Investigating the role of speculation in commodity futures markets: a multi-method approach

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Preface

The thesis you are about to read represents the formal ending of my two-years journey at Delft University of Technology, in which I pursued the Master in Management of Technology. This formal document merges my interests and skills in a unique work which investigates speculative activities within commodity futures markets through statistical, empirical, and theoretical methods. Before leaving you to the reading, I feel necessary to make some acknowledgments.

First, I would like to express my gratitude to my first supervisor, Dr. Servaas Storm. Without him, nothing of this would have been possible. He first captured my interest in economics and finance during his lectures, then, he introduced me to the topic of this thesis, and finally, he inspired me and motivated me throughout all the months in which I worked on this research, always giving me important suggestions and incentives. He awarded my work making me feel like I was really doing something meaningful, and this filled me with satisfaction and passion. A special thank goes also to my second supervisor and chair, Dr. Maarten Kroesen, for his insightful comments and suggestions that really helped to improve the quality of this thesis. I also want to thank Suzan van Arkel and Marise Tabaksblat, my "thesis circle" mates and friends: it has been a pleasure meeting you and teaming up with you; the help and suggestions we exchanged throughout the previous months have been a precious contribution to my work.

Thanks to my Mother and my Father, who always believed in me and inspired me to become who I am now. Thanks to my friends Alice and Aurora, who followed and enjoyed my journey from Milan. Thanks to Agata and Suzan, and to all the special people I have met in these two years: thank you for all the wonderful experiences we shared together, you made Delft my second home. Finally, thanks to my beloved Tommaso for all the support and motivation: thank you for always being there for me, sharing my moments of joy, or embracing my moments of discouragement.

Dear reader, I also want to thank you for the time you will dedicate to this thesis, I hope you will enjoy the reading and find the argument interesting and worth to be further discussed. Finally, by reading my words, I hope you will be able to feel the attention, dedication, and passion I devoted to this work.

Delft, 18 June 2023
Carlotta Breman

Executive Summary

Our economies have become financialised: the financial sector has grown much faster than the real economy and financial considerations and motivations have grown in significance (Epstein et al., 2001). This process, started in the early 1950s, has led to the emergence of new kinds of financial markets, such as futures markets. In these markets, participants exchange a particular type of contract ("futures") which represents an agreement to buy or sell an asset or a security at a set future date for a set price (called "futures price", as opposed to the "spot price" which is the present price of the asset). The underlying asset of a futures contract can be of any nature. In this thesis, the focus is on (food) commodity futures contracts, which are exchanged in commodity futures exchanges.

The uniqueness of commodity futures markets is that they see the participation of two structurally different market actors: physical commodity market participants and speculators (Masters & White, 2008). The difference between these two is that speculators are non-commercial actors: they buy and sell futures only with the aim of making a profit out of them, they do not hold a physical commodity position. Conversely, physical commodity market participants are commercial actors, "physical hedgers": they hold and store a physical commodity and they enter futures markets with the aim of hedging the price risk they experience in the spot markets.

From the early 2000s, commodity futures have become popular among financial instruments. Additionally, in the more recent period, financial deregulation measures have been applied to futures markets (Ghosh, 2010), and commodity index investments have become popular for large financial portfolios' diversification. This attracted more and more (non-commercial) financial investors - such as speculators and index traders - in commodity futures markets (Tang & Xiong, 2012).

The increasing participation of speculators in futures markets raised concerns on the effect that it would have had on the two main functions of such markets: risk-hedging and price discovery. Several claims have been made about speculation and speculative activity, and they gained particular attention after the 2008 Financial Crisis. One important claim is that the increase in speculative activity has, in certain periods of time, driven up commodity prices over and above the levels warranted by fundamentals of demand and supply. Today, these claims are even more pronounced due to the Covid-19 crisis and the current conflict in Ukraine, in which again we see a tremendous spike in commodity prices.

Nevertheless, contrasting claims are still found within the literature. Specifically, authors differentiate on the extent they perceive speculation playing a role on food commodity prices. Some authors claim that food commodity prices can be fully determined by fundamentals, while others also consider the increasing participation of "disinterested" investors - speculators - in futures markets as another important determinant.

This thesis investigates the role of speculation on the prices of two food commodities, corn (maize) and soybeans. Specifically, this thesis answers the following research question: *To what extent did financial speculation have a role in rising food commodity prices over the years 2004-2023?*
To do so, this thesis employs a so-called "multi-method" approach. Specifically, four methods will be employed, namely: a literature review; a replication of an econometric model; statistical inspections and linear Granger causality tests; and interviews with experts. The aim of this multi-method approach is to embrace, investigate and look at the same phenomenon (speculation on food commodity prices) from different perspectives and levels, and eventually obtain and construct a comprehensive framework.

To set the basis for the research, the thesis begins with a literature review (the first method). Apart from defining the main research question, this method also delineates some sub-questions that, chapter by chapter, will be addressed to build up the answer to the main research question.

The literature review shows that it is largely agreed among authors that food commodity prices are - at least partially - determined by market fundamentals. The oil price is generally considered to be one of the fundamental factors influencing food supply and demand. To explain this dependency, authors use the concepts of "linked markets" and "spill-over" effects, that is, oil markets deeply influence food

commodity markets. Specifically, oil prices are related to food commodity prices through mechanisms which are both market-related (through biofuel demand, land use, energy supply, etc.) and index-related (through commodity indexes). This means that if an increase in oil prices is experienced, an increase in food commodity prices might be expected too. This also means that if speculative activities in the oil market are found to have an effect on oil prices, then the effect will also be transmitted to food prices.

To properly investigate this "indirect" effect of speculation on food commodity prices through the oil market, this thesis answers two sub-questions.
The first sub-question, addressed in Chapter 3, asks the following: *How much of the oil price' changes can be explained by speculation within the futures market of oil?* To answer this question, the econometric model proposed by Knittel and Pindyck (2016) is used and extended (second method). This model enables to quantify (as a proportion) the impact of speculation on oil prices. The analysis shows that, in the recent period, speculation has to be accounted for around 11% of the oil price changes.
The second sub-question, addressed in Chapter 4, asks the following: *What are the factors and dynamics that link oil prices to food commodity prices?* The aim of this sub-question is to define and specify the relationship that links oil prices to food prices, once it has been proved that speculation has some role in affecting oil prices, and that dynamics in oil markets are transmitted to food markets. To answer this question, the chapter performs statistical analyses on oil prices and oil futures markets, as well as a comparative analyses - specifically, visual inspections and linear Granger causality tests - between oil prices and food (corn and soybeans) commodity prices (third method). Finally, the chapter considers the fertilizer price as a potential "bridging" variable between the prices of oil and the two food commodities, and eventually provides a potential chain of Granger-causation that links such variables. Specifically, the chapter concludes that for soybeans, the chain is linear: oil prices *Granger-cause* fertilizer prices, which *Granger-cause* soybeans prices. For corn, instead, the chain of Granger-causation is somehow "recursive": oil prices *Granger-cause* fertilizer prices, which *Granger-cause* corn prices, which *Granger-cause* fertilizer prices. This findings reinforce the argument that any (speculative) position taken in the oil market has an effect also on other markets, especially food markets, and closes the discussion about the "indirect" effect of speculation on food prices through the oil market.

The literature review also shows that there is a disagreement between authors on whether speculation within (food) commodity futures markets has an impact on food prices' dynamics. To address this knowledge gap, this thesis proceeds by looking at the more direct effects of speculative activities within the food commodity markets themselves on food commodity (corn and soybeans) prices. This is done in Chapter 5. The chapter begins by analyzing the relationship that holds between spot and futures prices, thus answering the following sub-question: *What is the relation between futures prices and spot prices in food commodities?* The results show that futures prices Granger-cause spot prices. This conclusion, which puts futures markets (and prices) in a leading position over spot ones, triggers the urge to know the extent to which speculative activities within futures markets can affect futures prices' dynamics. For this reason, the chapter proceeds by adressing the following sub-question: *To what degree do speculative activities found within the commodity futures markets of corn and soybeans explain the prices of such commodities?* To answer this question, the chapter quantitatively defines the concepts of "speculation" and "excessive speculation" through indexes and proxies, and performs Granger causality tests between such indicators and the food commodities' prices (spot, futures and futures' volatility). Even though the statistical evidence in support of our hypothesis that speculation did drive up commodity prices is found only in a few specific cases and under specific (model) conditions, the chapter concludes that speculation cannot be completely excluded from the factors affecting prices' dynamics. The reason why we find only limited evidence in support of the hypothesis that speculation 'caused' an increase in food commodity prices has probably to do with the fact that by considering, observing and assessing just the internal dynamics of a specific commodity futures market, we miss all the impacts of financial speculation that come from other markets (such as the oil market, as shown in Chapters 3 and 4) and through different channels and dynamics.

The fourth and last method of this thesis is an interview-based approach, which is presented in

Chapter 6. This method gives us insightful points of view and suggests some additional critical issues concerning financial speculation and, more in general, financial trading in commodities.

Eventually, this thesis comes up with a theoretical-cum-empirical framework which is justified and sustained by a literature review, a model replication, some statistical inspections and tests, and interviews of experts. The framework is further contextualized and evaluated with the consideration of real-life events and dynamics, such as the current state of development of the oil market, the Covid19 crisis, and the Ukrainian conflict. By doing so, the thesis concludes that excessive speculation has - to some extent - been driving up and affecting commodities prices; specifically, speculation has increased volatility in futures markets.

The thesis finally expands the discussion of excessive speculation to a broader level, embracing and assessing the current state of financialized markets. In particular, it is concluded that too much liquidity is now flushing futures markets; this increases volatility and uncertainty, thus giving additional space (and reasons) for speculating, and creating a vicious circle of an exponential, uncontrolled entry of purely financial investors and a phenomenon of spiraling volatility.

Alongside the execution of the different methods, the research of this thesis also leads us to some important recommendations regarding the methods applied.
First, statistical tests should not be the starting point for developing a claim; rather, their results should be contextualized and weighted based on a socio-economical and market knowledge - which can be acquired by deeply investigating the phenomenon from different perspectives and sources (a literature review is an appropriate way to do it). Furthermore, when making claims based on (statistical) models' outcomes, it is recommended to be as realistic as possible with the assumptions made. After that, it is important to weigh, assess, and evaluate the models' results and contextualize the conclusions in light of such assumptions.
Second, statistical evidences are largely dependent and affected by the data sample selected: for this reason, it is important to acknowledge that limitations and (external) validity of results are largely connected to the type and quality of data that have been used.
Third, the thesis recommends expanding the analysis performed by employing other statistical practices, as well as testing the robustness of the models and the assumptions adopted. This is recommended because it could be a way to overcome some of the limitations found for linear Granger causality tests, such as: the definition of the number of lags, the time-series stationary requirement, or its blindness for what concerns second-level, non-linear, long-term relationships.

The thesis concludes with a set of policy recommendations that will help to tackle the main concerns that the increasing financialization brought to the real-economy (such as higher food prices, increasing volatility, uncertainty, uncontrolled and irresponsible trading, hunger).
Market transparency, open data platforms, and shared, clear, precise information on prices, demand, supply and positions levels are fostered. These features are considered essential for ensuring the effective implementation of policy actions, keeping prices under control, and avoiding trading to become excessive and harmful. In this respect, position limits set and based on real supply and demand conditions of the commodity, as well as on the investor's real interest to the commodity, can be suggested as good actions for bringing prices back to what fundamentals suggest, and reduce unnecessary investors' positions. Eventually, price volatility will be reduced, and there will be less incentives for profit-seeking speculators to enter the market and gamble on food prices.

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1 Introduction

The term "financialization" refers to the increasing participation of the financial sector in the so-called "real economy", which identifies the set of all non-financial businesses (Epstein et al., 2001). The consequences of financialization on the real economy have been largely discussed, and the extent to which the financial sector is socially efficient rather than destructive is still an open debate (Epstein & Crotty, 2013).

With finance entering the real economy, new kinds of markets have emerged, such as futures markets. In these markets, also known as "futures exchanges", participants exchange a particular type of contract ("futures") which represents an agreement to buy or sell an asset or a security at a set future date for a set price (called "futures price", as opposed to the "spot price" which is the present price of the asset). From the early 2000s, commodity futures (i.e., futures contracts on commodities such as oil, gold, silver, wheat, corn, etc.) have become popular among financial instruments. In this respect, we talk about "financialization of commodity markets" (Tang & Xiong, 2012).

The uniqueness of commodity futures markets is that they see the participation of two structurally different market actors: physical commodity market participants and speculators (Masters & White, 2008). The difference between these two is that speculators are non-commercial actors: they buy and sell futures only with the aim of making a profit out of them, they do not hold a physical commodity position. Conversely, physical commodity market participants are commercial actors, "physical hedgers": they hold and store a physical commodity and they enter futures markets with the aim of hedging the price risk they experience in the spot markets, where they actually have their commercial activity. It is indeed because of this opportunity given to commercial actors that futures markets are considered carrying two important functions: offsetting price risk and price discovery (Masters & White, 2008). In the more recent period, financial deregulation measures have been applied to futures markets (Ghosh, 2010), and commodity index investments have become popular for large financial portfolios' diversification. This attracted more and more (non-commercial) financial investors such as speculators and index investors in commodity futures markets (Tang & Xiong, 2012).
Last but not least, either because of "real-economy" reasons or "financial" ones, oil markets and food commodity markets have become closely linked: effects in one market (oil) are quickly transmitted, spilled-over, to the another one (food commodities). For this reason, the oil price is generally considered as one of the fundamental factors influencing food supply and demand, and thus food prices.

The increasing participation of speculators in futures markets raised concerns on the effect that it would have had on risk-hedging and price discovery. Several claims have been made about speculation and speculative activity, and they gained particular attention after the 2008 Financial Crisis, which has seen the crash of financial markets and the dramatic increase in commodity prices. One important claim is that the increase in speculative activity has, in certain periods of time, driven up commodity prices over and above the levels warranted by fundamentals of demand and supply. Today, these claims are even more pronounced due to the Covid-19 crisis experienced and the current conflict in Ukraine, in which again we see a tremendous spike in commodity prices. Sharper opinions concerning the role played by financial speculators in transforming economic shocks into food price crisis have been raised (IPES-Food, 2022).

The devastating effects that rising commodity prices can have on social welfare and economy - especially in developing countries - are clear (Ghosh, 2010). For this reason, there is an increasing number of studies which investigates and attempts to discover what are the main causes of these dramatic price changes. The final goal of these studies is to provide policy makers with effective recommendations, and avoid similar situations to happen again in the future. Within these studies, several authors have tried to determine to what extent speculation played a role in commodity prices' increases, or whether these peaked prices could still be explained through the market fundamentals (supply and demand). Lastly, it is important to remark that speculators are acting in futures markets, and they deal (and perhaps manipulate) with future prices (Masters & White, 2008). Therefore, if we want to consider these actors as playing a certain role on spot prices of commodities, the underlying assumption that has to be made is that spot and futures prices are somehow connected to each other.

1.1 Research objective and research question

To address the knowledge gap found in the literature, the main objective of this research is to ***investigate the role of financial speculation in rising commodity prices over the years 2004-2023***. To achieve this goal, the following objectives should also be achieved:
- Investigate, analyze and specify the relationship that holds between food markets and oil markets, under the concepts of "market fundamentals", "linked markets", and "spill-over" effects.
- Define the relation between futures prices and spot prices in commodities.
- Test whether (excessive) speculation contributed to the rising commodity prices.
- Discuss reasons for the contrasting results found in the literature.
- Formulate some policy recommendations to keep food prices under control and avoid harmful increases and peaks.

By making use and going through some of the most-used market analysis practices, this thesis will estimate and analyze various market variables and dynamics, and it will subsequently assess market speculation through econometric models, visual inspections, and statistical tests. The period of focus will be from 2004 to 2023, with a particular attention to the most recent years.

The achievement of such objectives will add knowledge to the existing research, and the present research will thus have scientific relevance. Indeed, by performing analyses on data and information which reach year 2023, this thesis will add to the existing literature about speculation during the 2008 financial crisis an analogous analysis, which considers most recent events and today's (new) market dynamics. As a consequence, the conclusions that will be drawn about speculation in commodity markets will, to a certain extent, "renew" the claims made for the 2008's crisis in light of recent events and market situations.

Furthermore, by performing statistical and econometrical analyses itself, this thesis will also highlight some important limitations found within the practices that are usually adopted by economists and researchers who investigate this topic. Specifically, the limitations of statistical tests such as Granger causality tests will be assessed and discussed, and the challenge of (numerically) identifying speculation activities will be introduced as another limitation when drawing conclusions. This will, in turn, present some reasons why the literature about speculation is so controversial, and why the debate is still open.

The thesis is also socially relevant. Indeed, academic research and, more in general, the scientific literature have always been instrumentalized. Specifically, to this topic, (past) scientific literature, statistical evidence and market analyses have always been used to validate or support claims and policy actions. By keeping a critical eye on the methods used, by weighting the findings in light of model limitations, and by always keeping an impartial, agnostic view about the phenomenon of speculation on commodities, this thesis aims to be useful to policy-makers as a starting point for delineating tailored and unbiased policy actions.

According to the research objectives, the main research question can be formulated as follows:
To what extent did financial speculation have a role in rising commodity prices over the years 2004-2023?
And the sub-questions formulated:
- How much of the oil price' changes can be explained by speculation within the futures market of oil?
- What are the factors and dynamics that link oil prices to food commodity prices?
- What is the relation between futures prices and spot prices in food commodities?
- To what degree do speculative activities found within the commodity futures markets of corn and soybeans explain the prices of such commodities?
- Did (excessive) speculation contribute to the rising commodity prices?

Lastly, alongside the analysis, the following research questions will be addressed:
- What are the reasons for the contrasting results found within the literature? Are they due to model limitations, wrong assumptions, or are we still missing a part of the whole story?
- What policy actions should be recommended in order to keep food prices under control, and avoid harmful increases and peaks?

1.2 Structure of the thesis

This thesis investigates the role of speculation on the prices of two food commodities, corn (maize) and soybeans, through a so-called "multi-method" approach. The aim of this approach is to embrace, investigate and look at the same phenomenon (speculation on food commodity prices) from different perspectives and levels, and eventually obtain and construct a framework which is as much comprehensive as possible. Indeed, as it will be confirmed from the literature review, even though speculation is a well-defined term, it is far from being easily-detected in reality. For this reason, every method and analysis aimed to identify and measure speculation's effects has its own limits and blindness, and it is for this reason that a multi-method approach is used in this thesis. Specifically, the thesis makes use of four methods, namely: a literature review; a replication of an econometric model; statistical inspections and linear Granger causality tests; and interviews with experts.

The first method is the literature review, presented in Chapter 2. This method will be used to acquire proper knowledge about the topic and to find the main knowledge gaps from which to derive the research question. It will set the basis and the theory of the topic, giving an overview of the complexities, discrepancies and controversies concerning speculation activities and effects. Furthermore, the literature review will also give indications on how to choose, delineate and perform the other methods of the analysis, and it will be helpful for discussing and assessing the next findings with a critical, experienced eye. The literature review will have therefore an active role within the whole thesis; it will define knowledge gaps, approaches and methods, and it will shape conclusions, limitations, and further research. Finally, the literature review will provide a classification diagram concerning the main findings. Specifically, the authors and papers explored will be divided based on their claims and approaches. The controversies and contrasting points between the different "dimensions" of the classification diagram will be an additional reason for preferring a multi-method approach over a single one.

To construct a comprehensive framework of (possible) speculative forces on food commodity prices, the thesis will start by looking at the indirect effect of speculation on food commodity prices through the oil market. Directly and indirectly, oil is a crucial input into food production – and the oil price is generally considered to be one of the fundamental factors influencing food supply and demand. The thesis will first, in Chapter 3, analyse the role of excess speculation in the oil market. To do so, the econometric model proposed by Knittel and Pindyck (2016) will be replicated and extended. Specifically, the model will look at the oil market, and will determine whether speculation activities are found within that market. Then, under the notion of *linked markets*, which assumes that oil prices are connected (linked) to food commodity prices, the following claim will be made: if speculation has a role in driving oil prices, then the same speculative activities can be blamed on having an "indirect" effect on food prices. In this way, the possible "indirect" effects of speculation on food commodity prices will be assessed.

Then, Chapter 4 will continue and extend the findings of Chapter 3 by employing statistical assessments and tests. To begin, an introductory analysis of oil prices and of oil futures markets will be performed by looking at data on prices and trading positions. Then, the relation which holds between oil prices and food commodity prices will be assessed through a comparative analysis which will make use of visual inspections and Granger causality tests. The concept of *linked markets* will be extended by discussing some spill-over effects from the oil market to the food markets, and by considering fertilizer prices as a "bridging" variable between oil and food commodities (corn and soybeans). Specifically, Granger causality tests will be performed between oil and food commodity prices, and between commodity and fertilizer prices. These tests will help to construct a chain of Granger-causation which will further sustain the concept and dynamics of linkages between the oil market and food commodity markets. Moreover, the consequences and outcomes of *index investments* will be assessed and discussed in light of the stronger comovement and correlation observed between indexed commodities rather than between off-indexed commodities.

The thesis will then adopt a different perspective and will start looking at the more direct effects of speculation on food commodity (corn and soybeans) prices. This will be done in Chapter 5.

To begin, in Section 5.1 the relation between spot and futures prices of corn and soybeans will be investigated. This will be an important point for checking and evaluating the function of the food commodity futures markets, namely, price discovery and risk hedging. The analysis will make use of linear Granger causality tests, from which it will be concluded that futures prices Granger cause spot prices more than the contrary. This conclusion, which puts futures markets (and prices) in a leading position over spot ones, will trigger the urge to know the extent to which speculative activities within futures markets can affect futures prices' dynamics. Indeed, if speculation is found to have a role in manipulating and determining futures prices, then, based on the leading position of futures markets over spot markets previously found, the same activity can be blamed for affecting spot prices. Section 5.2 will precisely investigate these relationships. Specifically, the direct effect of speculation on prices of corn and soybeans will be investigated by considering a set of proxies for speculation alongside with spot prices, futures prices and the volatility of futures returns of corn and soybeans. The analysis will first make use of descriptive statistics and visual inspections, and then it will turn to linear Granger causality tests.

The fourth and last method will be an interview-based approach, which will be presented in Chapter 6. Specifically, results and conclusions coming from the previous methods will be presented to experts, and the validity and limitations of such findings will be discussed. The interviewees will also be asked about their stand with respect to speculation in commodities, the current state of commodity financial markets, and possible policy actions that could be implemented within these markets. These interviews will be the last building block of the multi-view, comprehensive framework that this thesis aims to offer. They will provide additional insights and points of view which will enrich and integrate the previous researches.

Lastly, Chapter 7 will conclude the thesis by summarizing the findings and giving some general recommendations concerning the methods employed as well as policy recommendations. Also, it will spark further research by discussing and questioning the following: *Where do we stand now?*.

As will become clear from the literature review, even though speculation is a well-defined term, it is far from being easily-detected in reality. As a consequence, every approach and analysis aimed to identify and measure speculation's effects has its own limits and blindness, and this appeals also to the analyses and tests which will be adopted in this thesis. For this reason, for every section, the limitations of the adopted method will be made clear, and the results obtained will be carefully discussed and interpreted. Furthermore, the fact that every method has its own weaknesses and limitations is precisely the reason why no jump to a conclusion is made based on just one approach or test, but instead, a multi-method approach is preferred and selected.

To conclude, as it will be clear form the presentation of the thesis structure, the order of the methods adopted in this thesis builds up both the research direction, questions and answers. The literature review sets the basis and the theory of the topic, giving the first oversight of the complexities, discrepancies and controversies concerning speculation activities and effects. It gives indications on how to choose, delineate and perform the other methods of the analysis, and it helps to discuss and assess the findings with a critical, experienced eye. The literature review has therefore an active role within the whole thesis, it defines knowledge gaps, approaches and methods, and it shapes conclusions, limitations, and further research.

Table 1 reports a summary of the thesis structure followed from the multi-method approach employed. For each chapter, the sub-question addressed is also reported in the table.

