH to examine the relative uncertainty of prices in the agricultural input, agricultural output, and retail food markets, as well as the degree by which price uncertainty in one market affects price uncertainty in the others for poultry market in Iran. They have used agricultural input prices index, producer prices index, and retail prices index of poultry market during
1997 – 2010. They find that information generated by both agricultural input and retail food prices could lead to changes in the volatility of agricultural output prices.

Another early paper on this issue is Apergis & Rezitis (2003b). They used ECVAR and MVGARCH in order to investigate volatility spillover effects between agricultural input, output and retail food prices in Greece. They used Greece agricultural input price index, agricultural output prices index, retail food price index \((1990=100)\) for the period 1985 - 1999. They conclude that the volatility of retail food prices had a larger impact than volatility of input prices on the volatility of output prices, indicating that demand-specific factors are stronger than cost factors in affecting the volatility of output prices.

Kostov & Mcerlean (2004) criticized Apergis & Rezitis (2003b). They argue that as in other financial markets, the theoretical framework of mixtures of distribution hypothesis (MDH) can explain the spillover effect better. They argue that a proper model for explaining agricultural price volatility should include (own) volume.

One of the first studies in this area of volatility analysis is Buguk et al. (2003). They examine the extent to which volatility in primary input markets - soybeans and corn - spills over into feed and fed animal catfish-market. They use the US catfish farm level price, catfish wholesale price, and corn, soybean, menhaden\(^8\), feed (32\% protein) prices. AR-EGARCH and modified univariate EGARCH models are applied in this study. There is significant unidirectional spillover between corn, soybean, and menhaden prices and catfish prices (feed, farm, and wholesale-level fish prices). Additionally, the market structure may have impacts on the asymmetric transmission of volatility. In this case, farmers hold "market power" and transmit asymmetric volatility at the farm level and farmer-owners are the primary decision makers in this market.

3.2.4.3 Volatility spillovers in commodity market

The last group of studies on volatility spillover effects addresses interdependencies between commodity markets, both within or between countries.

The major question for Sehgal et al. (2013) is whether the India commodities futures market effectively served price discovery, and if the introduction of futures trading has resulted in volatility transmission to spot market. They use VECM - Bivariate EGARCH on agricultural commodities such as chana, guar seed, soybean, kapas, potato agra; metal commodities such as gold, silver, zinc, lead, copper; energy commodities such as natural gas, crude oil, and indexes such as comdex, agri-index, metal-Index, energy-index for the period 2003 – 2011. They find that the error correction term of the spot market is greater than that of the future market for all commodities and indexes except for natural gas. It means spot price adjusts more than futures. Additionally, for soybean, zinc and natural gas there are bivariate volatility spillovers but the effect is stronger from the spot to the futures market, whereas for the rest of commodities there are no significant spillover effects.

Serra (2011) assesses the linkages between price volatility at different levels of the Spanish beef marketing chain resulting from the Spanish Bovine Spongiform Encephalopathy (BSE) crisis. She used the farm-gate and consumer beef prices in Spain for the period 1996 –

\(^8\) Menhaden is genera of marine fish and is being used as feed for livestock and aquaculture, such as salmon, shrimp, tilapia and catfish.
2005. The smooth transition conditional correlation GARCH is applied. She concludes that during turbulent times, price volatilities can be negatively correlated and one cannot expect that stabilizing one market will lead to stability in other related markets.

Rezitis & Stavropoulos (2011) examine the implications of the rational expectations in a primary commodity sector with the use of a structural econometric model with endogenous risk. They apply a MGARCH model for major meat markets in Greece (beef, lamb, pork, and broiler) from 1993 – 2006. They conclude that uncertainty caused by price volatility is a restrictive factor for the growth of the Greek meat industry.

In contrast, some of the studies have a rather specific focus on spot prices of multiple commodities. The issues surrounding the rise of biofuels motivate Serra et al. (2010) to use a VECM-MGARCH model with BEKK specification for Brazilian sugar, ethanol, and oil prices from 2000 – 2008. This approach allows evaluating price volatility transmission in the Brazilian ethanol industry over time and across markets (oil, ethanol and sugar). They find that an increase in crude oil / sugar prices has ended up in higher ethanol prices and, in the short run, higher price volatility. Moreover, while crude oil and sugar prices are exogenous for long-run parameters, the responses of these prices to changes occurring in the other markets are captured by short-run parameters. Given that ethanol markets have strengthened the link between food and energy markets, both sugar and oil prices are found to respond to changes in the other prices inside the model for oil, sugar and ethanol.

A group of studies have looked into the volatility spillover effect at the level of many countries and commodities or at the international level.

Alom et al. (2011) use Multivariate Threshold GARCH (MTGARCH) to analyze the relationship of inter-country food price returns. The MTGARCH consists of mean and variance equations (two stage model). Therefore, the spillover effect of food price returns is analysed at the mean level of the returns and for the volatility of the returns separately. They consider food price indices of Australia, New Zealand, the USA, Korea, Singapore, Hong Kong, Taiwan, India and Thailand for the period 1995-2010. The countries are selected in a way that cover importers and net exporters of food products, geographic spread throughout the region, recently grown economies and participating in free trade agreements. They conclude that there is no strong spillover effects at the mean level of the returns among countries except some evidence of regional cross country mean returns spillover effects mainly with geographical proximity. A strong mean spillover effect is revealed from the USA market to all other markets. Net food importers are highly influenced when the magnitudes are low for net exporter countries. Secondly, there is strong evidence of own lagged and cross innovation spillover and own and cross volatility persistence spillover effects of food price returns. Australia has the least influence in terms of volatility spillover effects. Despite the unique influence of the US market in terms of mean spillover effects, it is found that US market is less influential in case of volatility transmission where regional or geographical proximity matters.