Topic	Research question addressed	Method	What do we learn	Section
Literature review	-	Literature tables, critical review, classification	Develop a critical eye and shape direction of research. Define RQ and sub-RQ.	Chapter 2
Indirect effect of speculation on prices of corn and soybeans through the oil market. An analysis of the impact of speculation on oil prices, under the assumptions and notions of linked markets and spill-over effects.	How much of the oil price' changes can be explained by speculation within the futures market of oil?	Replication and extension of Knittel and Pindyck "Simple Economics" model (2016).	In the recent period, speculation has to be accounted for around 11% of the oil price changes. Speculation in oil markets also affects food prices because markets are linked.	Chapter 3
Indirect effect of speculation on prices of corn and soybeans through the oil market (ctd). The relation between the prices of oil and the prices of corn and soybeans, under the notion of index investments and through the consideration of fertilizer prices as bridging variable.	What are the factors and dynamics that link oil prices to food commodity prices?	Preliminary analysis on oil prices, also in relation to speculation; comparative analysis through visual inspection; linear Granger causality tests.	Speculation in oil markets also affects food prices because of index investments which increase commodity prices' comovements. Fertilizer prices can explain part of the dynamics which hold between oil and food prices. Granger causality tests should be carefully employed and interpreted.	Chapter 4
The relation between spot and futures prices of corn and soybeans. This is important to evaluate and validate the function of futures markets, under the assumptions and notions of price discovery and risk hedging.	What is the relation between futures prices and spot prices in food commodities?	Visual inspection; linear Granger causality tests.	Futures prices Granger-cause spot prices.	Chapter 5, Section 5.1
Direct effect of speculation on prices of corn and soybeans. The relation between prices of corn and soybeans and speculation (through different proxies).	To what degree do speculative activities found within the commodity futures markets of corn and soybeans explain the prices of such commodities? Did (excessive) speculation contribute to the rising commodity prices?	Visual inspection; linear Granger causality tests.	Speculation within the food commodities' futures exchange has some impact on prices. Granger causality tests should be carefully employed and interpreted.	Chapter 5, Section 5.2
Interviews: validation and final discussion.	Building up the answer to the main research question	Interviews	How the debate around speculation has evolved. Validity and limitations of statistical tests. Possible policy actions and limitations to those actions. Rethinking the food system.	Chapter 6

Table 1: Structure of the thesis: the multi-method approach. Research question: To what extent did financial speculation have a role in rising commodity prices over the years 2004-2023?

1.3 Data, variables and tests

In order to answer the research questions, this thesis will make use of some statistical and econometric practices. Specifically, by means of model replications, visual inspections, and econometric tests, the thesis will uncover the relationship between commodity prices, as well as the impact of speculation on such prices. For this reason, data represent the main, initial building block for discovering these relationships.

The data collected and used for this research refer to the US market, which is thus considered «a microcosm of the global market» (Knittel & Pindyck, 2016). The variables and approaches selected for the various analyses have been defined based on an exploration of the relevant literature. The findings concerning tests, data, proxies, variables and sources have been reported in the table in Appendix A.

For what concerns the prices of commodities, historical data of spot prices have been retrieved from different websites, such as the Energy Information Administration (EIA), the International Monetary Fund (IMF) (*International Monetary Fund*, n.d.), and investing.com. The reason why different websites have been used has to do with the availability of (free) data. Unfortunately, historical data on (spot/futures) prices and indexes is not always easily available and retrievable. Some websites require a (paid) subscription, while others just show a small part of the data for free. Furthermore, each website has its own way to present the data: some of them report price indexes instead of actual prices, some offer daily data, while others only offer weekly or monthly data. The availability and quality of data have been therefore crucial determinants for the development of the analyses and the practical choices made throughout the thesis.

To collect information about speculation within commodity futures markets, the publicly available data released by the Commodity Futures Trading Commission (CFTC) have been used. Created in 1974 under the US Commodity Futures Trading Commission Act (Commodity Futures Trading Commission (CFTC), 2023c), the CFTC regulates the U.S. derivatives markets and promotes «the integrity, resilience, and vibrancy of the U.S. derivatives markets through sound regulation» (Commodity Futures Trading Commission (CFTC), 2023e). For this reason, the CFTC has been publishing various market reports concerning investors' positions in futures markets. These reports uncover roles, intentions and positions of all actors trading in futures exchanges, mainly in the CBOT. The aim is to provide a transparent, clear oversight of the futures market's composition, health and dynamics, with a specific focus on the level of speculative activity found within it. To do so, market participants are divided based on their "intentions" when trading in futures exchanges. This division is easier said than done, since it is impossible to make a clear cut between "speculators" and "hedgers" (Fattouh, Kilian & Mahadeva, 2013; Knittel & Pindyck, 2016; Alquist & Gervais, 2013). For this reason, the CFTC provides different types of reports, explained below, which differ in the way traders are considered and categorized.

COT report

Since 1986, the Commitments of Traders (COT) report provides weekly data on open interest and positions. 'Open interest' is a measure of the total number of futures and/or option contracts that have been entered into and that have not yet been liquidated by a transaction or a delivery. (Alquist & Gervais, 2013). Option/futures contracts can be either short (purchased contracts) or long (sold contracts). Since for every short contract there is an opposite long contract, to measure the total open interest for a given market it is required to look at either the total of contracts long or the total of contracts short, not the sum of them (Algieri, 2012). The trader's position is defined as the open interest held or controlled by that trader.
The COT report is available in two forms: Futures-Only and Futures-and-Options-Combined. For the purpose of this research, the focus will be just on Futures-Only report. The report breaks down open interest positions by exchange and by trader category. Specifically, three categories are defined: commercial, non-commercial, and non-reportable. A trader falls under 'commercial' if it uses futures contracts of a particular commodity for hedging purposes (Commodity Futures Trading Commission

(CFTC), 2023a); conversely, a trader who enters a futures market without possessing an underlying physical asset (commodity), and thus who has other purposes rather than hedging (usually making a profit), is defined as 'non-commercial'. Non-commercial traders are largely speculating (Irwin & Sanders, 2012), and for this reason the terms 'non-commercial traders' and 'speculators' are, within the context of the COT report, interchangeable. Commercial and non-commercial positions are known as 'reportable positions', with 'reportable' indicating all traders that hold positions above specific reporting levels set by the CFTC. Reportable positions make up to around 70% to 90% of the total open interest in any given market. The remaining part is made up by non-reportable positions (Commodity Futures Trading Commission (CFTC), 2023a). For non-commercial traders, the open interest is divided into long, short and spreading, while for commercial and non-reportable only long and short open interest are presented. Irwin and Sanders (2012) provide the following explanatory formula on how the total open interest is calculated from the COT data:

$$[NCL + NCS + 2(NCSP)] + [CL + CS] + [NRL + NRS] = 2(TOI) \tag{1}$$

with NCL, NCS and NCSP representing the non-commercial long, short and spreading positions respectively; CL and CS representing the commercial long and short positions; and NRL and NRS representing the non-reportable long and short positions (Irwin & Sanders, 2012).
The accuracy of this report has been highly discussed within the literature (Irwin & Sanders, 2012), since market participants can, at the occurrence, self-define themselves as commercial participants rather than non-commercial traders. This might likely happen especially if regulatory limitations on speculative position limits are imposed in the market (Irwin & Sanders, 2012). However, the CFTC guarantees that proper checks and re-judgements are done to ensure an honest, accurate and consistent classification (Commodity Futures Trading Commission (CFTC), 2023a).

DCOT report

The Disaggregated Commitments of Traders (DCOT) report, published for the first time in September 2009, is a variation of the COT report in which the reportable open interest positions are furtherly disaggregated into four classifications: Producer/Merchant (PM), Swap Dealers (SD), Managed Money (MM) and Other Reportables (OR) (Commodity Futures Trading Commission (CFTC), 2023b). Producers and merchants (PM) are traditional commercial traders who use futures markets to hedge against price risks on the physical commodities they hold. As the name suggests, swap dealers deal with swaps contracts, and enter the futures markets to hedge on such transactions. A great part of swap dealers are commodity index investors – therefore, even if they don't perform the 'traditional' speculative activity, the impact of their positions on commodity prices is worth to be considered (Tang & Xiong, 2012). Large institutional investors such as commodity trading advisors and hedge funds who enter futures exchanges on behalf of clients fall under the 'managed money' (MM) category. These market participants represent the 'traditional' speculators (Irwin & Sanders, 2012). Lastly, other reportables (OR) are defined as all those reportable non-commercial traders who did not fall into the previous categories.
As for the COT report, for non-commercial traders the open interest is divided into long, short and spreading, while commercial and non-reportable are just divided into long and short. Irwin and Sanders (Irwin & Sanders, 2012) provide the following explanatory formula on how the total open interest is calculated from the DCOT data:

$$\begin{split}[SDL + SDS + 2(SDSP)] + [ORL + ORS + 2(ORSP)] + [MML + MMS + 2(MMSP)] \\ + [PML + PMS] + [NRL + NRS] = 2(TOI)\end{split} \tag{2}$$

SCOT or CIT report

With the growth of commodity index investments as a new way for traders to diversify, hedge and speculate, a new category of market actors - the so-called index investors - has been identified, and the way these new market actors contribute to increasing commodity prices is a primary debate within the literature (Tang & Xiong, 2012; Irwin, Sanders & Merrin, 2009; Irwin & Sanders, 2010; Sanders, Irwin & Merrin, 2010). Even though the DCOT report offers a more granular division of the market's participants, index investment positions can fall within swap dealers, managed money, and other reportables positions (Irwin & Sanders, 2012). For this reason, since 2007 the CFTC provides an additional report, called the Supplemental Commitments of Traders (SCOT) or Commodity Index Traders (CIT) report. The report provides Futures-and-Options-Combined data on 13 agricultural commodities, and breaks down the reportable open interest positions into three classes: non-commercial, commercial, and index traders (Commodity Futures Trading Commission (CFTC), 2023a). A limitation of this report is that index traders are identified based on private interviews, and the division between "index" or "non-index" is done at the trader level, rather than at the position level (Commodity Futures Trading Commission (CFTC), 2023d). If a trader is classified as "index trader", then all its positions taken will be classified as index positions, regardless their real nature (Irwin & Sanders, 2012).

Variables and proxies

After all the relevant time series have been collected, some additional modeling and computations have been made on the data in order to prepare them for the various analyses and tests, and also to obtain some important proxies.

For what concerns commodity prices, empirical research and tests can be done by considering not only the (spot/futures) prices' values, but also the (spot/futures) prices' volatility. With respect to volatility, this thesis focuses on the historical volatility (or realized volatility). Quoting Algieri (2012), historical volatility «is based on the observed movements of prices over the long term, and indicates how volatile an asset or commodity price has been in the past. It involves calculating the historical average variance or standard deviation of log price returns (growth rate). [...] Historical volatility models use time series of past market prices. [...] Historical volatility is a "backward-looking" measure of volatility». The author also defines two other types of volatility, namely conditional volatility, which is «a "backward-looking" historical forecast of future volatility reflected in current option prices» (Algieri, 2012) and it is usually assessed through GARCH models; and implied volatility, which is typically used in option pricing. Implied volatility is out of interest since the next analysis will only deal with futures and not options, and historical volatility has been selected over the conditional one since the two estimations typically lead to the same results (Algieri, 2012).

To assess the role of financial speculation on commodity prices, proxies for speculative activities have been created. Within the literature, several indicators of speculation have been proposed.
Robles et al. (2009) mention some of the most used proxies of speculation, among which the total open interest in futures contracts; and the ratio of noncommercial positions to total positions in futures contracts (long or short) (Robles et al., 2009).
Other indexes of speculation that appeared in the literature explored are the changes in net positions (long minus short) for both commercial and non-commercial actors.
The Working's speculative "T" (WT) index (Working, 1953) is another widespread measure of speculation which several authors use to quantify the impact of non-commercial actors in the commodity's market (Alquist & Gervais, 2013; Algieri, 2012; Sanders et al., 2010). This index aims to measure the amount of speculation that exceeds what is minimally required to meet short and long hedging demand, and it is defined as:

$$WT = 1 + \frac{SS}{HL + HS} \quad \text{if } HS \geq HL$$

$$WT = 1 + \frac{SL}{HL + HS} \quad \text{if } HS < HL$$

where SS (SL) defines the number of short (long) positions held by speculators, while HH (HL) represents the number of short (long) positions held by hedgers (Irwin et al., 2009). The interpretation given by Irwin et al. (2009) of the index is the following:
- If HS > SL (the increase in short hedging exceeds the increase in long speculation): long speculators

(as a group) are trading with short hedgers, and this is beneficial for the overall market performance, as speculators provide liquidity and risk–bearing capacity for hedgers (Working, 1960).
- If HS $<$ SL (the increase in short hedging was less than the increase in long speculation): the increase in long speculation is absorbed by an increase in short speculation. This destroys the market performance and we talk about "excessive speculation" (Working, 1960).
Similarly, Algieri (2012) defines the hedging (speculative) pressure as:

$$\text{Hedging pressure} = \frac{HL - HS}{HL + HS} \qquad \text{Speculative pressure} = \frac{SL - SS}{SL + SS}$$

Table 2 summarizes all the variables and proxies that will be considered, computed and assessed in this thesis.

Commodity Variables	**Abbreviation**	**Sources**
Spot price	SP	(*International Monetary Fund*, n.d.)
Futures price	FP	investing.com
Historical volatility of futures prices	HV	computed by the author with data from investing.com
Proxies for trading activities	**Abbreviation**	**Sources**
Changes in non-commercial net positions	Ch_NP_NonComm	computed by the author with data from CFTC COT report
Changes in commercial net positions	Ch_NP_Comm	computed by the author with data from CFTC COT report
Total open interest	Tot_OI	CFTC COT report
T-index	T	computed by the author with data from CFTC COT report
Speculative pressure	Spec_press	computed by the author with data from CFTC COT report
Hedging pressure	Hedg_press	computed by the author with data from CFTC COT report
Other indicators	**Abbreviation**	**Sources**
S&P GSCI		investing.com

Table 2: Variables and proxies for commodity prices and trading activities

For the purpose of the analysis and the indicators that have been selected, the research will make use of the COT report data. Indeed, the traders' divisions made within the DCOT and SCOT reports, apart from having some limitations, are not useful for the scope of this analysis. Another reason to prefer the COT report over the DCOT and SCOT ones is that the latter offers weekly data about positions from 1986 up to now, while the "new" DCOT and SCOT reports cover much smaller periods.

Food commodities: corn and soybeans

For what concerns the food commodities, corn (maize) and soybeans have been selected as units of analysis. Corn (maize) is mainly used as biofuel feedstock in the US (Gilbert, 2010), and also for this reason, it is the most widely grown crop today (*USDA, Economic Research Service*, n.d.). For what concerns soybeans, the United States is the largest global producer and the second largest global exporter. This commodity makes up to 90% of the whole oilseed production in the US (*USDA, Economic Research Service*, n.d.), however, it is not so popular for biofuel production (Gilbert, 2010). These two commodities also cover an important role in the (global) human diet, and thus they have a direct influence on the world's food security. Especially for the poorest countries, a higher, sometimes inaccessible, price of these commodities might quickly lead to a situation of food insecurity and hunger (IPES-Food, 2022). Therefore, investigating the role that speculation plays in the prices of these commodities also means assessing the impacts of speculation on some critical humanitarian matters.

Corn and soybeans futures are the most traded futures around the world, and thus the most affected by the process of financialization. Corn is one of the oldest commodities exchanged, with its first (spot) exchange market, the Corn Exchange of London, dating back to 1747, and its first spot-and-futures exchange market, the Liverpool Corn Trade Association, founded in 1853 (Clapp & Isakson, 2018b). For what concerns the United States, corn is one of the first commodities that has been trading on the Chicago Board of Trade (CBOT), which became the first grain futures exchange by the end of the 1850s, trading various types of commodity futures among which soybeans futures contracts too. The CBOT is today merged with the Chicago Mercantile Exchange (CME), the New York Mercantile Exchange (NYMEX), and the Commodity Exchange Inc. (COMEX), under the CME Group, one of the main global commodity exchanges.

Granger Causality test

Alongside some descriptive statistics and visual inspections, Granger (1969) causality tests will also be performed in this thesis. This method is widely used in econometrics for indicating a preliminary causal relationship between two time series variables (Andreasson, Bekiros, Nguyen & Uddin, 2016). As explained by Irwin and Sanders (2010), «a variable A is said to *Granger-cause* ("*g.c.*") B if knowing the time paths of B and A together improve the forecast of B based on its own time path, thus providing a measure of incremental predictability». It is worth to stress the fact that Granger causality should not be confused with normal causality: if A Granger-causes B, it does not mean that B is the result of A, but just that A helps predicting B, which practically means that adding lagged values of A improves the information about B (i.e., the coefficients of the lagged values of A are statistically significant) (Algieri, 2012). A Granger causality test which checks whether variable A Granger-causes variable B has the following formulation:

H_0: A does not Granger-cause B
H_1: A does Granger-cause B

Practically, through F-tests and Chi-squared-tests on lagged values of A and B, the test checks whether such values of A provide statistically significant forecasts about B.

The test produces a p-value - and the null hypothesis (H_0, no Granger causality) is rejected for low p-values. Usually, the test is executed at 1%, 5%, or 10% confidence level (i.e., H_0 is rejected for p-values lower than 1%, 5%, or 10% respectively). In this research project, variable B will be represented by the time series of prices returns, historical volatility of prices, etc., while variable A will represent the aforementioned measures of speculative activity. To check whether there is any causal relationship in the other direction, variables A and B will be inverted for an opposite Granger causality test. Within the literature, different types of Granger causality tests have been found, mainly: linear versus nonlinear (nonparametric). In this research, linear Granger causality tests will be performed, as explained by Robles et al. (2009).

For what concerns this type of test, two important aspects should be clarified. First, before performing the test, it should be guaranteed that the time series considered are stationary. A time series is stationary is its properties do not depend on the time at which the series is observed, which basically means that the time series should not present seasonality or trends. To check whether the data used for the test is stationary, the Augmented Dickey–Fuller test will be executed. The test has the following formulation:

H_0: Time series A is non-stationary
H_1: Time series A is stationary

The test will be executed at 10% confidence level. If the time series are found to be non-stationary (i.e., H_0 cannot be refused), then the data should be manipulated and "made" stationary. This is usually done by computing and using either the log prices, the log-returns, the percentage changes or the simple differences between consecutive data of the time series (Hernandez, Torero et al., 2010; Algieri, 2012).
Second, Granger causality tests requires us to define the number of lags to use, which are the number of lagged values of variables A and B to consider in the test. The literature about the correct number of lags to use is wide, and the selection approaches vary between statistical criteria and empirical considerations. Following the statistical approach, a Vector autoregression (VAR) model should be implemented for the raw data (i.e., the data without any modification, even if non-stationary). The VAR model will determine the appropriate maximum lag length by using information criteria, such as AIC, SIC, or BIC (Wooldridge, 2015). If the Akaike information criterion (AIC) is used, the best maximum lag length is the one that has the lowest AIC value. Following an empirical approach, since the current analysis considers monthly data, the appropriate number of lags ranges from 6 to 24 (Wooldridge, 2015), depending on the number of data points. However, focusing on the literature which performed Granger causality between commodity prices and speculation proxies using monthly data, also smaller values (between 1 and 10) are found to be statistically significant and used (Brunetti

& Buyuksahin, 2009; Cooke & Robles, 2009; Hernandez et al., 2010; Algieri, 2012). In this research project, the preferred lag for each test will be selected through the AIC criterion. In appendix D.1, the Python commands executed to perform the aforementioned tests are presented.

To conclude, some limitations of linear Granger causality test should be pointed out and kept in mind when discussing the results. First, the linear Granger causality test is the simplest test of the family of Granger tests, and it only gives information about linear features of effects (Hernandez et al., 2010). The linear test is certainly less powerful than nonlinear or non-parametric ones, especially in detecting indirect causal links (Gilbert, 2010). However, these more-sophisticated versions of Granger tests bring bigger computational efforts, and are more difficult to understand and use in practice (Hernandez et al., 2010). Second, Granger tests depend solely on the variables selected. This means that if it is found that variable A Granger-causes variable B, this does not rule out the possibility that other causal factors (not incorporated in the model) also Granger-cause variable B. Even if the causation between variables A and B is found to be strong (statistically significant at the lowest confidence level), it can never be stated - from the test - that A is the *only* or *main* variable affecting B. Furthermore, Granger tests between variables A and B assess the dynamic correlation between the two time-series, without however giving any information of what the two series might be responding to. It could be that A Granger-causes B but at the same time both A and B are responding to a third variable C not considered in the model (Alquist & Gervais, 2013).

2 Literature review

In the literature explored, speculation is found to play different, even contrasting roles. The interested authors assess the effects of speculation on either prices' volatility, spot prices, or both. Furthermore, the approaches taken by these authors vary in terms of methodology and assumptions.

The following literature review gives an overview of the different opinions that have been formulated with respect to speculation in commodity futures markets. The aim is to provide a general framework of actors and factors that may play a role in determining commodities' prices and prices' volatility, with a particular focus on the periods in which spot prices increased enormously. Furthermore, the literature collected has been classified in two categories based on the research approach used by the authors: empirical versus econometric. This helps to point out the opportunity and limitations of choosing one approach over the other.

Section 2.1 presents an overview of some core definitions and concepts related to the topic investigated. Section 2.2 discusses the main arguments found in the papers for what concerns the relation between spot and futures commodity prices, with a focus on the price discovery mechanism. Section 2.3 classifies all the literature considered based on main findings and research approach selected by the authors. Finally, Section 2.4 summarizes the main policy recommendations given by the authors, according to the findings and conclusions they reached.

2.1 Some definitions

It is important to begin the analysis of this topic by clarifying some core definitions for at least two reasons. First, it will be shown that some of these definitions are theoretically valid but difficult to identify in practice. It can be therefore argued that this "identification problem" might be one of the reasons why the debate on the role of speculation on commodity markets is still open. Second, different definitions lead to different approaches and focuses, and therefore different analyses of the same phenomenon. One could therefore question itself whether it is actually due to this initial conceptual misalignment that different works and approaches lead to different results. By changing the way we consider and interpret actions, roles, dynamics and data, aren't we just changing our observing lenses?

2.1.1 Spot and futures commodity markets

Commodities are traded in two main different markets: spot markets and derivatives (futures) markets. These markets are structurally different in the way the commodity exchange happens as well as for the participating actors.

"Spot", "physical", "cash" commodity markets is where investors sell commodities for cash at the current time (Collins Dictionary). The prices of the goods traded in these markets are called spot prices. Spot prices reflect the market fundamentals of the commodity markets, which means that they are a clear representation of supply and demand realities experienced by consumers and producers in their own, real businesses. It is therefore clear that physical commodity markets host holders of commodities such as producers and merchants. Conversely, in commodity derivatives (futures) markets, commodities are exchanged through derivatives contracts (forward, futures, open interests, options), under the regulation of the Commodity Futures Trading Commission (CFTC). The prices of the goods traded in these markets are called futures prices. Because there is no cash-commodity exchange at the current time, one can participate by buying and selling (in the future) commodities that it does not necessarily possess or need. For this reason, these markets involve not only physical holders of commodities, but also the so-called "speculators", or more generally, all the investors who do not have an interest on physically holding the commodity traded. These "unique" markets have been recognized by the Commodity Exchange Act of 1936 of carrying two vital functions for physical market participants: hedging against fluctuating prices and price discovery (Masters & White, 2008). It is because of these two features that it is claimed that, even if inherently different, spot and futures markets are highly connected.

2.1.2 Speculation and speculators

The term (commodity) "speculator" is broadly defined as any non-commercial actor who buys and sells (commodity) futures contracts or other derivatives in the (commodity) futures market with the hope of making a profit out of it (IPES-Food, 2022; Alquist & Gervais, 2013). It is argued that these authors can be beneficial as they provide the commodity markets with liquidity which makes them function (Algieri, 2012; Masters & White, 2008; Aulerich, Irwin & Garcia, 2014; Bos & van der Molen, 2012; Fattouh et al., 2013). The extent to which this argument are agreed and valid leads to some additional definitions described below.

Masters and White (2008) recognize the beneficial aspects that speculators can bring to these markets, however, when these actors become the main, prominent force of futures markets, every benefit is lost and they talk about "excessive speculation". In this "abnormal" state, the price discovery function is damaged (with, for example, an increase in price volatility) and prices are not anymore determined only by the market fundamentals (Masters & White, 2008; Algieri, 2012; Fattouh et al., 2013; IPES-Food, 2022; Kornher, von Braun & Algieri, 2022).