Examining the volatility spillover at the international level between oil, food, and agricultural raw material prices is the research question of Kaltalioglu & Soytas (2011). They use aggregated price index of IMF dataset during 1980 – 2008. They consider agricultural raw material price index, food prices index and world oil prices index. They use the estimated volatility by ARMA, GARCH and EGARCH models to test the spillover effect by the help of Cheung & Ng (1996) correlation test procedure. They argue that there is no volatility spillover from the oil
returns to the food returns and there is only a contemporaneous link between oil and agricultural raw materials.

3.2.5 Interaction between spot and futures price volatility

The major focus of some of the studies is the relation between futures and spot markets. Will et al. (2012), by doing a literature review of 35 empirical studies conclude that according to current state of research, the alleged financial speculation in commodity futures markets does not have a significant impact on spot prices' level or volatility, instead they find that fundamental factors seem to be the real responsible.

The next studies test the causal effects of futures price speculation on spot prices using different methods, data and assumptions. Algieri (2012) looks for relationships between (excessive9) speculation and price volatility, using as proxies for speculation the share of total open interest positions held by non-commercial traders and the speculative pressure. She applies Granger causality tests to find reciprocal effects between futures markets and volatility in spot markets for wheat, maize, soybean, palm kernel, palm oil, barley and rice. Her findings prove no significant relationships for the rice and soybeans. In the case of wheat, volatility leads the speculation, whereas for the maize there is a more complex bidirectional relation. Bohl & Stephan (2012) use expected and unexpected speculative open interest as explanatory variables, controlling for aggregate trading volume and aggregate open interest. They apply a GARCH model using weekly spot and futures prices for corn, soybeans, soft red wheat and sugar. Their results reveal that even though futures prices tend to lead spot prices in agricultural markets, the speculation seems not to hinder the price discovery process. Von Braun & Tadesse (2012) used a Seemingly Unrelated Regression to test the impact of supply shocks (production), oil price shocks and futures market speculation on spot returns and volatility. They consider monthly spot prices for maize, wheat, rice and soybeans. The realized volatility is calculated as the standard deviation from the long run average price. The trading volume of commercial and non-commercial positions in futures markets are used as a proxy for speculation. The results show that the speculation has a larger impact than oil and supply shocks on spot price spikes, and oil shocks have a larger impact than speculation and supply shocks on spot price volatility. Dwyer et al. (2011) examine the fundamental and financial factors, especially Index Funds investment, as drivers of the level and volatility of commodity prices. Using graphical representations of daily and monthly spot and futures index prices, they conclude that despite speculators may have some impact on the spot price volatility, their contribution seems to be short term and relative small if compared with the effect of the fundamentals.

The interaction between spot prices and futures of group of agricultural and non agricultural commodities is the main focus of Dwyer et al. (2012). They use spot prices and futures from the Chicago Board of Trade (CBOT) price data for agricultural commodities (corn, soybeans and wheat) and London Metal Exchange (LME) prices for non-agricultural commodities (US natural gas, gold, silver, aluminium, copper, nickel and zinc) for the period 1997-2011. A GARCH (1,1) model and principal component analysis are applied for this research. The re-

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9 Is the level of speculation that surpasses the need of hedging transactions and market liquidity.
results for the agricultural commodities (corn, soybeans and wheat) show strong evidence that developments in futures prices have a bearing on spot prices. For the agricultural products, the authors conclude that the results of granger test is acceptable as spot markets for agricultural commodities tend to be relatively fragmented (i.e. they consist of a relatively large number of producers with specialist local knowledge). They use the descriptive analysis and PCE. They claim that since 2003, individual commodity prices are driven primarily by a single common factor, which appears to be related to macroeconomic fundamentals. Finally, they conclude that the theoretical relationship between commodity futures and spot prices does not imply that changes in futures prices need necessarily lead to changes in spot prices.

The relative importance of drivers on corn price volatility is analysed by McPhail et al. (2012). They use structural vector autoregressive (SVAR) model and the forecast error variance decomposition. The data which are used in this study consists of US corn futures prices, working speculative index, crude oil spot prices, Baltic dry index (BDI) as a proxy of corn demand, and US ethanol production. They find that within a month about 73% of variation in real corn prices is accounted for by corn market shocks, which include any shocks affecting corn prices not captured by shocks in global demand, crude oil prices, ethanol demand, or speculation demand. Additionally, speculation demand shocks explain about 14% of corn price variation within a month, crude oil prices explain about 9.5%, and ethanol demand explains about 3%, while global demand explains about 1%. This is addressed by computing the forecast error variance decomposition based on the SVAR estimates. They conclude that in addition to corn market shocks, speculation is the most important of the considered factors in explaining corn price variations, but only in the short run. However, in the long run, energy is the most important followed by global demand, while the effect of speculation is minimal given the effects of global demand and energy.

The efficiency of futures market for agricultural commodities is the major focus of Shanmugam et al. (2012). They also interested in causal relation and volatility aspects between spot and futures prices during periods of serious price spikes and distortions. They consider the return price data of 12 commodities from different markets in US. They use corn, soybeans, wheat, soybean oil, cotton No. 2, coffee C, sugar No. 11, cocoa, live cattle, lean hogs and feeder cattle. The near month’s futures contract and spot prices for the above commodities for the period of 1995-2011 are considered. The cointegration test shows a long term relation between spot and future prices for all commodities. Additionally, linear Granger causality test is applied. The test shows that futures prices are Granger causal for spot prices in the case of wheat, soybean and lean hogs during 1995-2011. A GARCH (1,1) model is applied for all series, providing evidence for volatility clustering and persistency throughout the period. No specific evidence is found that volatility has increased significantly in the post 2006 period. Overall, the authors conclude that futures markets in the US are highly efficient for the agricultural commodities.

Dahl & Iglesias (2009) analyze the implications of Muth (1961)’s theory within a new and general empirical modelling framework. According to Muth (1961)’s rational expectations theory, current spot prices are functional of future prices (and vice versa). Therefore it is suggested that spot prices should be modelled in conjunction with traded commodity prices futures. They used AR-GARCH model for many agricultural commodities in USA. Authors supported the Muth (1961) rational expectation theory, i.e., It means spot price risk associated with storable commodities has predictive content. Furthermore, inventory carryover,
which is reduced by a larger price variance, creates autoregressive conditional heteroskedasticity in storable commodity spot prices.

Yang et al. (2005) empirically examine the lead-lag relationships between the level of futures trading activity and cash price volatility in commodity futures markets by the help of forecast error variance decompositions. They used corn, soybean, wheat, cotton, hogs, and live cattle futures of US market and sugar at international level during 1992 – 2001. They conclude that unexpected increase in futures trading volume unidirectionally causes an increase in cash price volatility for most commodities, while there is weak causal feedback between open interest and cash price volatility.

3.2.6 Price formation in futures markets
This section presents a compilation of studies that concentrate in the impact of index fund speculation on the level and volatility of futures prices. Despite most of the authors arrive at similar conclusions, their methodologies, data sets and assumptions vary across the studies. Aulerich et al. (2012) assess the impact of financial index investment in agricultural futures prices returns and (implied) volatility, using disaggregated data from the Large Trading Reporting System (LTRS) of the US Commodity Futures Trading Commission (CFTC). The advantages of this new data set are that the commodity index trader positions are available in a daily frequency; contracts are separated by maturity; and there is information available before 2006. They use daily futures prices for corn, soybeans, soybean oil, wheat, feeder cattle, lean hogs, live cattle, cocoa, cotton, coffee and sugar. The authors apply Bivariate Granger causality tests using the changes in aggregate new net inflows and the rolling of existing index positions from one contract to another as explanatory variables. The results confirm no bidirectional causality between aggregate positions and returns/volatility, whereas for the rolling positions, they also do not cause futures price returns or volatility. Brunetti et al. (2011) apply also Granger causality tests using Generalized Methods of Moments with Newey-West robust standard errors. They use five commodities but only corn from agricultural futures markets and data from the LTRS. Their findings demonstrate that speculators do not lead price changes, rather they reduce market volatility and add liquidity to the system.

Irwin & Sanders (2012) test the ‘Masters Hypothesis’ applying the Fama-MacBeth cross-sectional regression test. They argue that the variation of index funds across markets at a given point in time may be more informative than the behaviour of one market across time. They use quarterly data for corn, soybeans, soybean oil, wheat, cotton, live cattle, feeder cattle, lean hogs, coffee, sugar and cocoa futures prices. As a proxy for the index fund activity they use the Index Investment Data from the US Commodity Futures Trading Commission, found to be more accurate than the Supplemental and Disaggregated Commitments of Traders, because of the adjustment by ‘special calls’. The findings fail to demonstrate the ‘Masters Hypothesis’. There is no significant evidence of index funds activity affecting returns or volatility in the considered futures prices, implying that the markets are sufficiently liquid and that futures’ traders do not confuse index fund position changes with changes in markets’ fundamentals. Bastianin et al. (2012) investigate whether speculation drives volatility and levels of futures price returns and which macroeconomic or financial factors are relevant to model the returns. They apply GARCH and MGARCH models using weekly data for corn,

10 The Masters hypothesis was called after the hedge fund manager Michael Masters, who argues that the large buy-side positions from index funds created a bubble in commodities, moving prices far away from their fundamental values.
oats, soybean oil, soybeans and wheat; and gasoline, heating oil, crude oil and natural gas. Their findings show that excess speculation does not significantly explain commodities’ returns, whereas macroeconomic and financial factors are more relevant in this regard, especially equity returns and exchange rates. They also observe that spillover effects are statistically relevant within and between both groups i.e. energy and agricultural commodities.

Bohl et al. (2012) use a Stochastic Volatility model to find out whether the index fund investment activity induces an increment of futures’ prices volatility. This type of model can be used to control for simultaneity problems between conditional volatility and trading activity that are jointly influenced by new information. They use weekly data for cocoa, coffee, corn, cotton, feeder cattle, lean hogs, live cattle, soybean oil, soybeans, sugar and soft/hard red wheat. The results show that there is no robust evidence that expected and unexpected commodity index trading is causing higher volatility in futures markets. Instead, they find that unexpected overall trading volume is positively correlated with volatility and provokes volatility persistence. Sanders & Irwin (2011) look into the impact of index fund investment in US commodity futures market. They use log relative returns of weekly nearby futures contracts for wheat, soybean and corn and commodity index trader (CIT) data. They use granger causality tests and long-horizon regression. The results do not show any evidence of linking commodity index positions with the grain futures market prices.

Gilbert (2012) focuses on the impacts of speculative trading on grain price volatilities. He uses the cash prices, four front futures contracts on the Chicago Board of Trade (CBOT) for soft wheat, corn, soybeans and soybean oil. Additionally, he uses position data which are taken from CBOT Commitments of Traders report for the period on 2006-2011. A GARCH (1,1)-X model has been used by adding lagged position variables to normal GARCH (1,1) model. The results do not present any statistical significant effects of financialisation on cash and futures returns of Chicago grains and vegetable oil markets.