From 2003, commodity (futures) markets have started to experience an increase in the so-called index investments. The two main commodity indices usually reported in the literature are the S&P's GSCI and the Dow-Jones-UBS commodity Index. Therefore, a new type of investor appears in the market: the "index-investor" or "index-speculator". Index investors have no interests whatsoever in single commodities, their trading does not consider the market fundamentals of any single commodity, they just invest in a group of commodities (an index) to diversify and hedge the risk of their portfolio. It is claimed that commodity index trading (CIT) has deeply damaged commodities' price discovery and stability, as it has caused a co-movement of different, unrelated commodities' prices (Alquist & Gervais, 2013; Masters & White, 2008; Tang & Xiong, 2012; IPES-Food, 2022; Singleton, 2014; Hamilton & Wu, 2015; Juvenal & Petrella, 2015). Furthermore, index investors usually take long-only positions: there is no short-, canceling effect able to stabilize the prices, which therefore keep on increasing (Masters & White, 2008). Because of their price insensitivity and their never-ending long positions, Tilton et al. (2011) call them "passive investors" (Tilton et al., 2011, p. 188).

On the other side, Von Witzke and Noleppa (2011) define "professional speculators" as particular actors who have a deep market knowledge which enables them to correctly anticipate future prices. For this reason, they cover an important role for the markets' price discovery and the reduction of price distortions. Likewise, Gilbert (2010) mentions the difference between "informed" and "uninformed" speculation. Informed speculators bring commodity (spot) prices to their fundamental values (defined by market fundamentals), while uninformed speculators move the commodity's prices away from it. The ratio between informed and uninformed speculators is what defines the degree of the market's efficiency. According to the literature, a market is efficient if commodity prices' changes can be fully explained by market fundamentals. In efficient markets, futures simply incorporate market fundamentals' information into prices.

Opposite to "speculators", the literature defines "physical commodity market participants", commercial actors who enter the futures market to hedge against the price risk of holding a particular commodity. Masters and White (2008) name them "bona-fide" physical hedgers, or simply "hedgers".

It is important to point out that even if these definitions apply to structurally different actors and do not theoretically overlap, in reality the boundaries are way more blurred. Indeed, not only identifying speculative activities or excessive speculation from historical data and analyses is a challenging task (Fattouh et al., 2013), but also «identifying speculators, as opposed to investors or firms hedging risk, is not simple» (Knittel & Pindyck, 2016, p. 86). Last but not least, nothing prohibits actors to cover both roles: commercial traders can decide to also take speculative positions (Fattouh et al., 2013). This is why Alquist and Gervais (2013) recommend to better «think of the behaviors of hedgers and speculators arrayed along a continuum» (Alquist & Gervais, 2013, p. 37). It comes natural that banning speculators from the market is not straightforward, if not even damaging for the market itself in the way they provide beneficial liquidity. This feature has non-negligible consequences on the way authors choose to perform their analyses and make assumptions, as well as on they way they describe desirable policy recommendations.

2.1.3 The Masters Hypothesis and excessive speculation

Two important concepts related to the analysis conducted by many authors are The Masters Hypothesis (Masters & White, 2008) and the notion of *excessive speculation*.
From the previous section, it is clear that just looking for simple "speculation" is too broad and would not be an appropriate approach for either performing an analysis or making policy recommendations. This is the reason why most of the authors focus on a specific type of speculators (such as index speculators), on a specific type of commodity (or index), and on a specific time. One approach largely used by authors is to test the so-called Masters Hypothesis (Aulerich et al., 2014; Fattouh et al., 2013; Irwin & Sanders, 2012). The "Masters Hypothesis" comes from Masters and White (2008) theoretical model. The authors state that the massive entry of financial (long-only) index investors in commodity futures markets after 2003 has caused a bubble in the commodity futures prices. These futures price spikes have been then transmitted to spot prices. The bottom line is that because of such *excessive speculation*, commodity prices are not anymore determined by fundamental values (Masters & White, 2008; Irwin & Sanders, 2012; Fattouh et al., 2013).
The Working's speculative "T" (WT) index (Working, 1953) and Algieri's (2012) speculative (hedging) pressure aim precisely to measure such *excessive speculation*, that is, that amount of speculation that exceeds what is minimally required to meet short and long hedging demand.

2.2 Price discovery and the relation between spot and futures prices

The main focus of the papers analyzed is to answer the question on whether speculation raises commodity prices, meaning "spot" prices. However, it has been shown that speculative activities take place in futures markets which deal with future prices. Therefore, claiming that «speculation affects spot prices» means implicitly claiming that «changes in futures prices cause changes in spot prices». While it is largely agreed that speculation has an effect on futures prices, opposing opinions are found with respect to the relation between spot and futures prices. To explore and understand the different claims made throughout the literature, the concept of "price discovery" must be analyzed. Irwin and Sanders (2010) define price discovery as «the process of determining the price level for a commodity based on supply and demand conditions» (Irwin & Sanders, 2010, p. 29), which can occur in futures or cash markets (Irwin & Sanders, 2010). The extent to which market(s) serve and foster price discovery determines their efficiency. Specifically, a market is said to be efficient if «market prices adjust rapidly to reflect new information» (Irwin & Sanders, 2010, p. 27). Therefore, a necessary condition for an efficient market is a "perfect information" framework, in which arbitrage opportunities cannot exist and market participants cannot outperform the market for prolonged periods.

Price discovery is one of the two vital functions of commodity futures markets, together with risk transfer (Masters & White, 2008; Brunetti & Buyuksahin, 2009). As also recognized by the Commodity Exchange Act itself, futures markets have been created to help physical commodity market participants to accurately determine the current prices of commodities, to make estimations about the future prices of commodities and to hedge against risk accordingly and effectively (Clapp & Isakson, 2018b). The price discovery process should then start by an observation of the futures markets, in which - in principle - futures prices reflect the commodity's expected supply and demand (Clapp & Isakson, 2018b). By accepting the fact that price discovery and risk transfer are the fundamental reasons why commodity futures markets have been created, then a relationship between futures and spot prices cannot be denied. However, *effective* risk hedging can only be achieved if there is a well-functioning price discovery mechanism which connects futures and spot prices (Masters & White, 2008).

By contextualizing the price discovery mechanism in the current commodity futures markets' framework (which sees the - sometimes unbalanced - participation of structurally different actors with different purposes), several claims have been formulated by authors concerning the extent to which futures markets still contribute to price discovery in a meaningful and correct way, or the extent to which these markets still serve the price discovery function at all. It is clear that such discussions require us to define the drivers, mechanisms, actors and factors which build or affect spot prices, futures prices, or the relationship between them.

In the subsequent paragraphs, a summary of the relevant literature is reported. To assess whether the market is accomplishing the price discovery function, the authors usually analyze and make a statistical inference of the (futures) prices' volatility. Indeed, if futures prices are highly volatile, there is no meaningful information that physical commodity market participants can use to define or predict spot prices and hedge accordingly.
Section 2.2.1 gives an overview of the two main positions taken by authors with respect to the role that futures markets cover for what concerns price discovery. Section 2.2.2 provides some meaningful claims made by authors for what concerns the extent to which different market participants (e.g., hedge funds, speculators, index speculators) can either help or destroy price discovery.

2.2.1 The core and direction of price discovery

For what concerns the mechanisms underlying the spot–futures relationship, Ameur et al. (2022) recall the Law of One Price as the fundamental determinant of spot and futures prices relation, as well as Kaldor's (1983) theory of storage, which states that at the equilibrium, the future price of a storable commodity equals the sum of the commodity's spot price and its cost of carrying. The two theories give insights in the long-term relationship between spot and futures prices; however, they give little information about the nature of the spot-futures relationship in non-equilibrium, short-term periods. By employing a non-linear autoregressive distributed lag (NARDL) framework, the authors demonstrated that futures markets are crucial for price discovery, as changes in commodity prices appear first there, and then the information is transferred to spot markets through arbitrageurs' activities. By accepting «the leadership of the futures commodity market in the process of price discovery» (Ameur et al., 2022, p. 187), the authors finally conclude that the growing participation of structurally different (in terms of purposes, strategies and risk-appetites) actors in futures markets have increased (futures) prices' volatility, thus damaging the information transfer - and the whole price discovery process - to spot markets.
Likewise, Hernandez and Torero (2010) conducted linear and nonlinear causality tests on both spot and futures returns and their volatility and concluded that spot prices are discovered in futures markets. The conceptual examinations and empirical tests performed by Tilton et al. (2011), and Gulley and Tilton (2014) get more in the detail of this relationship, and conclude that spot prices are strongly determined by futures prices when the markets are in *contango*, which is defined by the CFTC as the «market situation in which prices in succeeding delivery months are progressively higher than in the nearest delivery month»[1]. Conversely, when the markets are in *backwardation* (that is, when futures prices are lower than spot prices) or weak contango, spot prices are mostly determined by current market conditions rather than futures markets' mechanisms (Tilton et al., 2011).

On the contrary, Dimpfl et al. (2017) studied the price dynamics of eight commodities and found that their prices are mainly formed in the spot market. They therefore conclude that the contribution of the futures market to price discovery is negligible, and thus that the widely-blamed speculative activities in futures markets do not affect spot prices in the long run (Dimpfl et al., 2017). This conclusion is in line with the efficient market theory, according to which, as recalled by Gilbert (2010), market fundamentals (supply and demand) are the only reason for the commodity prices' increases. Indeed, in the theory's view, futures markets cannot distort prices, as "informed" and "large" traders will offset the "uninformed" speculators' actions and bring the prices back to their fundamental values (Gilbert, 2010).

2.2.2 Stabilizing and destabilizing actors

A large group of authors has tried to indicate which particular activities or market actors have the power to either stabilize or destabilize prices' volatility. To begin, it is worth to mention that there is a common agreement among authors on the fact that a "bit" of speculation (meaning all those non-commercial investment activities) is beneficial for the futures market in terms of liquidity provision. After all, as stated by Boyd et al. (2018), «speculators are ultimately important counterparties

[1]See the CFTC's glossary here

who ensure that hedging opportunities are available in these markets» (Boyd et al., 2018, p. 102). Furthermore, as the number of market participants (speculators as well) increases, a more efficient information transfer to asset prices can also be expected, which would in turn improve price discovery and future price forecasting processes (Bekaert, Harvey & Garcia, 1995).

In their research, Brunetti et al. (2009; 2016) distinguished between hedge funds (the "large" or "traditional" speculators (Brunetti & Buyuksahin, 2009)) and other speculators such as swap dealers, and performed Granger causality tests to assess the relation between traders' positions changes and realized volatility of prices. They found that while speculators and swap dealers' activities have no effect on financial markets' (in)stability, hedge funds position changes not only provide the futures market with liquidity, but also facilitate price discovery by reducing price volatility. Therefore, hedge fund position changes have a strong effect on returns, but this effect is positive and stabilizing, and improves price discovery. For what concerns the reasons for the sharp increases in prices around 2008, the authors claim that commodity price volatility increased because of economic uncertainty, not because of hedge fund position changes (Brunetti et al., 2016).
Likewise, Kim (2015) states that «speculators either have no effect or stabilize prices during periods of large price movement» (Kim, 2015, p. 696). Bos (2012), von Witzke & Noleppa (2011), Hamilton & Wu (2015) and Smith (2009) reach similar conclusions.

Thus, according to these authors, speculation has no meaningful or harmful effect on spot prices, and they justify the price spikes with market-related factors. The main determinants pointed out are change in supply, demand, and inventories, the adoption of biofuel, population growth, weather and climate change, freight rates and global economic activities, exchange rates, and inflation.

It is worth to be pointed out that the most of the aforementioned authors usually refer to some "type", "level", or "extent" of speculation which can be considered beneficial. De Schutter (2010) calls it "traditional speculation": it is based on market fundamentals and it reduces price volatility because traditional speculators «buy when the price is low and sell when the price is high, thus evening out extremes of prices» (de Schutter, 2010, p. 4). Nevertheless, the author also indicates another form of speculation, which does not build upon commodity market fundamentals' forecasts and has caused the increase in price volatility and price bubbles. This form of speculation goes under the term "momentum-based speculation", and mainly refers to commodity index speculation. The author claims that the massive entry of commodities index funds in futures markets has destroyed the *normal backwardation* situation, under which futures prices are lower than spot prices, and turned commodity futures market into *contango*. As a result, the index fund triggered a «vicious circle of prices spiraling upward» (de Schutter, 2010, p. 4): higher futures prices led to an increase spot prices as well, which fed an increase in futures prices again. The futures prices' increases attracted more and more non-commercial actors in the commodity futures market. This phenomenon increased prices even more and ultimately led to a situation of *excessive* speculation (Masters & White, 2008).
Jennifer Clapp (2014; 2018a, 2018b) is another proponent of this argument: she claims that the growing "virtual hoarding" (Masters & White, 2008) of index investors is the main cause of more volatile commodity prices, and has been destroying the price discovery function of futures markets.

De Schutter (2010) and Clapp (2014; 2018a, 2018b) connect their claims to the Masters Hypothesis (Masters & White, 2008), which blames index speculators for driving up prices and damaging the price discovery function. Indeed, when investing, index speculators have no regard whatsoever for commodities' supply and demand fundamentals, and «every contract traded for reasons other than supply and demand is a contract that damages the price discovery function» (Masters & White, 2008, p. iii). It is precisely in this growing participation of index speculators in commodity futures markets that the authors identify the so-called *excessive* speculation: «speculators replace Physical Hedgers as the dominant force in the marketplace» (Masters & White, 2008, p. 29), (futures) prices do not reflect supply and demand fundamentals anymore, rather, they are way higher than what fundamentals may suggest. This eventually leads to a complete destruction of the price discovery function: prices «move for reasons that increasingly have little to do with specific commodity supply and demand fundamentals» (Masters & White, 2008, p. 36), and "bona-fide" physical hedgers are left with a distorted futures market which is no longer able to give them meaningful information for hedging their risks (Masters & White, 2008).

Opposite to these views, authors such as Irwin and Sanders (2009; 2010, 2012), reject the Master's hypothesis and claim that index funds did not harm price discovery and that futures markets are sufficiently liquid to welcome the large, increasing flow of index funds. They sustain their claims by performing linear and nonlinear Granger causality tests on prices' volatility and index traders' positions, as well as by pointing to some "conceptual errors" that bubble proponents make when claiming that the growing flow of index investments ultimately caused (spot) price bubbles through a chain reaction that started in the futures markets (Irwin et al., 2009).

2.3 Classification of findings

All the main features and findings of the papers have been recorded in the table presented in Appendix B. As a next step, all the literature has been classified based on two main domains. The first domain concerns the approach selected by the author(s) to assess speculation in commodity markets: the class "empiric" refers to all the literature which assess speculation by performing an empirical analysis / research, an analysis of the Working's speculative "T" index, a literature review, or through theoretical models; the class "statistics/econometrics" refers to all the literature which makes inference on specific data and performs (Granger) causality tests, VAR tests, cross-sectional analyses. Furthermore, this category also considers all the papers which introduce and apply dynamic models or economic / econometric models. The second domain refers to the main findings of the papers, and has a "yes/no" entry. A paper is classified under "yes" if it is found that speculation plays a (major) role in affecting commodity prices. By «affecting commodity prices» it is meant that speculation has contributed to increases commodity prices, increases in price volatility, and / or has damaged price discovery. Conversely, a paper is classified under "no" if it is found that speculation does not play a (major) role on commodity prices. With this it is meant that either the effect of speculation is negligible, is minimal or is spiky, or even that the effect of speculation is beneficial.

2.3.1 The trade-off between the two approaches: the proponents' "empirical bias"

As previously stated, the boundaries of the framework are blurred, and definitions better follow a continuum. Without surprise, it has been found that most authors take middle positions in their claims rather than radically promote or ban speculation in commodity markets. For this reason, the diagram on the right side of Figure 1 is more appropriate. The intersection within the domains are voluntarily of different sizes, as it has been found that authors tend to take "middle positions" more often when they perform statistical analyses. Conversely, when the analysis is based only on evidences or on empirical, observational analyses (Clapp, 2014; Clapp & Isakson, 2018a, 2018b; Ghosh, 2010; IPES-Food, 2022), the outcome is usually closer to a complete "yes" or "no", with "yes"s (proponents) prevailing on the "no"s (opponents). This pins out a first trade-off. On one side, not performing a rigorous, statistical analysis which appeals to data and makes inference on them, might lead to a biased view of the reality and a too drastic conclusion. On the other side, performing more rigorous steps might allow to sharpen the judgement, but it might also lead to less straightforward, and thus less useful - on the way they can help to develop policy recommendations - conclusions.

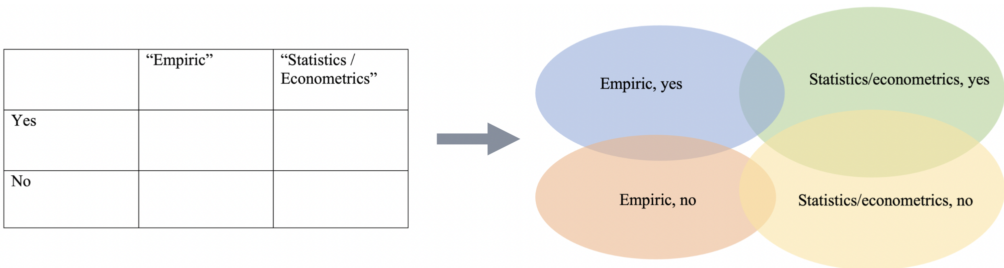

Figure 1: Classification diagram

2.3.2 A focus on the "yes/no" intersection

The "yes/no" intersection comprises all the authors who obtained unclear results for what concerns the impact of speculation on commodity prices and therefore took "middle positions". This happens especially when a numerical analysis is performed, rather than a simple empirical research. For example, Adämmer & Bohl (2015) adopted a Momentum threshold auto-regressive (MTAR) approach and identified the presence of speculative bubbles in wheat prices between 2003 and 2013, while they reached to inconclusive results for corn and soybeans, due to a low correlation between agricultural prices and market fundamentals. Similarly, Kilian and Murphy (2014) applied a vector-autoregressive (VAR) model to study the "asset price component" of the oil's spot price. For what concerns the oil price shock of years 1979, 1986 and 1990, they conclude that speculation moved the real price of oil. However, they find no evidence that speculation contributed to the dramatic rise of oil price between the years 2003 and mid-2008.

The way authors justify - or criticize - these contrasting results is by blaming on data repositories (Masters & White, 2008) or on models' limitations (Wimmer, Geyer-Klingeberg, Hütter, Schmid & Rathgeber, 2021).
Von Witzke & Noleppa (2011) promoted the use of monthly data in their analysis because «the use of daily price data may have left a larger part of the price fluctuation unexplained, as daily prices are affected by all kinds of technical reactions» (Von Witzke & Noleppa, 2011, p. 16). Conversely, Aulerich et al. (2014) claim that the weekly-nature of public data on financial index positions «reduces the power of time-series methods to detect index impacts» (Aulerich et al., 2014, p. 5). For this reason, in their analysis they use daily non-public data, leading them to reject the hypothesis that commodity index trading increased price volatility, thus invalidating the Masters Hypothesis.
Wimmer et al. (2021) conclude that «either there is no genuine overall speculation effect [...] or the research design of the frequently applied Granger Causality testing is not powerful enough to detect those effects» (Wimmer et al., 2021, p. 1).

2.3.3 Opponents

What it has been found is that most of the "no"s fall in the statistics/econometric area rather than in the "empirical" one. Again, this may suggest that qualitative studies lead to a biased, inaccurate and approximate view of reality, which brings to quickly conclude that «it is clear that speculation plays a role». However, conclusions from qualitative studies do not provide any information about the size of the speculation's effects on commodity prices, and therefore can only give broad recommendations on how to intervene on it. Contrarily, authors who reached a "no" conclusion usually performed more rigorous analyses. However, this "no" carries the weight of complex computations, imperfect models, approximate data, and arguable assumptions. Within these "opponents", two different classes of conclusions can be defined.

The first stream of authors concludes that speculation has little, negligible or even no power in rising commodity prices. They come to this conclusions by either showing no relation between spot and futures prices (Dimpfl et al., 2017; Smith, 2009; Hamilton & Wu, 2015), by performing statistical linear or non-linear (usually Granger) casuality tests (Robles et al., 2009; Andreasson et al., 2016; Irwin & Sanders, 2012; Irwin et al., 2009; Irwin & Sanders, 2010), by building non-parametric models (Bos & van der Molen, 2012), by analyzing the T-index (Alquist & Gervais, 2013; Irwin & Sanders, 2010; Sanders et al., 2010), through VAR tests, or through econometric models of supply and demand dynamics (Knittel & Pindyck, 2016; Von Witzke & Noleppa, 2011; Hamilton, 2009; Hamilton & Wu, 2015; Juvenal & Petrella, 2015).
Von Witzke & Noleppa (2011) conclude that «price volatility is all about supply and demand and not caused by speculation» (Von Witzke & Noleppa, 2011, p. 13), and that the 2007-08 price spikes can be fully explained by «changes in key supply and demand determining factors» (Von Witzke & Noleppa, 2011, p. 16).
Alquist & Gervais (2013) observed the T-index values throughout the years 1993-2012 and concluded that «that there was no substantial change in speculative pressure» during and after the 2008 crisis

(Alquist & Gervais, 2013, p. 42), thus concluding that speculation does not explain the 2003-2008 oil price increases.
Irwin, Sanders and other co-authors deeply investigated and tested the Masters hypothesis with different methods. They conclude that the increasing activity of index investments during the years 2006-08 did not cause a bubble in commodity futures prices (Irwin & Sanders, 2010). Through Fama–MacBeth tests using the CFTC's quarterly IID they found little evidence that index speculation has an impact on returns or price volatility (Irwin & Sanders, 2012). Instead, they justify the movements in commodity prices through economic fundamentals - such as the increasing demand of oil from China (Irwin et al., 2009), thus concluding that in their analyses there is no support for the Masters Hypothesis (Irwin & Sanders, 2012).
Bos & Van Der Molen (2012) built a non-parametric model and found that the effect of speculation on coffee's prices during the period 1989 - 2008 was spiky, therefore, even though speculation is found to have an effect on prices, they could not conclude that speculation has contributed to raise the prices of coffee. However, several authors show that index investments cause co-movements of prices within different commodities (Tang & Xiong, 2012). Thus, it can be argued that Bos's paper misses an important aspect of commodity markets by ignoring the effects of index speculation on the coffee's price. Likewise, Gilbert (2010) applied a Granger non-causality tests and an Autoregressive Distributed Lag (ADL) model and found that speculation rises food prices only for a short period of time.

The second stream of authors takes an even more radical position: they claim that speculation has positive, beneficial effects on commodity's markets. These authors do not differentiate between "speculation" and "excessive speculation", and reject the Masters hypothesis. Kim (2015) claims that speculators «contribute to lower price volatility, enhanced price efficiency, and better liquidity in the commodity markets» (Kim, 2015, p. 696). Borgards & Czudaj (2022) claim that «long-short speculators ethical correctly invest in agricultural commodities» (Borgards & Czudaj, 2022, p. 17). Aulerich et al. (2014) discuss the long-term positive effects for index trading. In their view, index investment may lead to a decrease in hedging costs for commercial participants and a smaller price volatility. Brunetti et al. (2009; 2016) focus on hedge funds as "speculators" and conclude that they facilitate price discovery, stabilize futures markets (and price volatility) and provide beneficial liquidity to such markets.