Manera et al. (2012) conduct a detail study on the speculation spillover issue. They use an OLS model to see if macroeconomic factors and speculation have effects on returns of the futures prices of different energy and non-energy commodities. In the next stage they use Multivariate GARCH DCC model to recognise the possibility of spillover across markets in speculations. They use four energy commodities (light sweet crude oil, heating oil, gasoline and natural gas) from New York Mercantile Exchange (NYMEX), five agricultural commodities (corn, oats, soybean oil and soybeans from Chicago Board of Trade and wheat from Kansas Board of Trade). The returns of futures price series are taken from Thomson Financials. Working’s T (1960) index is calculated by using Commodity Futures Trading Commission (CFTC) weekly data. This index measures the excess of speculation relative to hedging activity. Macroeconomic data consists of Moody’s corporate bond yield, Treasury bill, S&P 500 index and a weighted exchange rate index of US dollar. The analysis based on weekly frequency data during 1986-2010. The results of econometric model show that speculation which is measured by working’s T index doesn’t seem to significantly affect returns. Additionally, the results show that a depreciation of US dollar increases futures prices. S&P 500 has a significant and positive effect on the returns. As speculation is generally poorly significant, they do not detect a relevant impact on own market or other markets’ returns. The results show a linkage between energy market and biofuel market in recent years.
The effect of Rolling period\textsuperscript{11}, Contango\textsuperscript{12} and Backwardation\textsuperscript{13} are the main focus of Frenk & Turbeville (2011). By using a simple method, the authors seek to test whether the behaviour of one specific set of commodity futures market participants (the group known collectively as Commodity Index Trader (CIT)) has directly impacted commodities futures prices in a manner independent of fundamental supply and demand forces. They examine the futures prices before, during and after the monthly CIT “Roll” period. They have considered the Roll period of 6 commodities contained in GSCI (wheat, oil, heating oil, corn, feeder cattle and natural gas) from 1983 to 2011. The data are taken from Bloomberg data stream. They look simply into the distribution of data and they use the non-parametric Mann-Whitney U-Test to compare different periods. The results show that commodities futures price spreads display a consistent bias towards an increasing Contango curve during the Roll period. They find that this persistent Contango bias did not exist prior to the large growth in commodity index trading from 2004.

\section{Assessment of drivers}

In this section, we focus on the main results from the literature regarding the extent to which certain factors drive agricultural price volatility. The preceding sections have highlighted the influence of the researchers’ choices on the results. The variability in terms of methods employed, of commodities included, of differences in frequency, and nature of the price data and sample period suggest that some caution is warranted in extracting the main results. In the following subsections, we distinguish between those drivers where the scientific literature seems to be largely unanimous, and the more conflicting areas. We focus on the results for the more recent episodes in food price volatility (short-run perspective) but augment these, where feasible, with the expected development and impact of the identified drivers in the years to come (long-run perspective).

\subsection{Supply}

There seems to be a high level of agreement in the existing literature with regard to the rule which short run supply shocks play for increases in volatility. For crops, short term changes to expected harvests contribute to price volatility. This is particular visible on futures markets, where prices immediately before the harvesting dates in key producing and exporting regions are highly responsive to new information about weather changes or about sudden occurrences of pests. Similarly, the few studies on livestock prices usually find that the disease outbreaks, which in addition to the direct reduction in supply might also affect internationally traded volumes through trade restrictions because of quarantine requirements negatively,

\textsuperscript{11} A set period from the 5th to 9th business day of each month, during which funds tracking the most popular commodity index, the Standard & Poor’s Goldman Sachs Commodity Index (GSCI) must roll forward their expiring futures contracts.

\textsuperscript{12} A situation where the futures price of a commodity is above the expected future spot price. Contango refers to a situation where the future spot price is below the current price, and people are willing to pay more for a commodity at some point in the future than the actual expected price of the commodity.

\textsuperscript{13} Inverse to the Contango is Backwardation. Backwardation is the market condition where the price of a forward or futures contract is trading below the expected spot price at contract maturity.
lead to a thinning of the market on the supply side and thus to increased price volatility. Some studies emphasise the role of shocks on input markets, although the imminent effect on output price volatility is somewhat mitigated through the specific temporal nature of typical agricultural production processes, where the supply response usually takes place with a substantial delay after most inputs are applied.

The role of long-run supply shifters is discussed more controversially in the literature. There is still some degree of accordance with regard to the role which the diversion of agricultural land to non-agricultural uses plays as a long-run shifter of the supply curve for agricultural products. However, a minority of studies judges global land supplies as sufficiently high and expects the global supply of agricultural goods to be able to keep pace with the expected demand increases. But even these studies concede that pressure on local land markets might lead to locally thinner markets; the impact on local price volatility then depends in turn on the extent of market integration between local and international prices. Substantial underinvestment in agricultural technologies at the global level is often mentioned as an additional long-term factor. In light of the high returns promised by investment in publicly available agricultural innovations, the underinvestment observed over the past two decades or so is undoubtedly a challenge for the years to come. However, whether the looming danger of insufficient productivity growth in the future will have any impact on price volatility is much less clear than the (already hotly debated) expected increasing impact on agricultural price levels.

Climate change is also often mentioned as one of the long term drivers of price volatility. Many scenarios for the future climate predict an increased frequency of extreme weather events with possibly negative impact on agricultural supply in virtually all agricultural products. An increase in the frequency of crop failures, or an increase in the number of disease outbreaks in combination with spreading of tropical and subtropical animal disease to more temperate climate zones would then indeed suggest that prices of the corresponding commodities will fluctuate more strongly than in the past decades. However, the literature indicates that global agricultural commodity prices do react more strongly to supply shocks in key producing regions than to globally occurring changes which affect all regions. This suggests that the impact of climate change on price volatility might be more complex than this simple line of reasoning suggests. In particular, its impact will be specific for commodities and regions.

A final factor in the list of long-run supply shifters is structural change in farming. The argument relies on the presumed higher resilience of small-scale, locally adapted agricultural structures in comparison to more commercially oriented large scale farming. This argument is not frequently mentioned, which is perfectly understandable since the question of resilience is again very context-specific. The consensus in the existing literature does not count structural change in agricultural systems toward more commercialization as one of the key driving factor towards increased price volatility.

4.2 Demand
On the demand side, the most frequently listed short-run driver is the increasing role of bioenergy, in particularly grain- or oilseed-based biofuels. Virtually all studies which look into demand side drivers discuss the role of bioenergy markets and policies for agricultural price volatility. There exists general consent that biofuel policies exert a substantial influence on price volatility since in most countries the relevant policies are implemented in a way which makes the resulting additional demand for agricultural raw materials rather price inelastic. A
given quantity shock requires then, *ceteris paribus*, a stronger price change in order to balance supply and demand. This concern about the lack of flexibility in biofuel mandates is particularly strong for corn-based bioethanol in the US, and vegetable oil-based biodiesel in the EU. While the general mechanism is broadly supported in the literature, there is much less agreement as to its relative importance. The most recent price developments for corn in 2012 illustrate that even the US bioethanol blending requirements are actually more flexible than it was initially expected, mainly because of the possibilities to roll over parts of the blending mandates between years.

In the 2007/08 episode, additional demand was observed by hoarding behaviour of some major importing countries. In most cases, such hoarding was observed in particular in those countries where the import of agricultural commodities is substantially controlled by state trading enterprises. The resulting positive demand shock at a time where prices were already following an upward trend exacerbated the price momentum but also had an impact on price volatility since the market tended to react very sensitive to new information, even new rumours, about the actions of state trading enterprises. Timmer (2010) highlights the particular relevance of such hoarding behaviour also at the individual level of consumer and producers.

In the long-run, demand for agricultural products with potential repercussions on price volatility is affected by three factors. First, income and population growth in developing countries is expected to exert an influence on the tightness of the global balance sheets for major food crops. The tighter the markets, the more susceptible to shocks they will generally be. Second, the role of the westernisation of diets might additionally exacerbate these shifts in the constellation of supply and demand. The increasing move toward higher meat shares in hitherto more vegetarian diets in Asia and Africa will lead to an increasing competition in major agricultural products between food and feed. Again, this will make market balances tighter unless rapid productivity growth (see above) overcompensates this effect. Third, the longer term perspectives for bioenergy, in particular biofuels, could inflate price volatility levels if the policy instruments employed are retained with similar inflexibility as in the past. The literature is relatively in consent on these longer run factors.

### 4.3 Storage

Most of the staple foods traded on international markets are storable. Carry-over stocks from year to year (i.e., the quantities in stock in excess of working stocks) play a crucial role for dampening price volatility over time. The nature of demand for and supply from storage, in combination with the impossibility of negative stocks, suggest that the impact of stocks on price volatility is asymmetric: At relatively low stock levels, the dampening effect is close to nil, while with sufficiently filled stocks, storage demand and supply is able to neutralize shocks to a substantial extent. Since stocking outs are likely to occur at high prices, while low prices increase *ceteris paribus* the demand for storage, phases of increased volatility for storable commodities are likely to coincide with high prices (Wright, 2011).

The usual approach in the literature is based on an analysis of stocks-to-use ratios, and gives rather robust results. For cereals, low levels of carry-over stocks are indeed a major factor for volatility increases. For wheat, the early literature already reports a perceived threshold of about 20% although there is substantial residual uncertainty about the exact figure where to locate the critical threshold.
Speculative stockholding is a phenomenon which also can exert substantial impact on price volatility. The literature here is often related to the emergence of bubbles in commodity markets (which seemed to play a role in futures price developments for major agricultural products over the past decades, e.g., Gutierrez (2012). However, for the specific case of the 2007/08 crisis, speculative stockholding has been regularly rejected in the literature on the causes of the crisis because the official figures on stocks did not see any increase in stocks over the relevant time period.

There is a third aspect related to storage which probably will also exert a substantial impact on price volatility in the longer term. Official figures on stocks are usually published regularly, and aim at giving information on both private and public stocks, e.g., for major crops at a monthly frequency by the USDA in their World Agricultural Supply and Demand Estimates (WASDE). The published information on public stocks typically relies on national statistics, with varying degrees of precision. Reasons include the reluctance of some countries to provide sufficient and transparent figures on their public stocks (usually for political reasons), but also general problems with the statistical information systems in other countries. However, with the exception of a few countries, the situation is drastically worse as far as private holdings of stocks are concerned. A few countries (notably the US for major crops) have established reporting systems at both the farm and the downstream sector level. The vast majority of countries rely on ‘guesstimates’ for private stocks. Thus, figures on global stocks are expected to be severely affected by statistical errors.

The impact on price volatility is impressively illustrated by the development of wheat prices over the 2007/2008 crisis. Prices started to increase at an accelerating pace after the publication of the USDA WASDE report in May 2007. This report included the first forecast for the ending stocks of the wheat marketing year 2007/2008, and contained an alarmingly low figure for expected global wheat stocks at the end of this marketing year in June 2008. In the WASDE reports for the subsequent 9 months, the forecasts were even further reduced. The turning point was reached with the report of March 2008 when the forecast at 110 million t of wheat was again roughly equal to the forecast of May 2007; subsequently, the numbers where substantially increased to a final estimate of 126 million t. The turning point in March 2008 not only marked the end of the rapid price increases but also the end of a period of inflated price volatility. This episode emphasizes the importance of reliable information on stocks (and it also serves as a strong argument in favour of the efforts started by governments and international organisation in the AMIS initiative).

**4.4 Macroeconomic factors**

Under the admittedly broadly defined category of macro-economic factors, two subcategories can be identified. First, spillover effects from other markets outside agriculture are found to play an important role both for the development of price volatility over the past five years, and are expected to continue to do so for the years to come. Second, general economic policies and developments affect agricultural markets since the latter have become increasingly integrated with the rest of the economy. Macro policies have a substantial impact on the stability of a whole economy which in turn affects price volatility for agricultural products.