2.3.4 Proponents

From the classification, it turns out that most of the authors falling in the "yes" category have performed an empirical analysis, or built up a theoretical model. Specifically, they considered all the possible effects of price rises and concluded that the emergence of speculative bubbles is one of the causes that explains the spikes in prices: market fundamentals and economic shocks are not sufficient for explaining price peaks (de Schutter, 2010; IPES-Food, 2022; Ameur et al., 2022). As explained before, index speculators are often blamed as the main cause of unidirectional price changes (increases) (Masters & White, 2008; Tang & Xiong, 2012) and information asymmetries (Ghosh, 2010); and authors usually talk about *excessive* speculation as the main problem characterizing commodity futures markets (Algieri, 2012; Martin & Clapp, 2015).
Nevertheless, there are also some authors who performed a more rigorous analysis to assess the impact of speculation. Lagi et al. (2011) built a dynamic model which also includes speculation as one of the dynamic variables and found that their model sufficiently justified the real price increases in the period 2004-2011. This brought them to conclude that «the dominant causes of price increases are investor speculation and ethanol conversion» (Lagi et al., 2011, p. 1). Tang & Xiong (2012) performed a regression analysis to show the co-movements between different commodities' prices and concluded that index speculators were responsible for these. Ameur et al. (2022) built a nonlinear autoregressive distributed lag (NARDL) framework to show that futures price changes (caused by speculators) are mirrored in spot prices. Algieri (2012) carried out two batteries of Granger causality tests to show that excessive speculation affects price volatility.

2.4 Policy recommendations

The main goal of investigating the role of speculation on commodity markets is to provide policymakers, governments and financial institutions with policy recommendations. It is clear that these advises are strictly related to the findings and conclusions reached by the authors.

Most of the proponents of the Masters Hypothesis and more in general of the hypothesis that speculation raises commodity prices, point to the financialization of commodity markets alongside with financial deregulation as the main drivers of excessive and index speculation (Clapp, 2014; Clapp & Isakson, 2018a; Martin & Clapp, 2015). De Schutter (2010) suggests to restrict the trading of commodity derivatives to «qualified and knowledgeable investors» who take their decisions based on market fundamentals rather than «speculative motives» (de Schutter, 2010, p. 1). However, how could these knowledgeable investors be practically individuated? How could the inner sentiment that drives their investment decisions be assessed and defined?
Other authors suggest to «crack down on commodity speculation» (IPES-Food, 2022) or to enforce the regulatory framework (Lagi et al., 2011), however, they rarely give specific indications on *how* to do it. The reason is that most of these authors recognize the liquidity benefits that speculators bring to the market, therefore, it is important to limit speculation in a way that does not harm the market itself, which means intervening only to reduce *excessive* speculation, not speculation as a whole. Masters & White (2008) suggest to numerically quantify excessive speculation, but this is easier said than done. Similarly, Tang & Xiong (2012) conclude that «policy makers need to be cautious about imposing constraints on commodity index investment, because such constraints also limit the potential risk-sharing benefit» (Tang & Xiong, 2012, p. 72).

On the other side, opponents conclude that limiting speculative activities in commodity futures markets has to be done carefully. Irwin & Sanders (2012) conclude that the regulatory plans aimed at putting limits on index investments seem to be "ill-conceived", as index investors do not affect the price discovery. Policy actions aimed at fighting speculation may make commodity futures markets unable to serve their participants with liquidity and sources of risk-hedging (Irwin et al., 2009; Irwin & Sanders, 2010; Sanders et al., 2010; Sanders & Irwin, 2010). Brunetti et al. (2016) reach to similar conclusions for what concerns hedge funds.

A third stream of authors simply conclude that further research is needed to identify the main factors driving commodity prices movements. They blame current data to be not accurate for the analysis, and current econometric models too simplistic (Adämmer & Bohl, 2015; Wimmer et al., 2021). Fattouh et al. (2013) suggest that the current theoretical and empirical models should be developed into "more fully articulated economic models".

2.5 Conclusions

The growth and deregulation of the financial sector and its subsequent entry in the commodity markets since 2003 with index investments and commodity futures led speculation to become a widely discussed topic. As explained above, the main reason that brings several authors to investigate this topic lays in the deep connection between the financial sector and the real economy. If speculation actually plays a role in rising commodity prices, this is a clear evidence of the negative impacts of financialization of commodity markets on human lives and wealth (IPES-Food, 2022), opening flaws for what concerns the social efficiency of the financial sector (Epstein & Crotty, 2013). The topic becomes even more heated today, as we are slowly recovering from the Covid19 crisis but in the meantime we are facing a new one coming form the conflict in Ukraine. We don't want history to repeat and we certainly want to avoid making the same mistakes that brought to the 2008 crisis. In this respect, there is the need to understand to what extent speculation has the capacity of worsening the situation. When does speculation stop providing benefits and become harmful? How can we intervene on it?

This literature review has shown that answering these questions requires responding to an even more challenging question: does speculation actually matter? Authors are still debating on the impact of speculation on commodity prices, and no final answer has been yet given. The reasons are several.

First, by just analyzing the term "speculator" we can conclude that the definition largely refers to an inner spirit of financial actors, a behavior that is based on risk-appetite and personal attitudes. For this reason, practically detecting, identifying and distinguishing speculative activities within all the actions taking place in commodity markets is already a quite complicated task. Second, assuming we are able to come up with a measure of speculation (such as the speculative "T" index), assessing the extent to which speculation is influencing prices still brings several challenges. Econometric models might be too imprecise, assumptions might be too unrealistic, data might be inappropriate or not even existing, and so on. The reason for this is that commodity markets bring together the financial sector, the real economy, and people. The framework is therefore highly heterogeneous and complex, and its phenomena might be caused by an interconnection of numerous causes. Third, this literature review has shown that by simply following historical evidences we can "easily" conclude that speculation might have played a role in rising commodity food prices: after the deregulation of the financial sector and the massive enter of (index) investors in commodity futures markets in 2003, commodity prices peaked. It is hard to believe that these two events are not somehow interlinked. However, this is far from being useful from a policy point of view, as it tells us little about the strength of this connection and therefore the way we could manage it to obtain healthier market conditions.

This literature review showed that taking a massimalistic approach on speculation already means making a mistake, as speculation is rarely seen as "all good" or "all bad". Many studies indicate that there is a specific group of speculators (index investors) or a specific level of speculation (excessive speculation) that harms the most and on which policy makers should focus and intervene. Indeed, just the term *excessive speculation* leads to believe that there is something to re-balance and on which is worth to act through tailored policies.

Lastly, this literature review has shown the trade-off between the more empirical, observational approaches over more rigorous, numerical ones. Every method comes with its limits, and it is hard to favor one over the other. Furthermore, this literature review has shown that conclusions about the role of speculation are not univocal.

3 Fundamentals, linked markets, and the indirect effect of speculation in oil markets on food commodity prices

This chapter answers the following research question: *How much of the oil price' changes can be explained by speculation within the futures market of oil?*

Within the literature explored, there is a widespread consensus that, despite the role or the extent that speculative activities play in driving food commodity prices, market fundamentals can never be ruled out from being one of the main causes of commodity price movements and trends (Bos & van der Molen, 2012; Von Witzke & Noleppa, 2011; Hamilton, 2009; Smith, 2009; Gilbert, 2010).

With 'market fundamentals', the mainstream literature refers to all the possible demand and supply factors that might affect prices. The idea is that a change in the expectations of key supply and demand factors might cause changes in the price's behaviour, following a simple model of demand-and-supply in which the price is determined at the level at which demand equals supply.

Concerning the literature on food commodity prices, several market fundamental's variables have been mentioned as (main) causes of the price increases.
Rezitis and Sassi (2013) provide a literature review of the fundamental drivers for peaks in food commodity prices. The drivers are divided between supply and demand factors. What emerges from their review is that the "global biofuels production" (a demand-side factor) seems to be one of the most discussed among authors.
Wright (2012) investigates the grain market's price dynamics and categorizes the boost in biofuel production as one of the main «unpredictable factors» that have caused the sharp price (and price volatility) increases and made the grain market vulnerable to stock changes. Likewise, Von Witzke and Noleppa (2011) found that the growth in bioenergy had an impact on corn and soybean prices.
Gilbert (2010) expands the discussion by considering the effects of the growth of biofuels on land use. According to the author, «diversion of food crops for biofuels has raised potential demand for food commodities [...]. Biofuels demand might be responsible for the largest part of the rise in food prices» (Gilbert, 2010). However, the author claims that also food commodities which were not used as biofuel feedstock experienced an increase in prices. The reason is that the increase in land use for specific food commodities that were requested for biofuel is done at the detriment of all such commodities that are not used as biofuel, for which we see an increase in prices as well. Therefore, the growing demand for biofuels has - directly or indirectly - increased the prices of all food commodities.

The reasons behind the spectacular growth of biofuels can be largely traced back to another important market fundamental which is usually mentioned as one of the main drivers of food commodity price's dynamics: the oil price. Indeed, it is claimed that spikes in oil prices have fostered the "unpredictable" biofuel production (Wright, 2012; Rezitis & Sassi, 2013). Last but not least, the effect of oil price increases on food commodity prices can be also seen in financial (futures) markets. According to Tang and Xiong (2012), the growth of index investment has increased the correlation and comovement between food commodities prices and oil prices.

The bottom line of this discussion is that oil prices are related to food commodity prices through mechanisms which are both market-related (through biofuel demand, land use, energy supply, etc.) and index-related (through commodity indexes). In any case, if an increase in oil prices is experienced, an increase in the food commodity prices might be expected too.

The limitation of the literature mentioned above is that the authors have tried to trace back the food price spikes to market fundamentals (supply and demand factors). By doing so, they rule out speculation as one of the main causes of price increases. Their claim can be seen as true if we just focus on speculative activities playing within the specific food commodity (futures) market, however, the same claim becomes flawed if we embrace the (undeniable) concept of "linked markets", we accept the fact that non-energy commodity prices are affected by oil prices, and thus we look for speculation within this bigger framework.

This chapter precisely adopts this "linked markets" framework, thus assuming that the oil and the food commodity markets (and prices) are linked through market-fundamental factors as well as through financial (indexes) factors. The aim of this chapter is to investigate the role played by speculation in raising oil prices, and by doing so, evaluating the indirect, collateral, "side", effect of speculation in oil markets on food commodity markets. To quantitatively evaluate the impact of speculation on oil prices, the chapter makes use and extends the econometric model proposed by Knittel and Pindyck (2016). This models enables to isolate and quantify (as a proportion) the cumulative changes in oil prices and oil convenience yield due to speculation.

Lastly, it is worth to be reminded that the literature concerning speculation in oil markets is as debated as the one found for food commodities, as already shown in Section 2 and Appendix B. Authors differentiate from each other by the extent they believe speculative activity explains oil price's dynamics. For example, Juvenal and Petrella (2015) conclude that the main driver of oil prices is global demand, while speculation is the second biggest driver, accounting for 15% of the price rise.

This chapter is organised as follows. In the next section, Knittel and Pindyck (2016) 'simple' econometric model will be briefly introduced and explained. This model will be then used in Section 3.2 to evaluate how much of the recent oil price' changes can be explained by speculation. This will be done by extending the model to the most recent period: newer data about oil-related variables will be considered, and new assumptions will be made according to the current market situation. Alongside the discussion of the results, the limitations of the model adopted will be mentioned. Section 3.3 concludes.

3.1 Knittel and Pindyck (2016): a simple econometric model

In this section, the 'simple' econometric model proposed by Knittel and Pindyck (2016) is briefly presented and discussed.

The model provides an estimation of the cumulative changes in oil prices and oil convenience yield which are due to speculation, and it has been formulated and used by the two authors to evaluate the contribution of speculation in raising crude oil prices, specifically, to check whether speculation could be an explanation of the 2003-08 oil prices' increase (Knittel & Pindyck, 2016).

The authors consider supply, demand and inventories of crude oil as market fundamentals, and build a model based upon the theory of inventories and the interlinked cash and storage markets. By imposing and rearranging simple supply-and-demand equilibrium equations between the two markets, they reach to two formulas for evaluating the change in the oil (log) prices and in the (log) convenience yield (the price of oil storage) over a time period:

$$\Delta \ln P_t = \frac{1}{\eta_S - \eta_D}[\Delta \ln k_D - \Delta \ln k_S] + \frac{1}{\eta_S - \eta_D}\Delta \ln(X_t/Q_t) \tag{3}$$

$$\Delta \ln \psi_t = \Delta \ln k_N + \frac{1}{\eta_S - \eta_D}[\Delta \ln k_D - \Delta \ln k_S] + \frac{1}{\eta_S - \eta_D}\Delta \ln(X_t/Q_t) - (1/\eta_N)\Delta \ln N_t \tag{4}$$

According to the authors, the price at any time t (P_t) is a function of change in inventories (ΔN_t), which is in turn dependent on market fundamentals - supply (X, defined as (field) production minus net imports) and demand (or consumption, Q, defined as X minus changes in commercial stocks).
Equations (3) and (4) are constructed so that the parameters k_S and k_D incorporate market fundamentals. This implies that the elasticity of supply and demand (η_S, η_D) do not change if a shift in supply and/or demand is experienced because of shocks or other market-related movements of the curves. Likewise, the parameter k_N reflects any change in market fundamentals, thus keeping the price elasticity of demand for storage (η_N) constant. By doing so, the speculative component - everything that remains in equations (3) and (4) which does not incorporate market fundamental factors - can be isolated:

$$\Delta \ln P_t^S = \frac{1}{\eta_S - \eta_D}\Delta \ln(X_t/Q_t) \tag{5}$$

$$\Delta \ln \psi_t^S = \frac{1}{\eta_S - \eta_D} \Delta \ln(X_t/Q_t) - (1/\eta_N) \Delta \ln N_t \tag{6}$$

From equation 5, a relationship between speculative activity and inventory levels can be deducted. Specifically, assuming that, for a certain interval period, there are no changes in fundamentals and that speculative activity drives the price above its "fundamental" value, then from equation 5 an increase in inventories must be seen (Knittel & Pindyck, 2016).

From equations 5 and 6, the authors obtain the cumulative changes in (log) prices and (log) convenience yield due to speculation at any time (T) as follows:

$$\Delta \ln P_T^S = \ln P_T^S - \ln P_0^S = \sum_{t_0}^{T} \Delta \ln P_t^S \tag{7}$$

$$\Delta \ln \psi_T^S = \ln \psi_T^S - \ln \psi_0^S = \sum_{t_0}^{T} \Delta \ln \psi_t^S \tag{8}$$

Finally, the authors also consider spot prices and futures prices (specifically, F3 contracts) to estimate the capitalized flow of marginal convenience yield from holding a unit of inventory from t to t+T, defined as:

$$\psi_{t,T} = (1 + r_T)P_t - F_{t,T} + k_T \tag{9}$$

Where r_T the the risk-free T-period interest rate, P_t is the spot price at time t, $F_{t,T}$ is the futures price for delivery at t+T, and k_T is the T-period per-unit cost of physical storage (Knittel & Pindyck, 2016).

The previous analysis suggests that two vehicles for speculation can be identified (Knittel & Pindyck, 2016). These vehicles represent two common ways through which financial actors speculate, and they are usually considered being very influential on spot prices changes. Specifically, the first way has to do with the trading in futures market, namely, holding a short or long position in a futures contract. The second way, instead, deals with the inventory markets, and consists in holding physical inventories (Knittel & Pindyck, 2016). The first way is widely common between speculators, who do not any real interest in holding the physical commodity, while the second way is usually adopted by actors who are somehow already connected to the physical commodity, such as oil companies. These two ways, however, are not independent; rather, they are interconnected and they influence each other (Knittel & Pindyck, 2016). The reason the authors give for this mutually-reinforcing connection is, once again, traced back to the dynamics of prices and inventories. Specifically, the authors claim that speculative buying of futures pushes up the spot price only if inventories increase as well; and holding inventories for speculative purposes influences the convenience yield (namely, the price for storing the commodity) and this in turn has an impact on the futures prices (Knittel & Pindyck, 2016). Changes in futures prices will then cause changes in traders' expectations, which will respond by holding (new) long or short positions accordingly, reinforcing and closing the cycle.

The authors collected monthly data on crude oil from the Energy Information Administration (EIA), from January 1998 (t_0) to June 2012. They performed a monthly analysis (from which the monthly cumulative changes can be seen) as well as an epoch analysis, in which cumulative changes in price and convenience yield over a specific period are presented.

3.2 Application of Knittel and Pindyck (2016)'s simple econometric model

This section presents the application and extension of the econometric model proposed by Knittel and Pindyck (2016) to the more recent period. Indeed, the purpose of this chapter is to search and investigate the effects of speculation on oil prices, with a specific focus on the more recent years. The analysis performed by Knittel and Pindyck (2016), however, only reaches year 2011, therefore, the model needs to be extended with newer data.

Before extending the model, its robustness has been tested. Specifically, the model has been replicated and tested again on the same dataset and time period, and the outcomes of the analyses have been compared with the ones obtained by the authors. The comparison between the results of the period analysis performed by the authors and the ones coming from the replicated model can be found in Appendix C.1. From the comparison, it can be seen that the results obtained are slightly different. Reasons for the small discrepancies might be due to different models used for de-seasonalizing inventories. Furthermore, as the two final formulas present logarithms of fractions, a small difference between primary data quickly becomes bigger after the computation. This might rise concerns on the robustness of the model. However, results between the authors' experiment and the replicated one are not different in terms of information carried: the differences in the (numerical) results do not change the overall discussion based on them. Specifically, after having replicated the model, we can agree with the authors' conclusions and say that speculation is found to have a negligible, if not dampening impact on prices during periods and sub periods between 2007 and 2010.

Using the EIA data until end of 2022, the analysis has been then extended to the most recent period. In particular, data on spot prices, futures prices (F3 contract), (field) production, commercial stocks, imports and exports from January 2007 to December 2022 have been considered.

The aim of this section is to examine what Knittel and Pindyck's simple model can tell us about speculative activities during the Ukrainian conflict period. In particular, epoch analyses have been performed during the years 2020 and 2022: calculations of the changes in price and convenience yield due to speculation have been done for different periods and sub-periods. The epochs selected for the analysis are the following: epoch (1) from April 2020 to August 2020; epoch (2) from October 2020 to October 2021; epoch (3) from October 2020 to June 2022; epoch (4) from December 2021 to June 2022; and epoch (5) from December 2021 to March 2022. The reason for these choices is that during each of those epochs an increase in the (spot) price of crude oil is experienced, as shown in Figure 2, in which the beginning of the epochs (green lines) and the end of the epochs (orange dotted lines) are also reported.

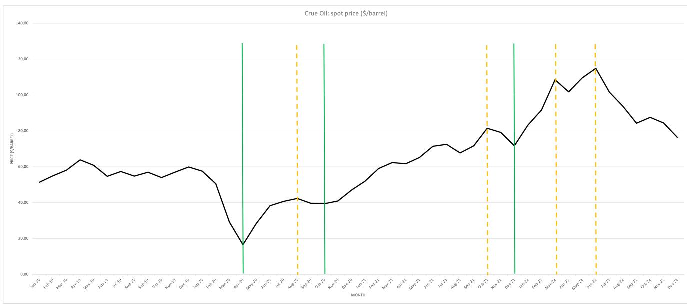

Figure 2: US crude oil monthly prices. Retrieved from EIA.

Section 3.2.1 will begin the analysis by making some reasonable and updated assumptions of some of the variables that appear in the formulas that will be used. Sections 3.2.2 and 3.2.3 present and discuss the results, respectively. Section 3.2.4 remarks some limitations found while replicating and extending the model.

3.2.1 Assumptions

Before discussing the results, it is important to make some reasonable estimations for the variables η_S, η_D, η_N, k_T and r_T. Estimations have been reported in Table 4.

The price elasticity of demand for storage, η_N, is set equal to 1, accepting and using the estimation made by the authors on the same data for crude oil (Knittel & Pindyck, 2016).
For what concerns the cost for storage k_T, it is estimated to be around \$1,5/barrel (Knittel & Pindyck, 2016).
As risk-free T-period interest rate r_T the T3-bill rate has been used. This is also the reason why the prices of 3-months futures contracts are used as futures prices when calculating $\psi_{t,T}$.
For what concerns the two elasticities η_S and η_D, estimations have been made based on a brief literat-

ure review on price elasticities. Specifically, Gilbert (2010) states that, especially during price booms (such as the one experienced throughout years 2021 and 2022), the supply curve may be inelastic (thus η_S is very close to zero). One reason for this is that booms usually happen after periods of low investments (Gilbert, 2010) - this is consistent with the 2020 period during which, because of Covid-19, investments have stretched. Secondly, the fact that today's markets are linked makes the supply curves of the single markets more inelastic, since they are affected not only by changes in their specific fundamentals, but also by changes in other linked markets' fundamentals (Gilbert, 2010). In line with this view, Caldara et al. (2019) have estimated a short-run oil supply elasticity of about 0.18. Likewise, Kilian's (2022) analysis reconfirms a one-month oil supply elasticity which is close to zero. For what concerns the demand elasticity, it can also be assumed to be very close to zero. Indeed, the current global economy is still highly dependent on oil - and this is again visible in today's critical situation. Finally, it is worth to point out that short-run elasticities are typically smaller than long-run elasticities (Knittel & Pindyck, 2016). For this reason, in the epoch analysis performed for the period from April 2020 to June 2022, it is assumed that $\eta_S - \eta_D = 0.4$ for epochs longer than one year (epochs 2 and 3), and that $\eta_S - \eta_D = 0.2$ for epochs shorter than one year (epochs 4 and 5). For epoch 1, different estimations for η_S and η_D have been used. The reason for this is that epoch (1) represents the first "recovery" period after the previous, dramatic and most critical months for what concerns the Covid-19 pandemic in the US. Figure 3 shows that from April 2020, crude oil consumption began to increase and to have a positive trend, compared to the previous months of year 2020.

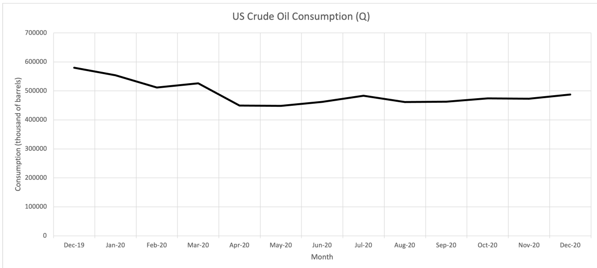

Figure 3: US crude oil consumption. Data elaborated by the author.

3.2.2 Results

The results obtained from the epoch analysis are reported in Table 3.

Epoch	(1) 2020:4-2020:8	(2) 2020:10-2021:10	(3) 2020:10-2022:6	(4) 2021:12-2022:6	(5) 2021:12-2022:3
Beginning price (P_0)	16.55	39.4	39.4	71.71	71.71
Ending price (P_T)	42.34	81.48	114.84	114.84	108.5
Beginning F3 price (F_0^3)	27.48	40.19	40.19	71.12	71.12
Ending F3 price (F_T^3)	42.98	79.5	109.2	109.2	102.52
Beginning X (X_0)	488153	461719	461719	520023	520023
Beginning Q (Q_0)	448262.0775	474057.5382	474057.5382	521431.2431	521431.2431
Ending X (X_T)	453151	524699	505161	505161	522124
Ending Q (Q_T)	462394.8692	516998.5382	494552.7014	494552.7014	527503.6296
Change in log price due to speculation (ΔlnP_T^S)	-15.06352%	10.28923%	11.89892%	11.96392%	-3.77313%
Beginning inventories (N_0)	514433.7791	496100.5905	496100.5905	434061.1101	434061.1101
Ending inventories (N_T)	511181.2595	438758.5905	411196.9238	411196.9238	405591.8567
Actual inventory build up over entire epoch (ΔN_T)	-3252.519676	-57342	-84903.66667	-22864.18634	-28469.25347
Beginning convenience yield (ψ_0)	-6.424210539	3.719846308	3.719846308	5.100754081	5.100754081
Beginning convenience yield (ψ_0) truncation (if needed)	1.5	3.719846308	3.719846308	5.100754081	5.100754081
Ending convenience yield (ψ_T)	3.870581033	6.490183091	10.56540935	10.56540935	10.59915358
Ending convenience yield (ψ_T) truncation (if needed)	3.870581033	6.490183091	10.56540935	10.56540935	10.59915358
Change in log conv. yield due to speculation ($\Delta ln\psi_T^S$)	-14.42926%	22.57217%	30.66957%	17.37523%	3.01067%

Table 3: Epoch analysis. $\Delta lnP_T^S = \frac{1}{\eta_S - \eta_D}(ln(X_T/Q_T) - ln(X_0/Q_0))$; $\Delta ln\psi_T^S = \frac{1}{\eta_S - \eta_D}(ln(X_T/Q_T) - ln(X_0/Q_0)) - (1/\eta_N)(lnN_T - lnN_0)$; ψ_0, ψ_T *have been calculated following equation 9.*

Variable	Value
η_S long	0.2
η_D long	-0.2
η_S - η_D long	0.4
$1/(\eta_S$ - $\eta_D)$ long	2.5
η_S short	0.1
η_D short	-0.1
η_S - η_D short	0.2
$1/(\eta_S$ - $\eta_D)$ short	5
η_N	1
k_T	1.5
k_N	1
η_S epoch (1)	0.2
η_D epoch (1)	-0.5
η_S - η_D epoch (1)	0.7
$1/(\eta_S$ - $\eta_D)$ epoch (1)	1.428571429

Table 4: Variables.