Spillover effects from markets outside agriculture are frequently listed among the major explanatory factors for the 2007/08 food price crisis. Most studies emphasise the importance of energy markets (usually exemplified through the crude oil markets), and conclude that these have been an important factor in driving the price developments before 2007/08. The causal
linkages, however, are much less clear. There are a number of potential linkages discussed in the literature. The intensification of agriculture in many production systems worldwide has made production processes in crop production more dependent on fossil fuels over time since fossil fuels are of substantial importance directly through diesel use in agriculture, and indirectly via increased use of fertilisers and pesticides, which both depend on fossil fuels in their production. E.g., a substantial part of nitrogen fertiliser production is highly dependent on natural gas. Thus, the relevance of the fossil fuel market as an input to agricultural production has increased over time. Over the past decade, the interdependence between agricultural and energy markets was further increased through the emergence of bioenergy related policies, mostly in emerging and industrialised economies. Biodiesel policies in the EU (Busse et al., 2012) and bioethanol policies in the US and Brazil (Serra et al., 2010) have made the price formation processes between energy and agricultural markets interrelated in a complex and often regime-dependent manner. The interdependence is not confined to price levels but leads also to price volatility spillover effects. Relative market sizes strongly suggest that the net effect of both input and output linkages leads to an inflated vulnerability of the relatively small international markets for agricultural products to price volatility shocks from the notoriously volatile global markets for crude oil.

Other commodity markets are occasionally mentioned as drivers of agricultural price volatility in the literature, too. Over the course of the food price crisis of 2007/08, virtually all major commodities were experiencing substantial price level changes. It is difficult to think of direct causal linkages between agricultural and most of the non-agricultural commodities, however. Therefore, most of the studies mentioning non-agricultural commodity market development focus on two indirect channels. First, macro-economic policies (which will be discussed in the next paragraph), and second, linkages through increasing financialisation (which deserves a separate section, see below).

Among macro-economic policies, exchange rates are viewed as important drivers of price levels. This holds in particular for the US-Dollar rates since most of the global trade in agricultural products is still denominated in US dollars. Volatility in exchange rates might hence be transmitted to domestic markets even in cases where international prices are not particularly volatile. For the 2007/08 food price crisis, exchange rates are generally acknowledged as a driver for price levels but are not singled out as particularly important for volatility transmission. For the longer run, exchange rate fluctuations might become more important, depending on the overall stability of the world economy.

This leads to the second major factor among macro-economic policies, the changing nature of monetary policies in many if not virtually all countries. Money authorities have gradually loosened monetary policy regimes in response to the economic and financial crisis and have injected liquidity for a long period of time, in combination with interest rate policies which frequently lead to negative real interest rates. The US’ quantitative easing policies are an important case at hand, as is the recent move of the Japanese central bank to loosen its monetary policy and to weaken the Yen exchange rate. The loose monetary policies will likely put an upward pressure on general price levels in the longer run, although current sluggish economic growth suggests that there is no immediate danger of substantial inflation. The impact on price volatility, however, is already felt in the shorter run. With substantial and virtually open-ended liquidity injections, price boom and bust cycles for individual commodities including agricultural and food commodities become more likely. This mechanism is most likely an import driver for future price volatility.
4.5 Specific policies

The literature on the causes of the 2007/08 food price crisis reaches a broad consensus: Policy measures in the field of trade policies by both exporters and imports have contributed substantially to the price development for major agricultural products, in particular for crops. Timmer (2010) explores this in detail for the case of rice. Many exporters introduced some type of export restriction in order to shield domestic consumers from international price increases. The measures included export taxes, quotas, or complete bans. Importing countries often responded with import alleviations, e.g., tariff reductions, import levy reductions, or new preferential market access opportunities. The overall impact of these measures on global price levels and volatilities should not be underestimated. Even if it seemed to make perfectly sense from the perspective of an individual country to introduce some policy which allows for a wedge between international and domestic prices, the combined use of such policies in many countries at the same time added to the upward trend in international prices while reducing global trade volumes. The new world trade equilibrium was then characterized by higher prices in thinner markets. Such a constellation inevitably increases the susceptibility of agricultural markets to shocks, in particular if there is a substantial lag in re-adjusting trade policy measures.

It is difficult to predict how such agricultural policies are going to affect price volatility in the longer run. It will be crucial to which extent countries pursue ‘beggar-thy-neighbour’ policies in the future. The experience of the 2007/08 crisis has clearly shown that the outcome of the WTO Uruguay round with its (relatively) strict disciplines on bound tariffs and on the use of export subsidies is not effective against ‘beggar-thy-neighbour’ policies which aim at lowering domestic agrifood prices below the international level. The Uruguay round agreement is a child of the experience of the 80s and 90s, where the major concern was about pushing domestic agrifood prices above the international levels. In the aftermath of the crisis, many countries verbally committed themselves to aim at export policy related disciplines in the ongoing WTO negotiations. However, given the lack of progress in the ongoing WTO talks, it seems unlikely that effective rules on such policies will become mandatory in the near future. The observable move toward regional and preferential trade agreements in the past years cannot be expected to substitute for the lack of progress in the multilateral trade negotiations. It is more likely that the additional degrees of freedom which trading blocs have in negotiating such agreements might lead to a complex network of trade relationships which in total might be harmful to global market integration. In consequence, discretionary policies in the agricultural sector can be expected as an additional driver for higher price volatility in the future.

Another longer term factor, albeit observable at a much lower frequency, is related to agricultural policy cycles. In many countries of the world, in particular in OECD countries, agricultural policies are subject to major revisions in relatively constant phases (e.g., US farm bill legislation, EU Common Agricultural Policy). Major policy shifts cause uncertainty which might lead to a higher degree of caution in investments in production capacities. After the uncertainty is resolved, previously delayed decisions will be taken relatively quick, which might induce synchronisation in investments, and hence contribute to cyclical supply patterns which in turn might lead to low-frequency price volatility.

Specific policies in other economic sectors might also contribute to agricultural price volatility in the longer run. This holds particularly true for policy measures with an impact on land use. Bioenergy related policies have already been discussed above, but broader environmental
policies might also divert agricultural land to other purposes so that intensification of the remaining agricultural areas might become necessary. This would not necessarily lead to higher price volatility; however, since the relationship between intensification and output variability is complex.

4.6 Financialisation

Financialisation in the context of the overall economy usually refers to the increasing importance of financial organisations and institutions in comparison to real economic activities. In the context of price formation for agricultural and food products, the term is less clearly defined but usually refers to the increasing role of non-commercial investors (perceived important actors include index funds, hedge funds, and OTC swap dealers) in agricultural markets (usually in futures or options). Concerns are voiced that financialisation might hamper the price discovery function of futures markets so that agricultural prices both on spot and futures markets are driven by money rather than by fundamentals. In order to shed light on the impact of financialisation on agricultural price volatility, it is helpful to clearly distinguish three aspects of financialisation which might have an impact.

As a first point, financialisation might open the window for market manipulation if individual economic agents are sufficiently large to exert influence on price formation. This danger is particularly obvious in futures markets which are not sufficiently liquid. A recent episode in London cacao futures, dating from 2010, involved the funds Armajaro taking delivery at maturity of the July contract of cocoa volumes equivalent to about 7% of annual world production. Since the open position held by Armajaro was anticipated before maturity of the July contract, prices experienced a substantial increase in July. However, this episode also serves as an example how difficult such mid-term market manipulation attempts are. Over the second half of 2010, prices for cocoa dropped by about a quarter so that the actual profit over this period for Armajaro was likely negative. Nevertheless, market manipulation fears, be they justified or not, will lead to increase price volatility because of the uncertainty they introduce to the market. Transparency requirements, involving e.g., regular reporting on open positions, seems an appropriate and effective instrument for reducing market manipulation attempts.

Secondly, financialisation is often associated with speculative bubbles. Speculative bubbles are characterised by prices which grow over a longer period of time up to a point where market participants seem to (suddenly) realise that prices are way above the fundamental values. Bubbles are a common feature in market economies. They have also been observed for agricultural products as early as the 17th century, when the famous Dutch tulip bubble led first to skyrocketing tulip prices, which crumbled down quickly again after the bubble burst. Agricultural commodity price bubbles exert an increasing influence on price volatility through their typical boom and bust sequence. They have recently been identified in agricultural commodity prices on futures markets (e.g., for the 2007/08 food price crisis see Gutierrez (2012), too. However, as is clearly stated in the published literature, finding statistical evidence for the presence of a bubble does not allow tying down the culprits. Self-enforcing price trends (at least over a certain period) can be driven by any group active on the relevant market; e.g., for spot markets, hoarding behaviour of producers and consumers has been suggested as a major factor for the emergence of a price bubble. Experiences outside agriculture also suggest that bubbles (which are relatively easy to identify once the bubble has burst but difficult to recognise while a strong trend is present) are usually driven by a combi-
nation of factors, e.g., the house price bubble in the US before the economic and financial crisis was affected by credit approval practices, and by loose overall monetary policies, to name only two of the factors involved. In summary, bubbles seem to be a common feature in capitalist systems, and it is difficult to identify a clear mechanism to prevent their occurrence on agricultural commodity markets.

Thirdly, price volatility might be affected by the composition of traders in a given market. In the context of agricultural and food prices, the literature often singles out the behaviour of index funds on futures (and related financial derivatives) markets. Index funds are a relatively new phenomenon which became more important over the course of the increasing interest in exchange traded funds (ETF). Their typical strategy is based on mimicking the price of an underlying index so that no active management of the fund composition is necessary. In the case of agricultural markets, commodity index funds are of direct interest. Concerns about the impact which these funds have on price volatility are related to the trading strategy of such a broad index fund, which usually is composed of a number of different commodities with fixed weights in terms of values. In order to follow the price movements of the underlying broad commodity index, the fund has to sell and buy futures or options in response to any relative change in the prices of the single commodities. E.g., consider a hypothetical fund mimicking an index with 50% wheat and 50% copper. A price shock on the futures market might drive up the price of the copper's future. Thus, the value share of copper in the commodity basket becomes too high, which requires either reducing the investment in copper futures or increasing the value share of wheat. If the fund manager chooses the last option, volatility from the copper futures market might spill over to the wheat futures market (provided that the positions held by the index fund is substantial on the wheat futures market). However, if the first option is chosen (i.e., changing the position in the market where the price changes originated, in this example copper), the index fund would contribute to lower price volatility in this market. It seems natural to assume that most index fund managers follow this approach, simply because in a complex composite index it is much easier (and less costly) to adjust only those positions which actually changed. This hypothesis is not rejected by the current literature. Will et al. (2012) and Gilbert & Pfuderer (2013) survey the relevant publications and conclude that the vast majority of all studies attributes a stabilising function to the position changes associated with index funds trading.

The increasing number of positions held by index funds has one additional (albeit relatively minor) impact on price volatility on commodity futures markets. Since the funds are forced to roll over (i.e., switch from the contract close to maturity to the following one) in regular and foreseeable intervals, other market participants might anticipate the settlement of a huge number of long positions shortly before maturity, and might try to react to this. However, this would require market power the latter group. Empirically, this very short run effect has not been analysed until now.

4.7 Miscellaneous drivers of price volatility

Parts of the empirical literature emphasises the role of information shocks for price formation. For food and agricultural markets, food scares and scandals are one important shock affecting not only price levels but also volatility. The increasing media attention to negative news about food suggests that such news about food scares will lead to huge price drops, with a relatively slow and volatile recovery.
5 Conclusions
Price volatility on agricultural and food markets has attracted considerable attention in the literature, both in mainstream agricultural economics but also in related fields. This attention is reflected in a growing number of studies published in peer-review journals, which is augmented by both some high-profile reports from relevant organisations. In addition, the scientific community has responded to policymakers concerns by publishing many working papers and technical reports (so-called gray literature), a substantial part of which will go to the journal over the course of the next years.