3.2.3 Discussion

Change in log price due to speculation. The first thing that can be noticed when comparing the results obtained for the period 2020-2022 with the results obtained by Knittel and Pindyck (2016) and their replicated model for years 2007-2011, is that the shares of the price change due to speculation are usually bigger in 2020-2022. Indeed, while during years 2007-2011 the percentages were close to zero (meaning that market fundamentals are the main factors of changes in prices), during years 2020-2022 higher percentages are obtained. These percentages are closer to the estimation made by Juvenal and Petrella (2015) who stated that speculation accounts for about 15% of price increases. By examining each epoch separately, it can be seen that for Epoch 1 the change is negative, thus meaning that speculation might had a stabilizing effect on prices. The same can be said for epoch 5. In epochs 2, 3, and 4, however, the results show that speculation has played a quite significant role in driving up the crude oil price.

Change in prices and inventories. Based on equation 5, a relationship between speculative activity and inventory levels has been proposed (Knittel & Pindyck, 2016). By construction, all the epochs selected refer to periods in which an increase oil prices is experienced. If speculation has to be blamed for having driven up the price over its fundamental value, then an inventory increase must be experienced too. However, this is inconsistent with the results obtained, in which we see a decrease, rather than an increase, in inventories. The reason for these inconsistencies can be partially explained by noting that the aforementioned phenomenon of price increase due to speculation and subsequent inventories increase happens based on the assumption that there are no changes in fundamentals. This is certainly not the case when looking at the historical events happened during epochs 2, 3 and 4, in which dramatic cuts in US crude oil imports and panic because of the Ukrainian conflict stretched inventories and led to negative changes. Therefore, it can still be claimed that speculation has played a role in raising prices, however, to the extent that it contributed to push them up, it was not as strong as other market fundamentals, and thus it didn't result in positive changes in inventories.

Change in log convenience yield due to speculation. As for prices, the shares of the convenience yield change due to speculation are bigger in 2020-2022 than what has been calculated by Knittel and Pindyck (2016) for years 2007-2011: while during the years 2007-2011 the percentages were close to zero (meaning that market fundamentals are the main factors of changes in convenience yield), during the years 2020-2022 higher percentages are obtained. For epochs 2, 3, and 4, speculation seems to have had an impact in raising the prices of convenience yield: it became more costly to store crude oil. This is certainly largely explained by the fact that during the epochs 2, 3, and 4 the US was experiencing shortages because of the Russian's cuts in oil supply, however, speculation might have to a certain extent contributed to this increase in costs. Nevertheless, Knittel and Pindyck (2016) also show that the net effect of speculation on convenience yields is ambiguous, since two opposing forces - speculative inventory accumulation which pushes the convenience yield down; and speculation through spot prices, which pushes the convenience yield up - contemporaneously operate. Therefore, conclusions drawn from the last row of Table 3 should better be reinforced by further market analyses.

3.2.4 Limitations

Knittel and Pindyck (2016) also mention some limitations of their model (which also appear in this experiment) such as the assumptions made on supply and demand elasticities, the construction of variables such as the US crude oil domestic consumption (Q) and the estimations of the parameter k_N and the assumption of its stability over time. Alongside these limitations, after a replication analysis and an extension to a recent period have been performed, the dataset selected, as well as the method adopted to de-seasonalize inventories should also be seen as limitations of the model. Indeed, little variations of preliminary data carried forward throughout the calculations rapidly lead to bigger differences in results.

3.3 Conclusions

It is largely agreed that a relationship holds between oil and food commodity prices. This relationship is built upon market fundamentals - demand and supply factors (Gilbert, 2010; Wright, 2012; Rezitis & Sassi, 2013) as well as through futures markets with the growth in commodity index investments (Tang & Xiong, 2012). For one reason or another, if price increases are seen in the oil market (spot or futures), price increases within the commodity market (spot or futures) might also be expected. Therefore, if speculation has somehow played a role in driving up oil prices, then the same activity can be blamed for having driven up also market- or index- related commodity prices. It can be therefore state that the potential effects of speculation in the oil market are indirectly reflected in the food markets.

The previous analysis has shown that, during years 2020-2022, speculation has, to some extent, played a role in pushing up the crude oil price. The effect is still limited compared to the share belonging to the crude oil's market fundamentals, however, it is not possible to completely rule out speculation as one of the driving factors. The analysis suggests that, when assessing food commodity prices' dynamics, it is not appropriate to draw a clear line between "market fundamental factors" (among which crude oil prices) and "speculation", since speculation can be also found in such fundamental drivers and has an indirect effect on food commodity prices due to the markets' linkages. To conclude, it is not possible to rule out speculation in food commodities' prices by just claiming that "food price spikes can be fully explained through market fundamentals", if such fundamentals are themselves partially manipulated by speculative activities.

4 Linkages between oil price and food commodity prices: a Granger-type causation chain

This chapter answers the following research question: *What are the factors and dynamics that link oil prices to food commodity prices?*

The following Chapter continues and deepens the discussion of Chapter 3. Specifically, it investigates and further specifies the relation which holds between oil prices and food (corn and soybeans) commodity prices. It does so by considering the fertilizer price as a potential "bridging" variable between the prices of oil and the two food commodities, and eventually providing a potential chain of Granger-causation that links such variables. By doing so, this Chapter closes the discussion about the "indirect" effect of speculation on food prices through the oil market.

The Chapter is organized as follows. Section 4.1 will investigate the WTI crude oil price dynamics through descriptive statistics and visual inspections. Then, Section 4.2 will continue the analysis by comparing oil variables with indexes such as the S&P GSCI and the prices of corn and soybeans. Reasons for possible comovements and trends will be given in light of the widely-debated discussion concerning the birth and growth of index investments (Masters & White, 2008; Tang & Xiong, 2012; Irwin et al., 2009). As a first attempt to delineate a possible chain of causation between oil and food commodities, in Section 4.3 Granger causality tests will be performed to check whether oil prices Granger-cause food commodity prices. Finally, Section 4.4 will consider an additional variable, the fertilizer prices, and - through Granger causality tests - a "more detailed" chain of causation between oil and food commodity prices will be delineated.

4.1 WTI crude oil: descriptive statistics and visuals

Figure 4 presents monthly spot and futures (first contract) prices for WTI crude oil, the monthly volatility of futures returns [2], and the daily compounded futures returns.

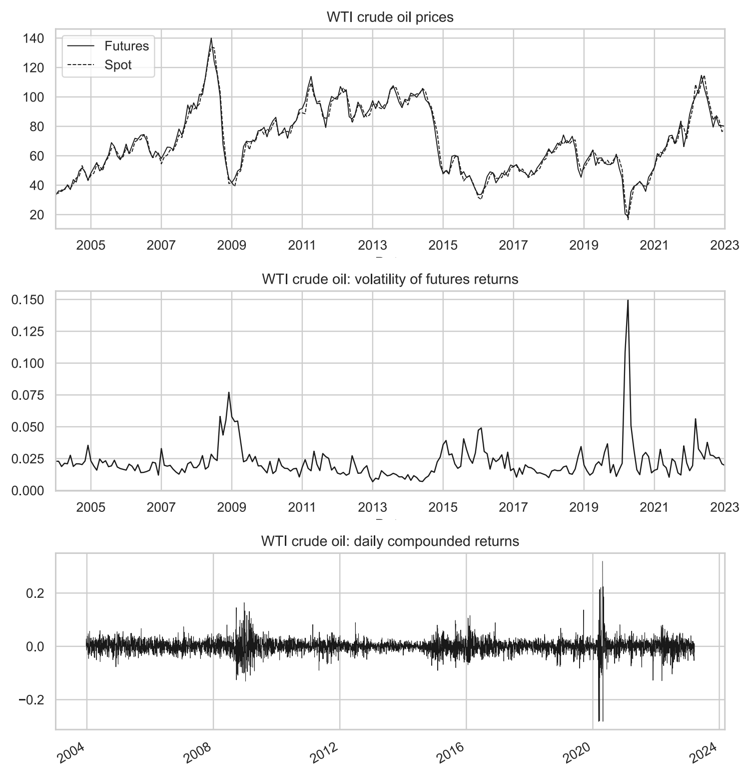

Figure 4: WTI crude oil (monthly) prices, (monthly) volatility of futures returns, and (daily) compounded futures returns

[2] The volatility of futures returns has been computed following the methodology proposed by Algieri (2012) for historical (or realised) volatility, see Appendix D.2 for more detail.

From the first graph in Figure 4 it can be seen that futures and spot prices of WTI crude oil are highly correlated, signalling the fact that futures and spot markets are strictly linked and that there is an information flow between the two. Specifically, it seems like futures price levels *anticipate* spot price ones. However, to clarify the way through which the two markets affect each other, a visual inspection lacks rigor, and statistical tests are a better option[3]. The second and third graphs in Figure 4 suggest that in periods of shock and uncertainty - which derive not only from market-related factors such as supply and demand, but also from dramatic events such as bank failures, which have nothing to do with oil ("real") supply and demand - the futures prices' volatility increases, as prices change dramatically. However, also excluding the "exceptional" periods with volatility peaks, it can be seen that the futures returns of WTI crude oil have been subjected to bigger fluctuations in the recent times. The damaging effects of a higher volatility of futures prices on the price discovery function have been discussed and presented in Section 2.2.1.

To continue the analysis, data about WTI crude oil positions and open interests have been retrieved from the CFTC COT report. The data have been cleaned, prepared, plotted and analyzed for the period 2004-2023.

Figure 5 shows the total open interest for the WTI crude oil. The curve presents a general upward trend, signalling the fact that, from 2004 to 2023, a growing number of contracts has been produced. The figure also reports the non-commercial positions (both long and short) during the same period. It can be seen that long non-commercial positions also increased, thus signalling that the growth of open interest was not only due to the entry of commercial traders, but also non-commercial ones. This is clear evidence of the financialization of the oil market.

Figures 6 and 7 focus on the non-commercial positions (both short and long) throughout 2004 and 2023. From the figures, it can be seen that short positions have stayed almost constant throughout the period, with a ratio of non-commercial positions to total reportable positions which varies between 0.0382 and 0.2182. Conversely, for what concerns long positions, it can be seen that they have increased throughout time until 2019. In 2020 there is an "exit" of non-commercial traders, probably due to the Covid-19 pandemic, and again in 2022 it can be seen that a part of non-commercial traders has left the market, probably "scared" by the current Ukrainian conflict.

The ratio of non-commercial positions to total reportable long positions is much more volatile than the one observed for short positions - it varies between 0.1112 and 0.363727. The reason for this difference between long and short non-commercial positions can be explained by the fact that non-commercial traders, especially index funds, are usually long-only (Masters & White, 2008; Sanders & Irwin, 2010; Sanders et al., 2010), while hedgers (commercials) are mainly found in the short market. Lastly, the ratio of non-commercial long positions to total reportable long positions predominantly shows an upward trend throughout the period: this suggests that the "balance" between commercial and non-commercial traders within the oil futures market has changed in the years. Recalling Masters and White (2008), the reason could be traced back to the birth of index investment as a new asset class, which caused the entry of long-only index investors which «lean only in one direction - long - and they lean with all their weight» (Masters & White, 2008, p. 11).

Table 5 presents an overview of the reportable position shares for the whole period (2004-2023) as well as for four sub-periods. The table confirms what it has been said before: the share of commercial long positions has decreased from 2004 to 2020, while the share of non-commercial long positions has increased - the oil market has become more and more financialized.

Table 5 also reports the share of commercial and non-commercial short positions. As explained in the previous sections, for every long position there is an opposite short position, and a good balance between long and short positions is beneficial for the market's liquidity (Masters & White, 2008). What the left columns of Table 5 show, however, is that while commercial short position shares stood almost the same, non-commercial short position shares have decreased from 12.79% of total open interest in 2004 to 6.67% of total open interest in 2020. This again is in line with the growth on

[3]The Granger causality tests executed for spot and futures prices of WTI crude oil are reported in Appendix E.

index investments and the birth of index investors, which usually take long-only positions rather than short ones. This "imbalance" is translated in a *market pressure*, which has been numerically defined through Working's T index (Working, 1960) and Algieri's (2012) hedging and speculative pressures.

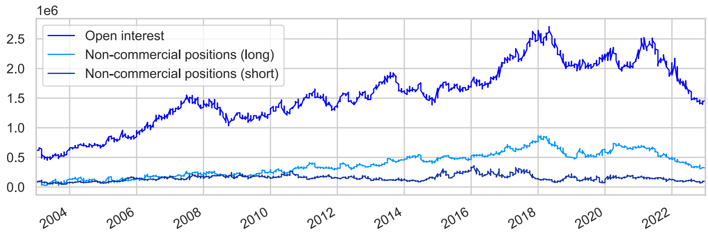

Figure 5: WTI crude oil: Open interest and non-commercial positions

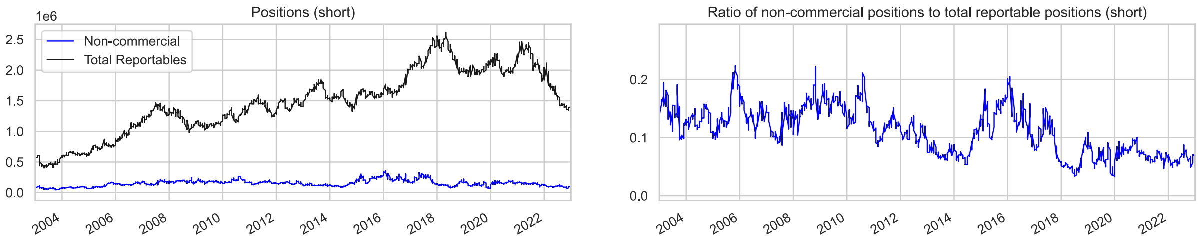

Figure 6: WTI crude oil: Non-commercial positions (short)

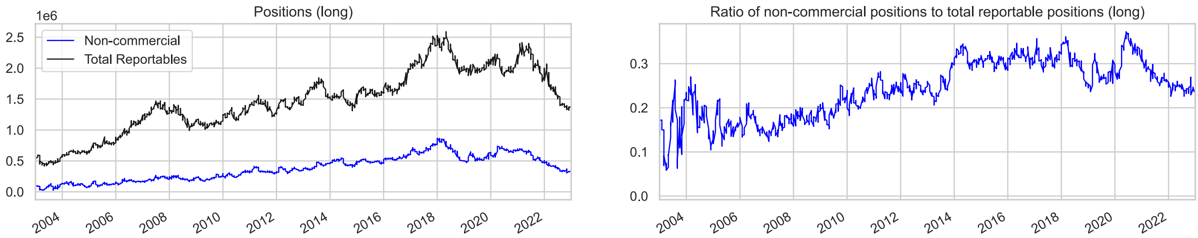

Figure 7: WTI crude oil: Non-commercial positions (long)

	%OI Commercials long	%OI Non-commercials long	%OI Commercials short	%OI Non-commercials short
2004:01-2007:01	61.958	15.777	63.967	12.798
2007:01-2015:01	45.658	21.360	56.157	11.431
2015:01-2020:01	33.930	28.891	53.701	9.613
2020:01-2023:01	34.825	26.759	56.633	6.687
2004:01-2023:01	**43.466**	**23.3072**	**56.845**	**10.418**

Table 5: Reportables position shares (percentages of total open interest).

Figure 8 shows Working's T index (Working, 1960) and Algieri's (2012) hedging and speculative pressures from 2004 to 2023. Table 6 reports some descriptive statistics for the three variables, divided into two sub-periods: 2004:01-2015:01 and 2015:01-2023:01. The T-index reaches its highest level, 1.241, in 2016, when oil prices were at minimum levels (see Figure 4). A T-index of 1.241 means that 24.1% of speculative funds in the oil market is not beneficial for providing liquidity and meeting the hedging positions, rather, it is *in excess*. The minimum value reached by the T-index is 1.041, 4.1% of speculation in excess. On average, the WTI crude oil market has around 10% of speculation in excess detected.
The hedging pressure has declined throughout the period. The maximum value reached is 6.439, while the minimum is -34.834. Conversely, the speculative pressure shows an upward trend, with a maximum value reached of 77.904. This is confirmed by Table 6, in which it can be seen that speculative pressure has, in both periods, a positive mean, while the hedging pressure shows negative (declining) means for both periods. The fact that positive values of speculative pressure's mean are reported signals that the market under analysis is a speculative market (Algieri, 2012).

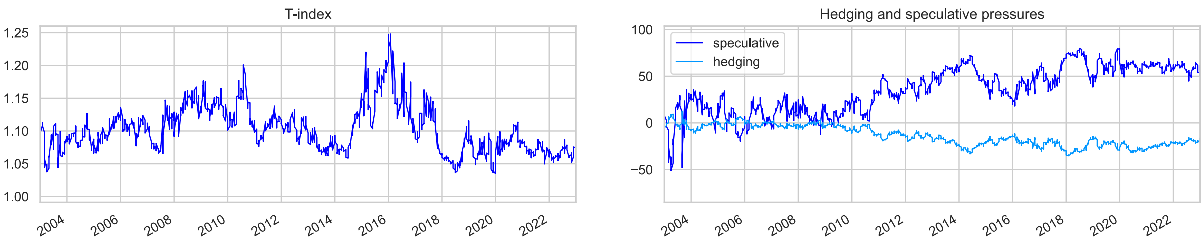

Figure 8: T-index; hedging and speculative pressures. Computed by the author.

	2004:01-2015:01			2015:01-2023:01		
	speculative pressure	**hedging pressure**	**T-index**	**speculative pressure**	**hedging pressure**	**T-index**
count	133	133	133	97	97	97
mean	24.398	-8.455	1.108	54.496	-22.979	1.098
std	20.174	8.727	0.026	13.023	4.716	0.044
min	-16.381	-31.858	1.063	21.211	-34.834	1.041
25%	9.660	-14.439	1.089	45.998	-26.697	1.064
50%	20.944	-5.378	1.108	56.789	-21.985	1.081
75%	37.621	-1.930	1.126	62.849	-19.554	1.125
max	69.520	6.439	1.178	77.904	-13.663	1.241

Table 6: T-index, hedging and speculative pressures: descriptive statistics.

Lastly, Figure 9 plots the open interest together with the spot and futures prices of oil. The open interest has been re-scaled for visual reasons; however, as the focus is on trends rather than on specific numbers, this does not affect the analysis. The graph shows that, from 2004 to 2015, open interest and prices predominately grew together. This is also confirmed by Table 7, which shows a correlation between open interest and spot prices of 0.819. The period 2015-2020 is more ambiguous, with open interest growing more and prices' changes reduced. Within this period, the correlation between open interest and spot prices goes down to 0.614. Lastly, in the period 2020-2023 there is an inversion of trends: while open interest declines, prices rise, with a correlation between open interest and spot prices of -0.626. The rise in oil prices despite the decrease in open interest can be explained by the fact that, especially during year 2022, historically-contingent events such as the Ukrainian conflict have played a major role in spreading panic and raising oil prices.

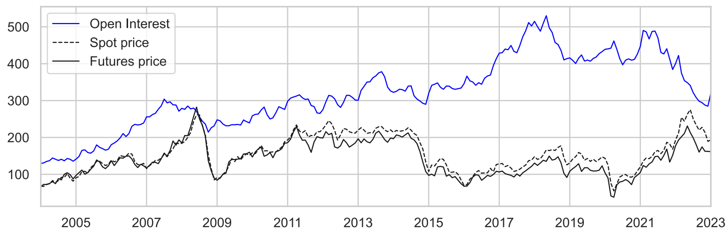

Figure 9: WTI crude oil open interest (re-scaled), futures prices and spot prices.

2004:01-2015:01	**Open Interest**	**Futures price**	**Spot price**
Open Interest	1	0.761	0.819
Futures price	0.761	1	0.966
Spot price	0.819	0.966	1

2015:01-2020:01	**Open Interest**	**Futures price**	**Spot price**
Open Interest	1	0.650	0.614
Futures price	0.650	1	0.923
Spot price	0.614	0.923	1

2020:01-2023:01	**Open Interest**	**Futures price**	**Spot price**
Open Interest	1	-0.526	-0.626
Futures price	-0.526	1	0.971
Spot price	-0.626	0.971	1

Table 7: WTI crude oil open interest, futures prices and spot prices: correlation matrix.

4.2 Comparative analysis

Figure 10 reports the monthly spot prices of WTI crude oil, corn and soybeans back to 1994. The prices of the three commodities could be re-scaled to a common index, however, since the next analyses will just explore trends and dynamics, the re-scaling is not necessary.

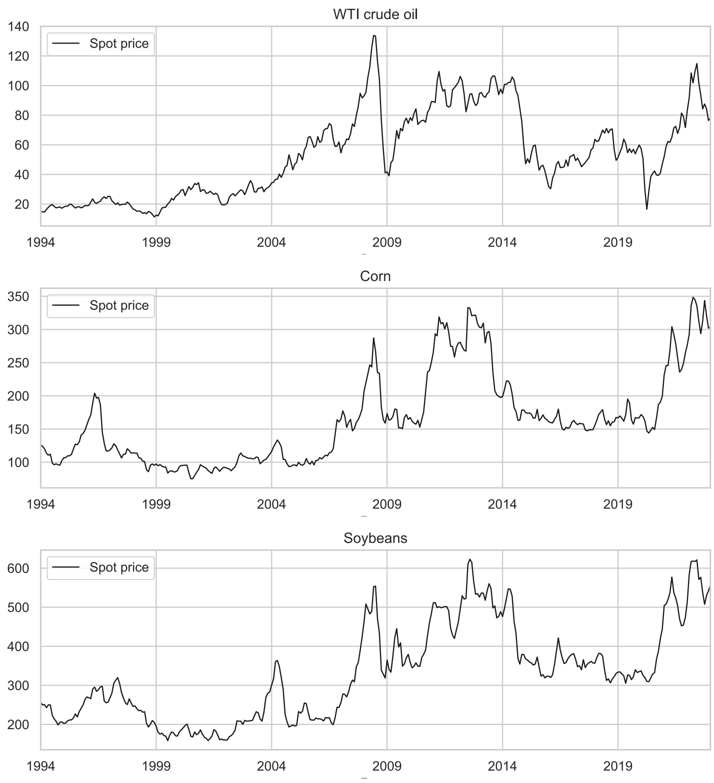

Figure 10: Spot prices.

From a first graphical inspection, the following observations can be made. First, the average price has generally been increasing: price levels as low as the ones reported in 1994 have been rarely reached again. A reason for this can be traced back to market fundamentals: the supply and consumption of oil, grain and oilseeds has increased dramatically over the past decades, especially with the growth of emerging economies such as China and Asia at the beginning of the millennium (Alquist, Bhattarai & Coibion, 2020; Hamilton, 2009). However, the beginning of the current millennium also coincides with the explosive growth of the financial sector, with an enormous capital inflow in commodity futures markets (Peersman, Rüth & Van der Veken, 2021). Thereby, the general price increase can also be, at least partially, due to a demand-factor that stems from the 2000s' financialization of commodity markets (Tang & Xiong, 2012; Peersman et al., 2021).
Second, the trend shows periodic price spikes, some of them characterized by impressive price levels, such as the 2008 and the 2022 ones. Such spikes are characterized by a subsequent price drop, with prices reaching levels that were even lower than the ones before the spike.
These two observations lead to two considerations. From the first observation, it can be concluded that there are some factors - either coming from the "real" economy or the financial sector - that have led to a general increase in prices. From the second observation, it can be concluded that commodities' trends have a cyclical component: in periods of shocks such as the 2008 and the 2022 ones, prices tend to rise more than normally and, in a similar manner, they drop back to lower-than-normal values. The big question is again whether these cyclical episodes can be fully traced back to market fundamentals or whether there are some other factors (such as an increase in speculative activities in futures markets) that turn shocks (such as bank failures or wars) into price bubbles.
A third and final observation is that the three trends seem to co-move. This observation opens up the comparative analysis part of this chapter. In specific, the analysis will consider monthly data on futures prices of WTI crude oil, corn and soybeans from 2004 to 2023.