This already rich (but still further emerging) body of literature allows for honing out a relatively clear picture about the driving factors of the price volatility patterns in the past years. The literature seems in broad agreement the fundamental factors explain most of the observed price volatility increases in recent times. Supply and demand side factors, which in the short run lead to thinner markets and thus make the price finding mechanism more susceptible to the arrival of new information, can be identified as the major drivers. Many of these drivers will continue to play out in the medium and long-run. On the supply side, climate change might increase the frequency of rare detrimental weather events, which will generally lead to higher price volatility. The stagnation in terms of productivity growth in agriculture in particular in OECD countries, exacerbated by land diversion for non-agricultural purposes, will certainly not help in mitigating the susceptibility of agricultural and food markets for episodes of high price volatility. On the demand side, population and income growth are often mentioned as long-run driving factors. These long-term trends will be difficult to change, in contrast to another major driver, biofuel policies. The specific instruments employed in this policy field often lead to additional demand which is very price-inelastic. Given that current biofuel policies are not responsive in their requirements to short- and medium-run price changes in the main input markets, price volatility will be elevated.

However, information on stocks is an important factor, too. Much of the de-centralised stock-holding is not regularly monitored; even if public or private entities have the necessary information, these are still often treated as state secrets (public bodies) or as potentially very rewarding private information (private bodies). With increasingly integrated agricultural markets worldwide, national level information on carryover stocks, in particular in key exporting or importing countries, spills over to global markets. Country-specific statistical information systems have an important role to play in the future, as does the global coordination of information on available stocks, which is now pushed forward within the AMIS initiative.

Agriculture nowadays is integrated into the overall economy (even though most countries interfere in agricultural markets much more intensively than in other sectors of the economy). The interdependencies with non-agricultural markets exist both on the input and on the output side. Increasing integration implies also that price volatility from input markets will have repercussions on agricultural and food markets. This mechanism has been established in the literature for fossil fuel price volatility (and is exacerbated through biofuel policies). However, as a part of the overall economy, agricultural price formation will also be subject to the impacts of overall economic policy, in particular monetary policy. Inflationary risks will affect price volatility directly and indirectly (because many investors view agricultural assets as relatively safe from inflation).

The role of speculation and financialisation for price volatility on agricultural and food markets is, however, less clearly received in the literature. This is not surprising since speculation
itself is a very broad phenomenon which is difficult to capture quantitatively. Financialisation, on the other hand, is a relatively new phenomenon but again is not always consistently defined across different studies. However, the literature seems to have reached broad agreement on one specific aspect of financialisation, namely, the role of index funds for price volatility on futures markets. As of today, there is no sound scientific evidence in favour of a volatility increasing impact of index funds trading activities on agricultural futures. On the contrary, there is a tendency to find price volatility reducing impacts of index fund trading for major cereals. Reforms to the regulatory framework for futures markets should hence be applied rather carefully in order to not hamper the price discovery and hedging functions of those markets, although additional transparency requirements should be imposed as swiftly as possible.

A much less debated driver of volatility is the wide field of trade policies. The experience from the 2007/2008 food price crisis showed that policy responses from both importing and exporting countries have the potential to increase price volatility in international markets. Initially triggered by concerns about domestic food price inflation, both the reduction of import barriers and the implementation of export restrictions are essentially attempts to export domestic problems to the international market. Unfortunately, the current WTO regime is not adequate to tackle these issues. A renewed impetus for the multilateral trade negotiations looks like a promising pathway toward better functioning of the international markets during a food price crisis. From our point of view, the multilateral framework is better suited for imposing self-discipline in such trade policies than the approach via negotiations on bilateral and regional trade preferences (which seems to be currently the first choice by many important trading blocs).

Notwithstanding the quite substantial body of literature reviewed in this study, there are still some important research needs. A first set of issues is related to the methodological dimension. Price volatility is inherently unobservable and has thus to be estimated. Such estimation requires many conceptual choices. The estimates for, and the interpretation of price volatility depends crucially on these choices. Even if conceptual clarity has been reached, there are many estimation methods available. In order to apply these, additional assumptions are necessary, which often turn out to be rather restrictive. The impact on the generated volatility estimates is not always clear, and there is a danger that some of the estimated price volatility patterns might be driven by inappropriate estimation methods.

In terms of product coverage, there is a strong focus in the existing literature on cereal markets. On the one hand, this is perfectly understandable since cereal prices are still the key prices for agricultural and food markets. On the other hand, the lack of attention toward livestock and non-cereal staple crops is unsatisfactory since livestock products and staple crops are nowadays often more important for farmers and consumers than cereal prices. Farmers in the EU generate a substantial share of their revenues from livestock production; rural households in developing countries crucially depend on price development for local staple crops. Lack of appropriate data and heterogeneous product quality are two standard excuses for the focus on the relatively liquid international cereal markets but researchers view this as a challenge, not as barrier.

Finally, the identification of policy impacts with the goal to establish causal links between policy intervention and price volatility developments is also not yet settled in the existing literature. Instead of focusing too strongly on causality, the concept of predictability might
prove to be more fruitful in applied research. In particular, if certain factors are useful in predicting future price volatility, then these are also natural candidates for inclusion in medium- and long-term models, with the aim of capturing observable price volatility patterns also in these models.
References


Will, M. G., Prehn, S., Pies, I., & Glauben, T. (2012). Is financial speculation with agricultural commodities harmful or helpful?: a literature review of current empirical


## Appendix

### Summary table of the literature review on food price volatility

<table>
<thead>
<tr>
<th>Spot prices</th>
<th>Publication</th>
<th>Type</th>
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<td>Spot</td>
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