Figure 11 plots the monthly futures prices of WTI crude oil, corn and soybeans, together with the IMF food price index (*International Monetary Fund*, n.d.) and the S&P GSCI. Table 8 presents a summary of some descriptive statistics for the variables analyzed.

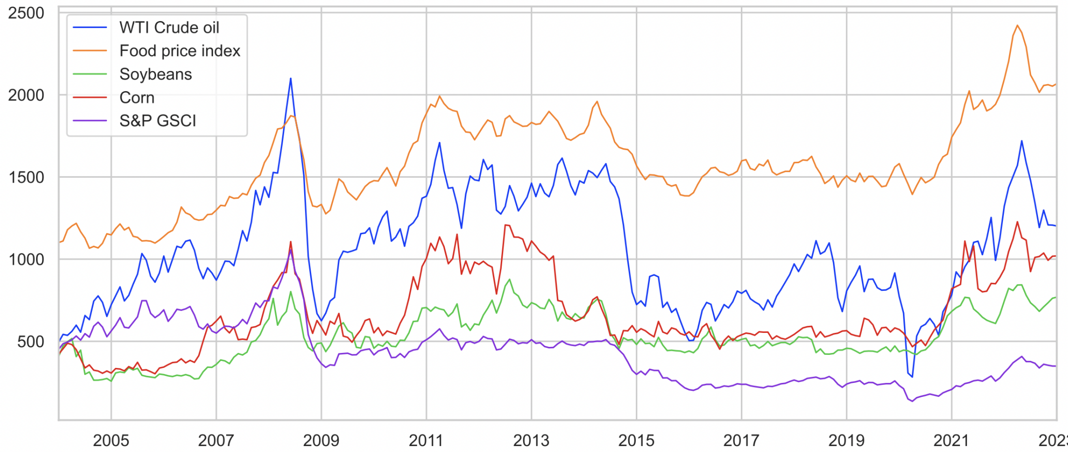

Figure 11: Futures prices of WTI crude oil, corn and soybeans; S&P GSCI and Food price indexes

	WTI crude oil: futures price	Corn: futures price	Soybeans: futures price	Food Price Index	S&P GSCI	Volatility of futures returns
mean	70.095	442.352	1061.961	105.360	4237.718	0.022
std	22.638	155.269	293.644	18.479	1774.313	0.014
min	18.840	201.750	514.750	71.099	1349.817	0.007
25%	51.560	351.500	882.380	93.629	2578.938	0.015
50%	66.630	387.750	1010.630	102.125	4276.100	0.019
75%	88.910	556.500	1319.130	119.819	5254.619	0.025
max	140.000	818.250	1754.370	161.518	10558.650	0.149

Table 8: Descriptive statistics. Period: 2004-2023

	S&P GSCI	WTI crude oil: futures price	Food Price Index	Soybeans: futures price	Corn: futures price
S&P GSCI	1***	0.555***	-0.136**	-0.045	0.056
WTI crude oil: futures price	0.555***	1***	0.667***	0.652***	0.678***
Food Price Index	-0.136**	0.667***	1***	0.912***	0.879***
Soybeans: futures price	-0.045	0.652***	0.912***	1***	0.906***
Corn: futures price	0.056	0.678***	0.879***	0.906***	1***

*Table 9: Correlation matrix. Period: 2004-2023. * = 10% significance; ** = 5% significance; *** = 1% significance.*

	S&P GSCI	WTI crude oil: futures price	Food Price Index	Soybeans: futures price	Corn: futures price
S&P GSCI	1***	0.294***	-0.109	-0.139	-0.055
WTI crude oil: futures price	0.294***	1***	0.860***	0.748***	0.722***
Food Price Index	-0.109	0.860***	1***	0.918***	0.881***
Soybeans: futures price	-0.139	0.748***	0.918***	1***	0.893***
Corn: futures price	-0.055	0.722***	0.881***	0.893***	1***

*Table 10: Correlation matrix. Period: 2004-2015. * = 10% significance; ** = 5% significance; *** = 1% significance.*

	S&P GSCI	WTI crude oil: futures price	Food Price Index	Soybeans: futures price	Corn: futures price
S&P GSCI	1***	0.934***	0.778***	0.664***	0.737***
WTI crude oil: futures price	0.934***	1***	0.839***	0.748***	0.798***
Food Price Index	0.778***	0.839***	1***	0.949***	0.950***
Soybeans: futures price	0.664***	0.748***	0.949***	1***	0.943***
Corn: futures price	0.737***	0.798***	0.950***	0.943***	1***

*Table 11: Correlation matrix. Period: 2015-2023. * = 10% significance; ** = 5% significance; *** = 1% significance.*

From Figure 11 a co-movement between the different commodities as well as with the indexes can be observed. The co-movement between energy and non-energy commodities is a common finding in the literature. Authors trace back causes for these co-movements to either (co-movements in) fundamentals (Hamilton, 2009; Gilbert, 2010) or, alternatively, to the financialization of commodity markets (Tang & Xiong, 2012).

Examining Figure 11 in more detail, it can be observed that the co-movement becomes more visible during the periods 2008-2012 and 2020-2023. However, it looks like prices of different commodities usually behave in a similar manner throughout the whole period analyzed. One exception is the year 2020, in which it can be seen that the WTI price dropped to its lowest value, while soybeans and corn prices just experienced a small decline. The reason for that can be traced back to the historical conditions of the year: the pandemic forced the whole population to a lockdown which reduced dramatically the consumption of oil for transportation purposes. Furthermore, the drop is experienced during the warm season of 2020 (WTI prices are based on the US), thus energy consumption for heat was also smaller.

From this first visual inspection, what can be concluded is that, for one reason or another, it is clear that the assumption of "linked markets" (Gilbert, 2010) cannot be rejected, and this implies that different markets communicate and have "spillover effects" on other markets (Peersman et al., 2021). These spillover effects can have any kind of nature.

As showed in Chapter 3, spillover effects can be traced back to fundamentals - to the increasing demand for biofuels, for example. As explained in the chapter, different commodities, directly or indirectly through changes in land use, are subjected to the effects of the shift to biofuels (Gilbert, 2010), and this plays a role in creating co-movements between prices.

Additionally, spill-over effects can also come from the financial sector. For example, the 2008 financial crisis disrupted the financial sector, and the increased risk on stocks and investments spilled over into commodity markets, increasing their prices (Ma, Ji, Wu & Pan, 2021). As already observed previously, co-movements become more pronounced during periods of shocks and panic, in which spill-over effects are bigger and even more immediate. This is in line with the *contagion effect* (Cai, Fang, Chang, Tian & Hamori, 2020) which characterizes (linked) markets during heated periods.

This shows up an important, negative feature that comes along with the growth of the financial sector and the subsequent financialization of commodities: information, risks, panics, price increases and other dynamics happening within the financial sector overflow into the real economy. This is in line with what has been found, through a rolling-window analysis, by Ma et al. (2021): financial market information affects the commodity prices' dynamics.

What Figure 11 also shows, however, is that some sort of co-movement between different commodities can also be seen in periods of global "stability". Tang and Xiong (2012) examined the period from 1992 and 2012 and claimed that this co-movement has to do with the growth of index investments.

Extending the period to recent years, the findings of Tang and Xiong (2012) remain consistent with what is reported in the correlation tables 9, 10, and 11[4]. Indeed, it can be seen that futures prices of oil are correlated with futures prices of corn and soybeans, as well as with the food price index. This correlation increases over time for what concerns oil and soybeans (from 0.7480 in the period 2004-2015 to 0.7483 in the period 2015-2023) and oil and corn (from 0.721 in the period 2004-2015 to 0.797 in the period 2015-2023), while it slightly decreases with the food price index.
Again, the reason for that can be traced back to the index investment's theory proposed by Tang and Xiong (2012). Indeed, as reported by the IMF, (*International Monetary Fund*, n.d.) the food price index includes cereal, vegetable oils, meat, seafood, sugar, and other food such as apple (non-citrus fruit), bananas, chana (legumes), fishmeal, groundnuts, milk, and tomato. The big majority of these foods are not traded in commodity markets, and thus do not have related contracts that might be interesting asset classes for financial investors. Conversely, soybeans and corn are two of the most traded commodities in futures markets, and they represent - both singularly and through commodity indexes - a popular asset class for hedgers and speculators. Therefore, under the assumption that index investment has played a role in increasing the co-movement between commodities, it should be expected to observe an increased correlation especially between the indexed commodities, rather than between off-indexed commodities. This is exactly what tables 10 and 11 confirm.

[4]The correlations reported refer to the Pearson's unconditional correlation. The p-values for these coefficients are reported in Appendix F.

Lastly, the great increase in the correlation between the S&P GSCI, corn futures prices, and soy futures prices is another remarkable sign of the effects of index investments on commodity futures prices. The financial sector, with its indexes, measures and related activities and investments, has linked these markets even more tightly, increasing the spill-over effects.

This discussion sparks a chain of reactions that begins with the financialization of commodities, continues with the growth of index investments and proceeds with an increased correlation between futures prices of commodities, which move according to spill-over effects and (financial) information flows.
The next step is to investigate the relation between spot and futures prices, and whether it can be stated that the dynamics of futures prices are transmitted - with the obvious "real", and sometimes harmful, consequences - to spot prices. In Section 5.1, this relation will be examined and tested (through linear Granger causality tests) for corn and soybeans.

4.3 Granger causality tests between oil and food commodity prices

Linear Granger causality tests have been used to check whether futures oil prices forecast futures corn (soybeans) prices. Precisely, the tests aimed to investigate whether knowing the time path of oil prices together with corn (soybeans) one would improve the forecast of corn (soybeans) prices. Before computing the tests, the ADF test has been performed to check whether the time series were stationary. The null hypothesis of the ADF test could not be rejected in any of the cases; therefore, compounded returns (i.e., the changes in consecutive logarithmical prices) have been computed for each variable (see equation 10 in Appendix D.2). The time series of compounded returns were found to be stationary in all the cases treated, and, therefore, Granger causality tests could be applied to them. For each couple of time series, the test has been computed in both directions (A -> B and B -> A) for the whole sample (2004:01-2023:01) as well as for sub-samples. The p-values of all the tests performed are reported in table 12. For each test, the number of lags has been selected through the AIC. For the vast majority of tests performed, no statistical evidence of Granger causality has been found between oil and the two food commodities. The reason for that can be that the relation between oil prices and food commodity prices is not a Granger-type causation in which the price of oil "forecasts" the price of another commodity, rather, they co-move together under the "simultaneous" effects of index investments and information flows. Conversely, the results show that the food price index Granger-causes the oil price - meaning that the previous information about the food price index helps in the explanation of oil prices. This is reasonable: an increasing food price index (inflation in the overall food sector) might likely lead to an increase in energy prices. Finally, oil futures prices seem to Granger-cause corn futures prices in the sub-period 2015:01-2023:01. This is explained by the fact that the correlation coefficients between oil and corn prices reaches the highest value in that sub-period.
The fact that the tests do not provide meaningful evidences might be seen as inconsistent with what has been found in the previous analysis with the correlation matrices. However, (contemporaneous) correlation should not be confused with causation (Irwin & Sanders, 2010). The fact that two variables are highly correlated does not imply that one must cause the other. Furthermore, the fact that no linear Granger causality has been found between two variables does not imply that there are no relationships whatsoever linking the two variables (as stated before, linear Granger causality tests only give information about linear, direct features of effects). Rather, relationships might be more complex or indirect (thus not identifiable through a simple, linear, 2-variables Granger causality test), or there might even be "third variables" influencing both of them (even in a "Granger" sense). Focusing on what has been discussed and observed previously, one of these "third variables" which is influencing all commodity prices is likely to be the level of (index) investments in commodity futures markets. Section 5.2 will precisely examine this relationship, by assessing and testing the Granger-causality between investment (either hedging or speculative) activities and prices for corn and soybeans.

Null Hypothesis	Time frame	Lags (AIC)	F-test p value	Decision
Compounded futures returns of oil do not Granger-cause compounded futures returns of corn				
	2004:01-2015:01	3	0.6063	do not reject
	2015:01-2020:01	1	0.2554	do not reject
	2020:01-2023:01	7	0.9542	do not reject
	2015:01-2023:01	1	0.0630*	reject
	2004:01-2023:01	3	0.5247	do not reject
Compounded futures returns of corn do not Granger-cause compounded futures returns of oil				
	2004:01-2015:01	3	0.2247	do not reject
	2015:01-2020:01	1	0.4766	do not reject
	2020:01-2023:01	7	0.3819	do not reject
	2015:01-2023:01	1	0.9737	do not reject
	2004:01-2023:01	3	0.1236	do not reject
Compounded futures returns of oil do not Granger-cause compounded futures returns of soybeans				
	2004:01-2015:01	7	0.6815	do not reject
	2015:01-2020:01	2	0.3219	do not reject
	2020:01-2023:01	7	0.1534	do not reject
	2015:01-2023:01	1	0.1420	do not reject
	2004:01-2023:01	2	0.4141	do not reject
Compounded futures returns of soybeans do not Granger-cause compounded futures returns of oil				
	2004:01-2015:01	7	0.5060	do not reject
	2015:01-2020:01	2	0.0724*	reject
	2020:01-2023:01	7	0.2945	do not reject
	2015:01-2023:01	1	0.5258	do not reject
	2004:01-2023:01	2	0.1174	do not reject
Compounded futures returns of oil do not Granger-cause compounded returns of food price index				
	2004:01-2015:01	3	0.5680	do not reject
	2015:01-2020:01	1	0.8004	do not reject
	2020:01-2023:01	7	0.9885	do not reject
	2015:01-2023:01	2	0.1447	do not reject
	2004:01-2023:01	3	0.1665	do not reject
Compounded returns of food price index do not Granger-cause compounded futures returns of oil				
	2004:01-2015:01	3	0.0248**	reject
	2015:01-2020:01	1	0.8126	do not reject
	2020:01-2023:01	7	0.3442	do not reject
	2015:01-2023:01	2	0.1972	do not reject
	2004:01-2023:01	3	0.0045***	reject

*Table 12: Granger causality test: p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

4.4 Granger causality tests between commodity and fertilizer prices

Section 4.2 introduced a first delineation of a possible chain of reactions which could explain the rising prices of commodities. Section 4.3 showed that oil prices do not Granger-cause food commodity prices, rather, the relationship might be indirect or might include other factors. The aim of this final section is to conclude the analysis of the relationship between oil and food commodities and have a "more detailed" chain of causation. In order to do so, fertilizer prices have been considered. Indeed, fertilizers might likely represent one of the "bridges" that connect oil to food commodities, one of the "channels" through which effects in one market (oil) are spilled-over to another one (food commodities).
Specifically, linear Granger causality tests have been used to check the following two (null) hypotheses:

1. Oil prices do not Granger-cause fertilizer prices.
2. Fertilizer prices do not Granger-cause food commodity prices.

The Producer Price Index (PPI) by Commodity: Chemicals and Allied Products: Mixed Fertilizers (WPU065105) has been used as an indicator of the fertilizer prices. Monthly data of the WPU065105 have been retrieved from the FRED website. The use of a price index rather than the direct price does not affect the analysis, as the index presents the same proportional changes as the price. Also for this reason, the tests' hypotheses mentioned above improperly refer to the WPU065105 variable as the «fertilizer price». Figure 12 plots the (re-scaled) prices of WTI crude oil, corn, soybeans and the PPI Mixed Fertilizers between 2004 and 2023.
The null hypothesis of the ADF test could not be rejected for none of the variables (oil, corn and soybeans prices, and the WPU065105); therefore, compounded returns (i.e., the changes in consecutive logarithmical values) have been computed and used for the tests. The Granger tests have also been computed in the opposite directions (i.e., fertilizer prices do not Granger-cause oil prices; commodity prices do not Granger-cause fertilizer prices). The tests have been executed for the whole

sample (2004:01-2023:01) as well as for sub-periods. As food commodities, corn and soybeans will be considered.

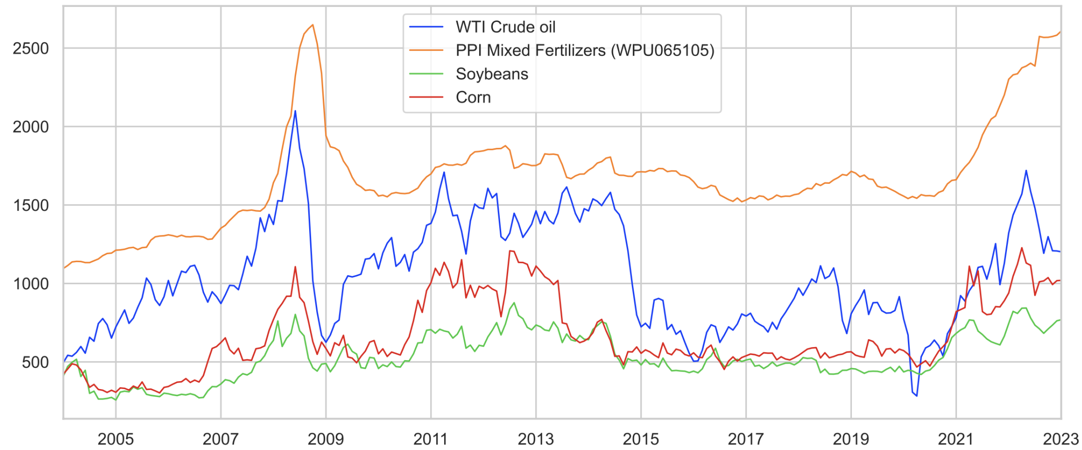

Figure 12: Prices of oil, corn, soybeans and the PPI of Mixed Fertilizer (WPU065105).

From a first graphical inspection, in can be seen that fertilizer prices show a trend which is similar to the ones of oil and food commodities. Furthermore, it seems like fertilizer prices *respond* to oil price changes, meaning that the price peaks of oil *precede* the ones of fertilizer. This is indeed confirmed by the results found through Granger causality tests, reported in Table 13. The null hypothesis that prices of fertilizers do not Granger-cause oil prices cannot be rejected (the p-value is equal to 0.1282); conversely, the opposite null hypothesis can be rejected at 1% significance for the whole sample: oil prices Granger-cause fertilizer prices, with a strong statistical significance (the p-value is equal to 0.0045). The same null hypothesis cannot be rejected for the sub-samples 2020:01-2023:01 and 2015:01-2023:01, which however have less statistical power. A reason for this is that the sub-samples focus on critical periods in which prices were also affected by well-known historically contingent factors (such as Covid19 pandemic) that dampened the oil prices and played the major role in determining the oil prices. Therefore, price data concerning those years need to be treated carefully and wisely.
For what concerns corn, a bi-directional linear Granger causality is found: for the whole sample (the most statistically powerful one, thus the most meaningful one to check), fertilizer prices Granger-cause corn prices, but corn prices also Granger-cause fertilizer prices, with a strong statistical significance (the null hypothesis is rejected at 1% significance level). For soybeans, instead, the linear Granger causality flows in only one direction, from fertilizer prices to soybeans prices.

These results delineate two different chains of Granger-causation for the food commodities. For soybeans, the chain is linear: oil prices *g.c.* fertilizer prices, which *g.c.* soybeans prices. For corn, instead, the chain of Granger-causation is somehow "recursive": oil prices *g.c.* fertilizer prices, which *g.c.* corn prices, which *g.c.* fertilizer prices. This suggests that other factors should be considered in the analysis, and non-linear Granger tests would be more appropriate. The reason for this difference between the two commodities can be explained by the fact that corn is intensively used as biofuel feedstock in the US, while soybeans are not. For this reason, the demand and production of corn is bigger than the one of soybeans, and this might make corn a commodity with bigger power to influence other variables, such as the fertilizer prices. Additionally, in the US, corn and soybean are grown in rotation, and N and P fertilizers are used for both commodities, and routinely applied too (Clay et al., 2013, ch. 21). Specifically, these fertilizers are usually applied when corn is grown, in a quantity which is enough also for soybeans. Therefore, if the growth of biofuel demand (which uses corn as feedstock) increases corn production (and land use) and prices, then the demand of fertilizers for corn crops will increase too; as a result, fertilizer prices will increase. This does not happen for soybeans, since they use the N and P fertilizers already applied during the corn culture; therefore, an increase in the demand (and prices) of soybeans will not have the same effects on fertilizers' prices as what it is seen for corn.

Null Hypothesis	Time frame	Lags (AIC)	F-test p value	Decision
Fertilizer prices do not Granger-cause oil prices	2004:01-2015:01	2	0.6719	do not reject
	2015:01-2020:01	15	0.5499	do not reject
	2020:01-2023:01	11	0.7532	do not reject
	2015:01-2023:01	11	0.3702	do not reject
	2004:01-2023:01	4	0.1282	do not reject
Oil prices do not Granger-cause fertilizer prices	2004:01-2015:01	2	0.0024***	reject
	2015:01-2020:01	15	0.0278**	reject
	2020:01-2023:01	11	0.5222	do not reject
	2015:01-2023:01	11	0.6736	do not reject
	2004:01-2023:01	4	0.0045***	reject
Fertilizer prices do not Granger-cause corn prices	2004:01-2015:01	2	0.8518	do not reject
	2015:01-2020:01	14	0.0091***	reject
	2020:01-2023:01	11	0.3532	do not reject
	2015:01-2023:01	4	0.0614*	reject
	2004:01-2023:01	5	0.0022***	reject
Corn prices do not Granger-cause fertilizer prices	2004:01-2015:01	2	0.0084***	reject
	2015:01-2020:01	14	0.9675	do not reject
	2020:01-2023:01	11	0.7184	do not reject
	2015:01-2023:01	4	0.9160	do not reject
	2004:01-2023:01	5	0.0031***	reject
Fertilizer prices do not Granger-cause soybeans prices	2004:01-2015:01	2	0.8443	do not reject
	2015:01-2020:01	15	0.0349**	reject
	2020:01-2023:01	11	0.5124	do not reject
	2015:01-2023:01	11	0.5418	do not reject
	2004:01-2023:01	5	0.0010***	reject
Soybeans prices do not Granger-cause fertilizer prices	2004:01-2015:01	2	0.1297	do not reject
	2015:01-2020:01	15	0.2969	do not reject
	2020:01-2023:01	11	0.5465	do not reject
	2015:01-2023:01	11	0.3734	do not reject
	2004:01-2023:01	5	0.1135	do not reject

*Table 13: Granger causality test: p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

4.5 Conclusions

The empirical analysis and the Granger causality tests performed in the previous sections gave several important insights about commodity markets' dynamics and price relationships. Specifically, the tests helped to further expand the discussion on the recent oil price surcharges and its spill-over effects on food commodities, by also considering fertilizers' prices as one of the intermediating factors.

The fact that there is evidence of oil prices' dynamics being transmitted to food prices gives an additional reason for being worried about the current state of the oil market. Indeed, the practice of trading with oil futures contracts has grown enormously in the recent years, and has enabled the biggest (private and public) European energy traders to substantially increase their profits (Wilson, 2023, May 3). Nowadays, the daily trading volumes of the European majors' reach values that are several times bigger than what they actually produce (Sheppard, 2023, May 11).

The complexity which characterizes today's energy system is also responsible for the increased volatility of oil prices (Sheppard, 2023, May 11). With high volatility and uncertain forecasts, speculation through oil contracts became a widespread practice - for oil companies but also for investors in general - for making profits. As a vicious circle, the massive entry of profit-seeking investors and the subsequent growth of trading volumes also contributed to the increase in oil price volatility, thus attracting even more speculators and transforming the oil futures market into an uncontrolled "betting" platform.

The Russian war to Ukraine gave an additional boost to the growth and popularity of oil trading: by dramatically raising the prices of oil, it enabled the big majors' to make enormous profits (Wilson, 2023, May 3). Based on estimations, in 2022, trading activity accounted for 20% of Shell's EBITDA and 14% of BP's in 2022 (Wilson, 2023, May 3).

What it can be seen is that there is a shift of the European majors' from conventional oil and gas producers to expert oil traders who make (an increasing) part of their profits trough trading in oil futures. It is just a matter of time before other smaller oil and gas producers start to invest in developing their own trading division too (Wilson, 2023, May 3).

What is even more worrying about this shift is that the public European majors' (Shell, BP and Total) - whose total trading profits exceed the ones made by the four largest private energy traders (Vitol, Trafigura, Mercuria and Gunvor) - are not so transparent for what concerns their trading business and the profits they gain from it, even though that practice is gaining larger ground within their business model (Wilson, 2023, May 3). The companies do not disclose specific, quantitative information about the earnings made from such activity, thus making it even more difficult to quantify the extent to which their activity are actually manipulating the oil prices at their own convenience.

The previous sections have shown that the increasing, excessive speculation within the oil futures' market has to be considered responsible for the oil prices surges, and that these price dynamics are easily transmitted to food prices. Therefore, the fact that futures market of oil is now becoming more and more exploited by a growing number of investors - among which also the European big majors', which trade with huge volumes -, and that information about trading activities and practices are not so clear, should be worrying us about the damaging consequences that will have in the future for what concerns not only energy prices, but also food prices.

5 Speculation in food commodity futures markets and its impact on food prices

The following Chapter investigates the "direct" effect of speculation on food commodity prices. It does so by analyzing the impact of speculative activities within food commodity futures markets[5] on food prices. As said in the previous sections, the food commodities selected for the analysis are corn and soybeans.

The Chapter is organized as follows. Section 5.1 will uncover and study the relationship between spot and futures prices, while Section 5.2 will investigate the relation between the prices and the speculative activities identified within the respective futures markets. Section 5.3 will conclude the Chapter with a discussion on the results obtained, in light of the limitations found while performing the Granger causality tests.

5.1 The relation between spot and futures commodity prices

This chapter answers the following research question: *What is the relation between futures prices and spot prices in food commodities?*

This section investigates the relation between spot and futures prices for corn and soybeans. Reminding the "active role" played by the literature review in this thesis, the next discussions, observations and conclusions will stem from and be compared with what has been learned from Section 2.2 for what concerns price discovery and the relation between spot and futures prices. Specifically, in Section 5.1.1 a first visual inspection will be presented, while in Section 5.1.2 the results from bi-directional, linear Granger causality tests will be reported and commented.

5.1.1 Descriptive statistics and visuals

Figure 13 plots both spot and futures prices for corn and soybeans between 2004 and 2023. For both commodities, the trends followed by spot and futures prices are very similar. This is a first important signal of the strong link between spot and futures markets. From this first graphical inspection, it seems like peaks and drops of spot and futures prices happen almost simultaneously; however, there might be a "directional" dynamic (that is, from spot to futures or from futures to spot) which is not detectable from just a visual analysis. For this reason, bi-directional linear Granger causality tests represent a more appropriate approach for defining and specifying the relationship which holds between spot and futures prices.

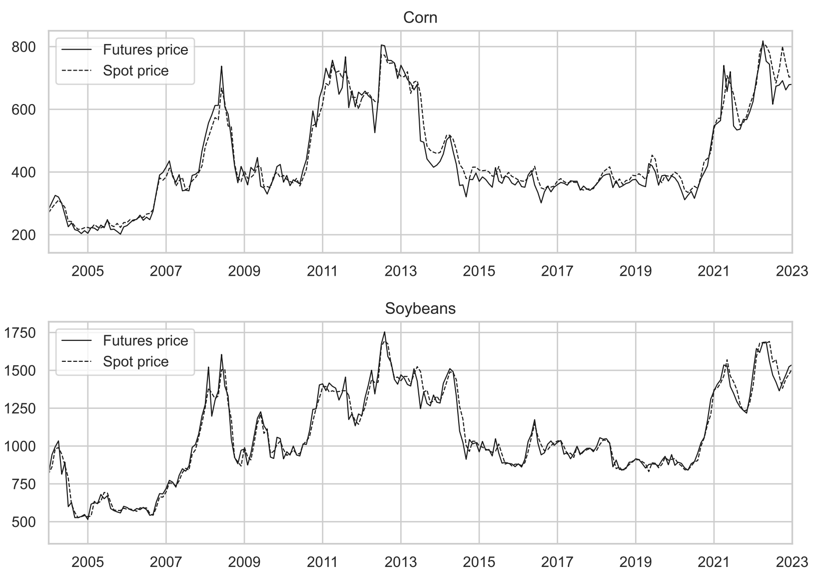

Figure 13: Spot and futures prices for corn and soybeans.

[5] Such activities have been identified through to the variables and proxies presented in Section 1.3

5.1.2 Granger causality tests

Linear Granger causality tests have been used to assess the relation between spot and futures prices, and determine the direction of "price discovery", as defined in Section 2.2. Precisely, the tests have been used to determine whether futures prices forecast spot prices, or if the opposite relation holds. The outcome of ADF test signalled that the time series (of spot and futures prices) were not stationary; therefore, compounded returns (i.e., the changes in consecutive logarithmical prices) have been computed for each variable (see equation 10 in Appendix D.2). For each couple of time series, the test has been computed for the whole sample (2004:01-2023:01) as well as for sub-samples. The p-values of the first set of tests, for which the null hypothesis is that futures prices do not Granger-cause spot prices, are reported in Table 14, while the p-values of the second set of tests, for which the null hypothesis is that spot prices do not Granger-cause futures prices, are reported in table 15. For each test, the number of lags reported refers to the one selected through the AIC; however, the same tests have also been repeated for a range of lags, varying from 1 to 12. The p-values for these set of tests are reported in Appendix G.

From the results reported in Table 14 it can be stated that the compounded returns of futures prices significantly Granger-cause the compounded returns of spot prices, for both corn and soybeans. Indeed, the null hypothesis is rejected with great statistical significance for almost all periods, and especially for the whole sample (the most statistically powerful one). Conversely, from the results reported in Table 15 the null hypothesis that spot prices do not Granger-cause futures prices cannot be rejected. Therefore, it can be stated that, for both corn and soybeans, futures prices Granger-cause spot prices.

Commodity	Time frame	Lags (AIC)	F-test p value	Decision
Corn				
	2004:01-2015:01	2	0.0000***	reject
	2015:01-2020:01	2	0.0000***	reject
	2020:01-2023:01	11	0.3726	do not reject
	2015:01-2023:01	3	0.0000***	reject
	2004:01-2023:01	3	0.0000***	reject
Soybeans				
	2004:01-2015:01	2	0.0000***	reject
	2015:01-2020:01	1	0.0000***	reject
	2020:01-2023:01	11	0.0446**	reject
	2015:01-2023:01	1	0.0000***	reject
	2004:01-2023:01	2	0.0000***	reject

*Table 14: Granger causality test. $H0$: Futures prices do not Granger-cause spot prices. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

Commodity	Time frame	Lags (AIC)	F-test p value	Decision
Corn				
	2004:01-2015:01	2	0.8482	do not reject
	2015:01-2020:01	2	0.2525	do not reject
	2020:01-2023:01	11	0.3227	do not reject
	2015:01-2023:01	3	0.3969	do not reject
	2004:01-2023:01	3	0.2585	do not reject
Soybeans				
	2004:01-2015:01	2	0.1413	do not reject
	2015:01-2020:01	1	0.7837	do not reject
	2020:01-2023:01	11	0.0614*	reject
	2015:01-2023:01	1	0.2669	do not reject
	2004:01-2023:01	2	0.1324	do not reject

*Table 15: Granger causality test. $H0$: Spot prices do not Granger-cause futures prices. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

To conclude the analysis, it is interesting to observe how the outcome of the Granger causality test changes if a different time period or a different number of lags are selected. For example, from Table 15 the null hypothesis that spot prices do not Granger-cause futures prices is not rejected for corn for the whole sample 2004:01-2023:01 (the p-value is 0.2585). However, if Table 44 in Appendix G is considered, it can be seen that the null hypothesis is instead rejected for 9 out of 12 lags explored. Thus, it would be more appropriate to state that in the case of corn, a bi-directional Granger-causality can be observed: futures prices *g.c.* spot prices with strong statistical significance, but also (with a weaker statistical significance) spot prices *g.c.* futures prices. If the tests had relied only on the AIC, this part of the relationship would not have been uncovered. Even if the AIC represents a widely-used method to select the number of lags, it still has some limitations. First, there are also other criteria for selecting the number of lags (for example, the Bayesian information criterion (BIC)). Therefore, a first error can be made by simply selecting a particular criterion (and not considering other criteria). Second, as already stated, the selection of the number of lags can be made based on statistical criteria as well as on empirical considerations. For what concerns the latter, since the analysis deals with futures contracts with a relatively short expiration date (few months), it would not make sense to use a number of lags bigger than one year (12 months). In any case, nothing guarantees that the number of lags selected with the AIC gives all the meaningful information about the test performed; this is the reason why every outcome obtained with the AIC lag length has also been compared with the outcomes obtained from the range of lag lengths. The bottom line of this discussion is that results obtained from statistical tests - such as the one performed here - need to be interpreted carefully, and conclusions need to be well-weighted and sustained by not only statistical evidence, but also by a theoretical background, a graphical inspection, and a common sense.

5.1.3 Discussion

The previous analysis showed that futures prices Granger-cause spot prices for corn and soybeans. Furthermore, by extending the analysis from the AIC lag length to a range of lengths that varies between 1 and 12, it has been shown that spot prices of corn Granger-cause (with less statistical significance) futures prices of corn. It can therefore be concluded that, in general, changes in futures prices cause changes in spot prices more than what happens in the opposite direction. This is consistent with what it has been found by Ameur et al. (2022); indeed, the authors stated that their results «highlight bidirectional feedback between both markets, but the lead of the futures market on the spot returns is greater than the contrary» (Ameur et al., 2022, p. 187). The results obtained suggest that futures markets cover a "leading" position in the dynamics of price discovery, with the information flows' direction going mainly from futures to spot markets. This should not be a surprise, as the price discovery is one of the two vital functions of futures markets (Masters & White, 2008; Brunetti & Buyuksahin, 2009).

Even though the Granger causality tests gave information about the relationship that holds between spot and futures prices, these tests are silent for what concerns the nature of the relationship. Futures prices Granger-cause spot prices: under which mechanisms? As explained in Section 2.2.1, the information transfer from futures to spot markets can be traced back to the Law of One Price and to Kaldor's (1983) theory of storage for what concerns the long-run equilibrium relationships; conversely, in non-equilibrium situations, the information transfer is based on arbitrageurs' activities (Ameur et al., 2022). Under this view, financial actors trading in commodity futures markets must be considered as important determinants of spot prices' dynamics, that is, trading activities within futures markets must be considered when explaining spot prices' dynamics. Again, recalling the futures markets' vital function of price discovery, the fact that dynamics within futures markets are transferred to spot markets should not be a surprise. However, a step forward can be made, and the *quality* of such information can be assessed too. It has been claimed that trading activities within futures markets must be considered when explaining spot prices' dynamics. In a normal situation in which hedgers and speculator are balanced, these trading activities largely reflect current market fundamentals' dynamics, that is, hedgers and speculators take short and long positions based on expected levels of (real) demand, supply and inventories. However, if speculation becomes *excessive*, and if trading activities are driven by other "gambling" sentiments which are not related to market fundamentals but instead come from a "biased", "extreme" risk appetite and a growing profit hunger, then the quality of information transfer becomes poorer. First, excessive speculation breaks the balance between hedging and speculative positions. As a result, futures prices begin to increase, under what can be seen as a "bubble" of positive expectations driven by arbitrage-advantages, followed by drops when such expectations start to decrease (Tilton et al., 2011). All these price features are transmitted to spot prices, which experience the same dynamics. Second, the growing number of structurally different (in terms of purposes, strategies and risk-appetites) participants in futures markets increases (futures) prices' volatility (Ameur et al., 2022), and this damages even more the quality of information transfer, leading to a situation in which there is no meaningful information that "bona-fide" hedgers can get by looking at futures markets.

The previous considerations suggest that it is important to investigate the (negative) effects that unbalanced, unjustified, excessive trading activities within commodity futures markets have on futures prices. Indeed, following what the price discovery direction revealed, the same effects are likely to be transmitted to and experienced by spot prices, with harmful consequences on the real economy (IPES-Food, 2022). If, for example, it can be shown that the growing number of speculators and index investors in commodity futures market (as well as the general growth of the financial sector) have raised futures prices, then the same factors can be considered responsible for what happened to spot prices. Section 5.2 will specifically focus on this matter, by investigating the relationship that holds between speculation (translated into a series of proxies) and three variables of prices, namely, spot prices, futures prices and futures prices' volatility.

5.2 The relation between speculation and commodity prices

This chapter answers the following research questions: *To what degree do speculative activities found within the commodity futures markets of corn and soybeans explain the prices of such commodities? Did (excessive) speculation contribute to the rising commodity prices?*

This section investigates, for both corn and soybeans, the relation that holds between the two principal domains of futures markets: prices and trading activity. For what concerns the first domain, spot prices, futures prices, and the volatility of futures returns have been considered. For the second domain, different indicators of trading activities have been considered and computed, as summarized in Table 2 and reported again in Table 16 below. Specifically, the change in non-commercial net positions and the total open interest serve as indicators of the levels of speculative activity within futures markets. Opposed to them, the change in commercial net positions has been considered and assessed as a "comparative" proxy. The T-index and speculative pressure serve as indicators for **excessive** speculation. As for the change in commercial net positions, the hedging pressure has been considered and assessed as a "comparative" proxy.

Proxies for trading activities	**Abbreviation**	**Sources**
Changes in non-commercial net positions	Ch_NP_NonComm	computed by the author with data from CFTC COT report
Changes in commercial net positions	Ch_NP_Comm	computed by the author with data from CFTC COT report
Total open interest	Tot_OI	CFTC COT report
T-index	T	computed by the author with data from CFTC COT report
Speculative pressure	Spec_press	computed by the author with data from CFTC COT report
Hedging pressure	Hedg_press	computed by the author with data from CFTC COT report

Table 16: Proxies for trading activities

Section 5.2.1 presents a preliminary analysis based on visual inspections and some descriptive statistics. Section 5.2.2 reports and comments the results of the linear Granger causality tests that have been performed between the two domains.

5.2.1 Descriptive statistics and visuals

In addition to Figure 13 which plots the spot and futures prices, Figures 14 and 15 plot the volatility of futures returns for corn and soybeans, respectively. What can be observed is that corn futures prices have been on average more volatile than the soybeans ones. This is illustrated by the fact that in 2009 the peak in volatility is much more visible for soybeans than for corn. For both commodities, the period between 2015-2020 is characterized by lower levels of volatility (prices were more stable). The two commodities differentiate again from 2020 onwards, with corn experiencing another large increase in volatility (with peaks even higher than the ones experienced during the period 2008-2010), while soybeans experience peaks which remain much smaller than the one experienced during the 2008 financial crisis. A reason for this difference can be traced back to the current Ukrainian conflict, which disrupted and changed the supply of corn around the world (Janzen & Zulauf, 2023) and, as a consequence, increased the risk perceived by investors for what concerns the trade of such commodity.

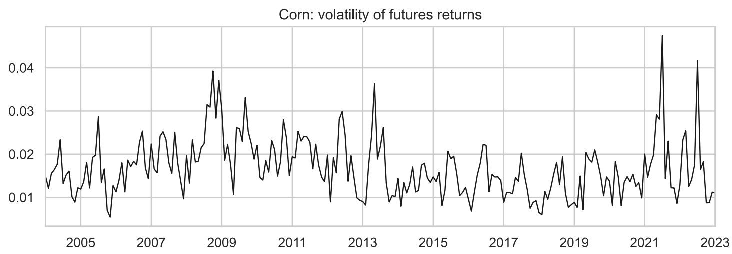

Figure 14: Corn: Historical volatility of futures returns

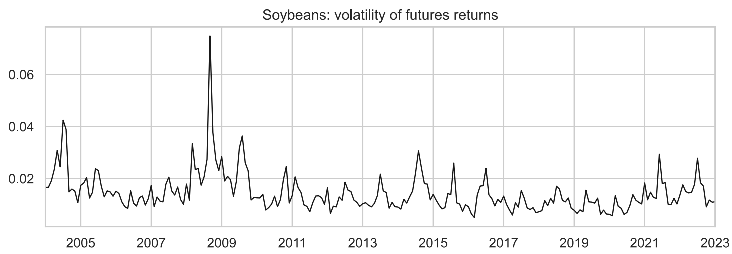

Figure 15: Soybeans: Historical volatility of futures returns

As for oil, data about corn and soybeans positions and open interests have been retrieved from the CFTC COT report. The data have been cleaned, prepared, plotted and analyzed for the period 2004-2023. Figures 16 and 17 show the total open interest for the two commodities. Both the curves show a general upward trend: as has been observed for the WTI crude oil futures contracts, also the number of corn and soybeans contracts has been growing since 2004, thus giving additional evidence of the financialization of commodities and the growth of the financial sector.

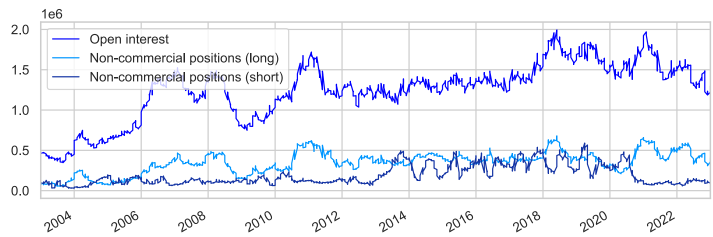

Figure 16: Corn: Open interest and non-commercial positions

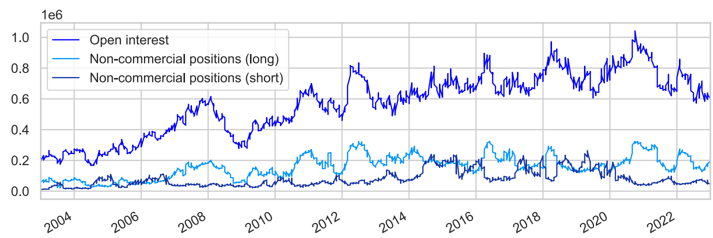

Figure 17: Soybeans: Open interest and non-commercial positions

Figures 18, 19, 20, and 21 focus on the non-commercial positions (both short and long) throughout 2004 and 2023 for the two commodities. For both corn and soybeans, long positions present a general upward trend. This trend is not so steep or well-defined as has been seen in the WTI crude oil case, however, it can still be observed that this upward trend is more visible in long positions rather than in short positions. Indeed, short positions seemed to have remained constant throughout the period analyzed, with a similar variation observed in period 2014-2020. This period differs from the previous one and the next to come for its stronger market stability; therefore, it can be stated that non-commercial traders also felt confident to take short positions.

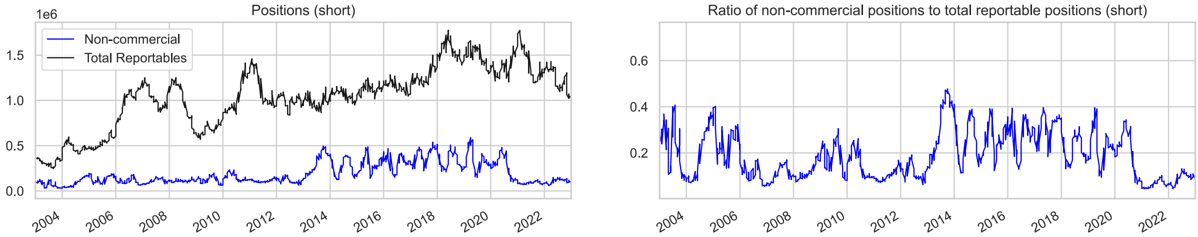

Figure 18: Corn: Non-commercial positions (short)

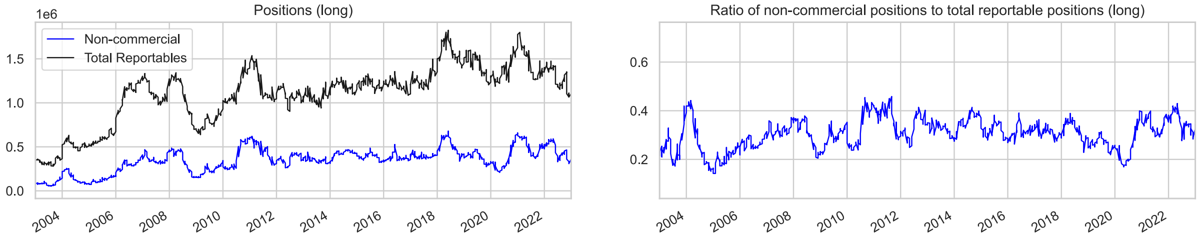

Figure 19: Corn: Non-commercial positions (long)

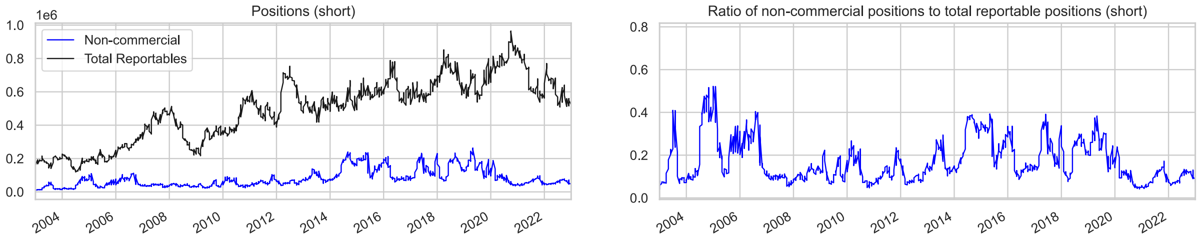

Figure 20: Soybeans: Non-commercial positions (short)

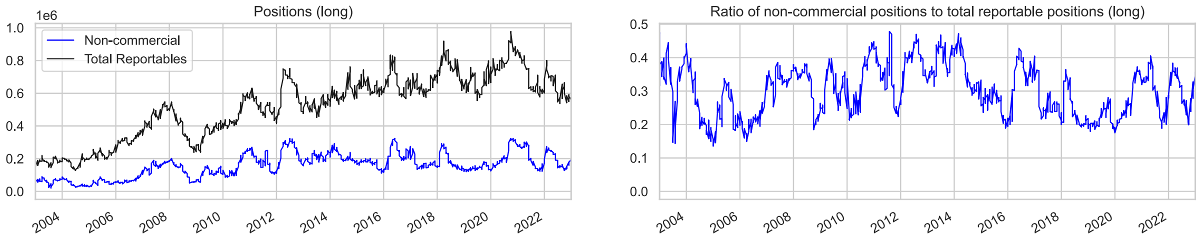

Figure 21: Soybeans: Non-commercial positions (long)

For what concerns the ratios of non-commercial positions to total reportable positions (both long and short), the graphs do not provide any meaningful result; however, some observations can be made from Table 17, which reports some descriptive statistics concerning the ratios. Specifically, it can be observed that the ratio of non-commercial positions to total reportable positions is on average higher in the long market (0.3069 versus 0.1879 for corn; 0.3013 versus 0.1716 for soybeans), signalling the fact that, as expected, non-commercial traders and speculators - who do not hold physical commodities - usually take long positions rather than short ones.

	CORN		**SOYBEANS**	
	Ratio of non-commercial positions to total reportable positions short	**Ratio of non-commercial positions to total reportable positions long**	**Ratio of non-commercial positions to total reportable positions short**	**Ratio of non-commercial positions to total reportable positions long**
min	0.048	0.154	0.046	0.143
max	0.467	0.445	0.474	0.458
mean	0.188	0.307	0.172	0.301

Table 17: Corn and Soybeans. Ratio of non-commercial positions to total reportable positions (long and short): descriptive statistics.

Tables 18 and 19 present the reportable position shares for the whole period (2004-2023) as well as for four sub-periods for the two commodities. Focusing on the long market - which is the most interesting one to speculators -, the share of commercial long positions has slightly decreased from 2004 to 2020, while the share of non-commercial long positions has experienced a large increase, from an average of 21.57% (for corn) and 19.65% (for soybeans) during the period 2004-2007 to an average of 28.43% (for corn) and 26.80% (for soybeans) during the period 2020-2023. For what concerns the short market, the increases and decreases are less pronounced, especially for the corn market. Overall, this situation signals that there is much more "movement" within the long market than in the short market, and this is due to the fact that the former market is more suitable for taking speculative actions, and therefore hosts more non-commercial actors. The concluding claim is that the previous graphs and tables gave evidence of the financialization of commodity markets, which has been characterized by an increasing number of non-commercial actors entering the market and taking (mainly) long positions with the hope of making a profit out of their trades.

	%OI Commercials long	%OI Non-commercials long	%OI Commercials short	%OI Non-commercials short
2004:01-2007:01	52.739	21.570	52.520	13.902
2007:01-2015:01	46.605	29.471	54.429	13.404
2015:01-2020:01	45.029	27.309	48.311	22.293
2020:01-2023:01	46.600	28.439	62.143	10.680
2004:01-2023:01	**47.198**	**27.487**	**53.728**	**15.427**

Table 18: Corn. Reportables position shares (percentages of total open interest).

	%OI Commercials long	%OI Non-commercials long	%OI Commercials short	%OI Non-commercials short
2004:01-2007:01	51.180	19.649	45.846	18.774
2007:01-2015:01	45.015	31.074	58.188	11.861
2015:01-2020:01	51.190	24.661	51.068	19.599
2020:01-2023:01	49.819	26.803	65.408	8.832
2004:01-2023:01	**48.372**	**26.917**	**55.569**	**14.479**

Table 19: Soybeans. Reportables position shares (percentages of total open interest).

Figures 22 and 23 show Working's T index (Working, 1960) and Algieri's (2012) hedging and speculative pressures from 2004 to 2023, for both commodities. Tables 20 and 21 report some descriptive statistics for the three variables, divided into two sub-periods (2004:01-2015:01 and 2015:01-2023:01), for both commodities. From the T-index's descriptive statistics reported in the tables, it can be seen that, on average, 13.84% of activities in the corn market were of a speculative nature during years 2004- 2015. Speculation became even more excessive during the period 2015-2023, with an average level of speculation in excess of 17.97%. Conversely, the soybeans market shows a level of speculation in excess which stays around 13% for both the sub-periods.
The hedging pressures of corn and soybeans show negative means for both corn and soybeans, and are less volatile than the speculative pressures. Furthermore, hedging pressures usually assume lower values than the ones assumed by the speculative pressures for both commodities. This can be seen in the figures as well as confirmed by the tables, in which the speculative pressures' means show only higher, positive values, also signalling the fact that both corn and soybeans markets are speculative markets (Algieri, 2012).

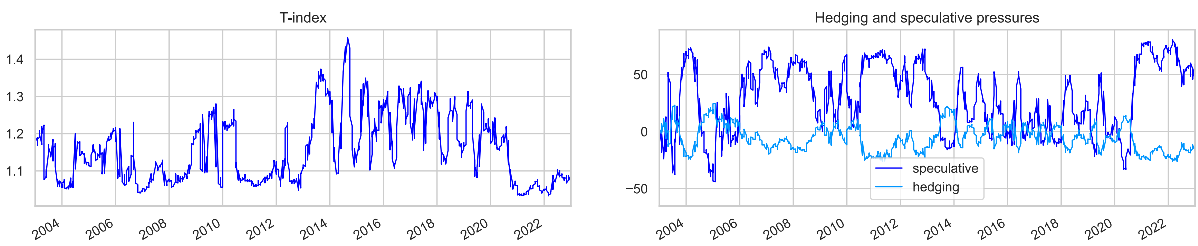

Figure 22: Corn. T-index; hedging and speculative pressures. Computed by the author.

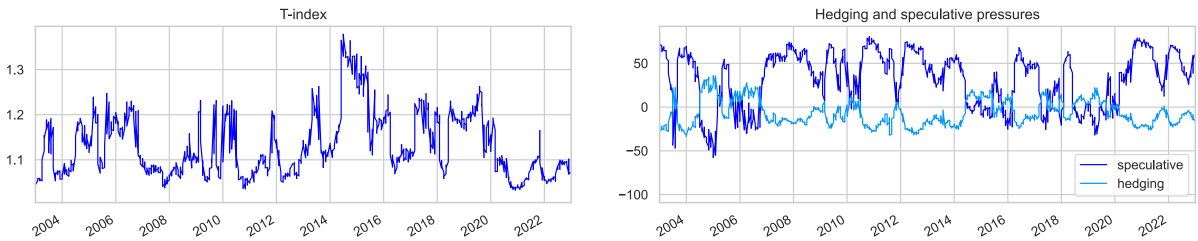

Figure 23: Soybeans. T-index; hedging and speculative pressures. Computed by the author.

	2004:01-2015:01			2015:01-2023:01		
	speculative pressure	**hedging pressure**	**T-index**	**speculative pressure**	**hedging pressure**	**T-index**
count	133	133	133	97	97	97
mean	35.045	-5.047	1.138	24.761	-7.091	1.180
std	27.566	11.646	0.087	29.972	10.028	0.094
min	-37.623	-24.252	1.042	-30.205	-24.995	1.036
25%	15.336	-13.761	1.076	-1.265	-15.532	1.082
50%	41.482	-6.410	1.114	19.034	-6.352	1.183
75%	59.884	3.906	1.170	51.831	1.076	1.270
max	72.838	21.935	1.454	78.943	12.937	1.345

Table 20: Corn. T-index, hedging and speculative pressures: descriptive statistics.

	2004:01-2015:01			2015:01-2023:01		
	speculative pressure	**hedging pressure**	**T-index**	**speculative pressure**	**hedging pressure**	**T-index**
count	133	133	133	97	97	97
mean	34.806	-7.298	1.131	26.423	-4.736	1.140
std	30.767	15.560	0.070	29.893	11.636	0.070
min	-51.787	-32.538	1.045	-26.743	-24.448	1.035
25%	11.644	-18.523	1.077	-1.961	-13.281	1.083
50%	45.263	-12.268	1.107	28.468	-5.436	1.126
75%	58.515	4.155	1.184	50.277	4.637	1.195
max	75.283	30.102	1.352	77.157	18.186	1.305

Table 21: Soybeans. T-index, hedging and speculative pressures: descriptive statistics.

Lastly, Figures 24 and 25 plot the open interest together with the spot and futures prices for both corn and soybeans, respectively. The open interest has been re-scaled for visual reasons; however, as the focus is on trends rather than on specific numbers, this does not affect the analysis. The graphs show trends and dynamics which are similar to the ones observed for the WTI crude oil. During the period 2004-2015, open interest and prices predominately grew together. During the period 2015-2020, open interest grew more, while prices' changes reduced. Finally, during the period 2020-2023, there is an inversion of trends, characterized by declining open interest and rising prices. This rise in prices despite the decrease in open interest is explained by the historically-contingent events (such as the Ukrainian conflict) of such period, which spread panic, raised prices, and increased the indirect, spill-over effects within markets such as, for example, oil and food commodities markets.

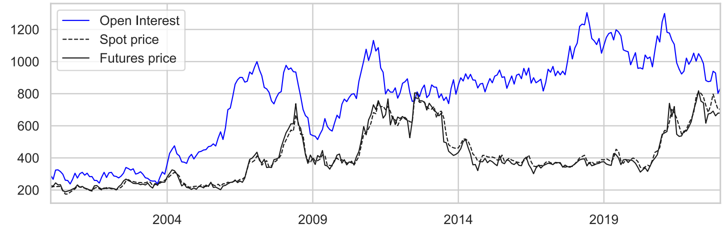

Figure 24: Corn open interest (rescaled), futures prices and spot prices.

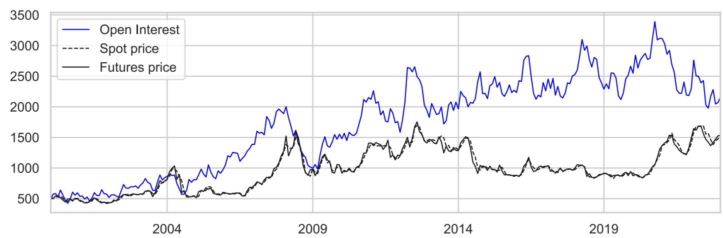

Figure 25: Soybeans open interest (rescaled), futures prices and spot prices.

5.2.2 Granger causality tests

Linear Granger causality tests have been used to assess the relation between prices and speculation. Specifically, spot prices, futures prices, and volatility of futures returns have been considered as indicators of commodity prices' dynamics; while six proxies for trading activities have been considered and computed to quantify trading activities, namely: the change in net positions (long minus short) for both commercials and non-commercials, the total open interest, the Working's T index (Working, 1960), and Algieri's (2012) speculative and hedging pressures. The aim of this analysis was to uncover the relation that holds between commodity prices and trading (specifically, speculative) activities. For this reason, Granger causality tests have been performed in both directions, which means that the following two broad (null) hypotheses have been tested:

- Speculation does not Granger-cause prices.
- Prices do not Granger-cause speculation.

With «speculation» and «prices» defined through the aforementioned variables and proxies.
Lastly, Granger causality tests have been performed also between prices and the S&P GSCI. Therefore, the following two broad (null) hypotheses have been tested:

- S&P GSCI does not Granger-cause prices.
- Prices do not Granger-cause S&P GSCI.

For each couple of time series, the test has been computed for the whole sample (2004:01-2023:01) as well as for sub-samples. The most powerful test remains the one executed considering the whole sample, as it works with a bigger number of data points; however, performing tests also on sub-periods helps to uncover some additional relations, to tailor and extend the discussion, to sharpen the observations, to check the robustness and validity of the results, and, most importantly, to properly select and weight the conclusions that can be made from the analysis. Tables 22, 23, 24, 25, 26, 27 report the p values of the tests performed on corn and soybeans. The lag length has been selected through the AIC; however, the appropriateness of this selection criterion can be debated, since the choice of the number of lags is both a statistical and an empirical matter (Wooldridge, 2015). For this reason, Appendix H reports, for both corn and soybeans, the same tests executed on a range of lags that varies between 1 and 12. For these tests, only 4 out of the 6 proxies of speculation have been considered (namely: the change in non-commercial net positions, the total open interest, the Working's T index (Working, 1960), and Algieri's (2012) speculative pressure), and the S&P GSCI. Furthermore, the tests have been performed for the whole sample and repeated for two sub-periods: 2004:01-2015:01 and 2015:01-2023:01.

For what concerns the time series' stationarity, the outcome of ADF test signalled that the time series of spot and futures prices were not stationary for both corn and soybeans; therefore, compounded returns (i.e., the changes in consecutive logarithmical prices) have been computed for each variable (see equation 10 in Appendix D.2). Conversely, the historical (or realized) volatility of futures returns has been found to be stationary in all cases, and for both commodities. For what concerns the proxies of speculation, the open interest was found to be non-stationary for both corn and soybeans; therefore, percentage changes between two consecutive data points of the data set have been computed, and the (stationary) times series obtained has been used for the tests.

From a preliminary overview of Tables 22 to 27, it can be observed that a Granger-causality is more often found from prices to speculation, rather than from speculation to prices. This should not be a surprise, since it is reasonable to expect that investors and traders change their behaviors and hold positions accordingly based on prices' dynamics. Therefore, a change in price will surely cause a change in trading dynamics and pressures. These changes will take place in futures markets, where investors actually perform their activities, thus a stronger causation is expected to be found when futures prices are considered, rather than spot prices. This is indeed confirmed by the p-values reported in the last column of Tables 22 and 23 for corn and Tables 25 and 26 for soybeans: futures prices Granger-cause the six proxies of trading activity in more cases and with more statistical significance than what spot prices do. This is especially true for corn, which presents high statistical significance (the null hypothesis is always rejected at 1% significance) for all the six proxies, when considering the whole sample. These results also tell us that the model built, the proxies computed, and the tests performed properly replicate and predict the expected and well-known market dynamic of «traders following prices». This dynamic is an intrinsic and natural feature of trade markets; therefore, it would have been source of concern if no Granger-causality was to be found from prices to proxies.

Corn

Table 22 reports the p values obtained from Granger causality tests between spot prices of corn and speculation. The null hypothesis that proxies of speculation do not Granger-cause spot prices is never rejected for the whole sample (2004-2023), with an exception made for the change in commercial net positions (p value of 0.0462) and the total open interest (p value of 0.0075). However, if the analysis is extended over the AIC-selected lag length and more lags are considered, as shown in Table 46 reported in Appendix H, there is evidence that the change in non-commercial net positions Granger-cause spot prices for a low numbers of lags (from 1 to 4 lags), thus, a Granger-type causality in the short period can be hypothesized. The Granger-causality is lost when more lags are considered: the AIC suggests a lag length of 6, thus no statistically significant Granger-causality is detected. Likewise, Table 46 suggests that total open interest Granger-cause spot prices; indeed, the null hypothesis can be rejected for six out of twelve lags. Finally, from Table 46 it can be stated that the S&P GSCI Granger-causes spot prices for 1 and 2 lags: knowing the (closest) past values of the S&P GSCI gives some additional information for spot prices' forecasts.
By looking at the sub-periods, some statistical evidence of Granger-causation can be found, especially for what concerns T index and the S&P GSCI. Precisely, by analyzing Tables 22 and 46 together, it can be seen that, for some lags, the T index Granger-causes spot prices in the period 2015-2023. However, for most of the lags, no evidence is found, therefore, no definite conclusion on the relationship should be made. More solid conclusions can instead be made for what concerns the relationship that holds between the S&P GSCI and spot prices in the period 2015-2023. Indeed, the null hypothesis is rejected with statistical significance for eleven out of twelve lags. It is interesting to observe that the only lag length for which the null hypothesis is not rejected, 4, is the lag length selected through the AIC. Thus, while Table 22 leads us to conclude that the S&P GSCI does not Granger-cause spot prices in the period 2015-2023, Table 46 shows that the Granger-causality is more than present.

Table 23 reports the p values obtained from Granger causality tests between futures prices of corn and speculation. The null hypothesis that proxies of speculation do not Granger-cause futures prices is, again, never rejected for the whole sample (2004-2023). However, if the analysis is extended over the AIC-selected lag length and more lags are considered, as shown in Table 47 reported in Appendix H, there is evidence that total open interest Granger-causes futures prices. Indeed, for eight out of twelve lags (precisely, from 5 to 12 lags), the null hypothesis can be rejected. Again, the AIC led to select a lag length (4) that was precisely one of the four that did not present statistical significance to reject the null hypothesis. From the combined analysis, it can be concluded that total open interest Granger-causes futures prices, in the sense that adding total open interest provides additional information about the futures prices' forecasts, if we consider a number of lags strictly bigger than four.

Table 24 reports the p values obtained from Granger causality tests between volatility of futures returns of corn and speculation. For the whole sample (2004-2023), the null hypothesis that the total open interest does not Granger-cause volatility can be rejected (p value of 0.0040); likewise, also the null hypotheses that speculative and hedging pressures do not Granger-cause volatility can be rejected, with a higher statistical significance for the speculative pressure (p values are, respectively, 0.0101 and 0.0644). However, to check the validity and robustness of these results, the analysis has been extended over the AIC-selected lag lengths and more lags have considered, as showed in Table 48 reported in Appendix H. The extended analysis confirmed the results, giving additional evidence on the Granger-causality from open interest to volatility, and from speculative pressure to volatility, for the whole sample (2004-2023). Indeed, the null hypothesis that open interest does not Granger-cause volatility is rejected for nine out of twelve lags; likewise, the null hypothesis that speculative pressure does not Granger-cause volatility is rejected for the first eight lags. This strong Granger-type relationship from these two proxies to volatility is maintained also in the sub-period that goes from 2015 to 2023; indeed, the null hypothesis that open interest does not Granger-cause volatility is rejected for seven out of twelve lags, and the null hypothesis that speculative pressure does not Granger-cause volatility is rejected for ten out of twelve lags. The relationship is found to be less clear in the sub-period 2004-2015.

			H0: proxy does not Granger cause spot prices	H0: spot prices do not Granger cause proxy
Proxy	Time frame	Lags (AIC)	F-test p value	F-test p value
Ch_NP_NonComm	2004:01-2015:01	1	0.0255**	0.6629
	2015:01-2020:01	1	0.0661*	0.2872
	2020:01-2023:01	11	0.1154	0.0724*
	2015:01-2023:01	4	0.8339	0.8964
	2004:01-2023:01	6	0.2253	0.0567*
Ch_NP_Comm	2004:01-2015:01	1	0.0203**	0.3844
	2015:01-2020:01	1	0.0607*	0.3891
	2020:01-2023:01	11	0.2609	0.1238
	2015:01-2023:01	3	0.4523	0.7285
	2004:01-2023:01	4	0.0462**	0.8785
Tot_OI	2004:01-2015:01	14	0.5055	0.0413**
	2015:01-2020:01	13	0.6442	0.5377
	2020:01-2023:01	11	0.4992	0.5596
	2015:01-2023:01	3	0.5190	0.0000***
	2004:01-2023:01	14	0.0075***	0.0002***
T	2004:01-2015:01	2	0.6875	0.7707
	2015:01-2020:01	3	0.0040***	0.0229**
	2020:01-2023:01	11	0.0377**	0.0071***
	2015:01-2023:01	8	0.3046	0.0724*
	2004:01-2023:01	7	0.6793	0.0137**
Spec_press	2004:01-2015:01	2	0.6868	0.0263**
	2015:01-2020:01	2	0.0007***	0.8917
	2020:01-2023:01	10	0.4677	0.1885
	2015:01-2023:01	2	0.4510	0.0697*
	2004:01-2023:01	2	0.5707	0.0287**
Hedg_press	2004:01-2015:01	2	0.5209	0.0787 *
	2015:01-2020:01	15	0.6177	0.7820
	2020:01-2023:01	10	0.1306	0.2694
	2015:01-2023:01	2	0.7457	0.3062
	2004:01-2023:01	2	0.5811	0.0566*
S&P GSCI	2004:01-2015:01	2	0.0503*	0.1147
	2015:01-2020:01	15	0.2161	0.4419
	2020:01-2023:01	11	0.9721	0.7095
	2015:01-2023:01	4	0.1425	0.5291
	2004:01-2023:01	2	0.0416**	0.0558*

*Table 22: Granger causality test for spot prices of corn: p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

			H0: proxy does not Granger cause futures prices	H0: futures prices do not Granger cause proxy
Proxy	Time frame	Lags (AIC)	F-test p value	F-test p value
Ch_NP_NonComm	2004:01-2015:01	2	0.2984	0.1826
	2015:01-2020:01	13	0.5681	0.2773
	2020:01-2023:01	11	0.0595*	0.2659
	2015:01-2023:01	4	0.9175	0.0180**
	2004:01-2023:01	6	0.7539	0.0033***
Ch_NP_Comm	2004:01-2015:01	3	0.5693	0.2318
	2015:01-2020:01	13	0.7135	0.2180
	2020:01-2023:01	11	0.0816*	0.0782*
	2015:01-2023:01	4	0.8977	0.0203**
	2004:01-2023:01	6	0.8083	0.0076***
Tot_OI	2004:01-2015:01	14	0.0811 *	0.0026***
	2015:01-2020:01	1	0.9474	0.0164**
	2020:01-2023:01	11	0.0782*	0.0968*
	2015:01-2023:01	4	0.1782**	0.0001***
	2004:01-2023:01	3	0.1276	0.0000***
T	2004:01-2015:01	7	0.5959	0.0026***
	2015:01-2020:01	15	0.2609	0.0348**
	2020:01-2023:01	11	0.0450**	0.5963
	2015:01-2023:01	8	0.8469	0.0005***
	2004:01-2023:01	8	0.7439	0.0000***
Spec_press	2004:01-2015:01	2	0.3072	0.0000***
	2015:01-2020:01	15	0.0457**	0.0362**
	2020:01-2023:01	11	0.0870*	0.1655
	2015:01-2023:01	4	0.7763	0.0000***
	2004:01-2023:01	2	0.3317	0.0000***
Hedg_press	2004:01-2015:01	2	0.2593	0.0000***
	2015:01-2020:01	15	0.0535*	0.0279**
	2020:01-2023:01	11	0.0986*	0.4799
	2015:01-2023:01	2	0.4855	0.0000***
	2004:01-2023:01	2	0.2424	0.0000***
S&P GSCI	2004:01-2015:01	2	0.1708	0.1601
	2015:01-2020:01	1	0.4687	0.3743
	2020:01-2023:01	11	0.9964	0.8711
	2015:01-2023:01	2	0.1351	0.4304
	2004:01-2023:01	3	0.3983	0.1181

*Table 23: Granger causality test for futures prices of corn: p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

			H0: proxy does not Granger cause volatility	H0: volatility does not Granger cause proxy
Proxy	Time frame	Lags (AIC)	F-test p value	F-test p value
Ch_NP_NonComm	2004:01-2015:01	1	0.3020	0.6311
	2015:01-2020:01	6	0.3638	0.1835
	2020:01-2023:01	11	0.5300	0.9695
	2015:01-2023:01	1	0.9791	0.6254
	2004:01-2023:01	2	0.8801	0.6234
Ch_NP_Comm	2004:01-2015:01	1	0.4151	0.8891
	2015:01-2020:01	6	0.3660	0.1640
	2020:01-2023:01	11	0.1248	0.5502
	2015:01-2023:01	1	0.7550	0.3610
	2004:01-2023:01	2	0.7730	0.2812
Tot_OI	2004:01-2015:01	2	0.0665*	0.0475**
	2015:01-2020:01	15	0.3893	0.0581*
	2020:01-2023:01	11	0.3733	0.4530
	2015:01-2023:01	2	0.0844*	0.0086***
	2004:01-2023:01	14	0.0040***	0.1885
T	2004:01-2015:01	5	0.3835	0.2156
	2015:01-2020:01	7	0.0531*	0.0145**
	2020:01-2023:01	11	0.3366	0.4210
	2015:01-2023:01	8	0.7987	0.2137
	2004:01-2023:01	5	0.8347	0.3613
Spec_press	2004:01-2015:01	2	0.0855*	0.8525
	2015:01-2020:01	14	0.0561*	0.3825
	2020:01-2023:01	11	0.1994	0.6453
	2015:01-2023:01	3	0.0394**	0.2806
	2004:01-2023:01	2	0.0101**	0.5476
Hedg_press	2004:01-2015:01	2	0.1115	0.9265
	2015:01-2020:01	2	0.1418	0.0738*
	2020:01-2023:01	11	0.3614	0.4386
	2015:01-2023:01	2	0.1055	0.3743
	2004:01-2023:01	2	0.0644*	0.6572

*Table 24: Granger causality test for volatility of futures returns of corn: p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

Soybeans

Table 25 reports the p values obtained from Granger causality tests between spot prices of soybeans and speculation. For the whole sample (2004-2023), the null hypothesis that the change in non-commercial net positions does not Granger-cause spot prices can be rejected (p value of 0.0005); likewise, also the null hypotheses that the change in commercial net positions does not Granger-cause spot prices can be rejected (p value of 0.0001). For what concerns the change in non-commercial net positions, the evidence of a Granger-causation is maintained in all the sub-periods except from the period 2020-2023. It can be claimed that during those three years, prices were mostly driven by and changed due to historically-contingent events rather than trading activities. Therefore, the extent to which the past change in non-commercial net positions contributes to forecast spot prices is small; as a result, the null hypothesis is not rejected. For what concerns the change in net positions of commercials, the evidence of a Granger-causation is maintained in only in two out of four sub-periods. Again, to check the validity and robustness of these results, the analysis has been extended over the AIC-selected lag lengths and more lags have considered, as shown in Table 49 reported in Appendix H. The extended analysis confirmed the results: for the whole sample (2004-2023) the null hypothesis that the change in net positions of non-commercials does not Granger-cause spot prices is rejected for all the lags. This strong Granger-type relationship from the change in net positions of non-commercials to spot prices is maintained also in the sub-period that goes from 2004 to 2015; indeed, the same null hypothesis is again rejected for all the lags. The relationship becomes less clear in the sub-period 2015-2023, in which the null hypothesis is rejected only for four out of twelve lags.

Table 26 reports the p values obtained from Granger causality tests between futures prices of soybeans and speculation. As a first observation, it is interesting to see that the null hypothesis that the change in net positions of non-commercials does not Granger-cause futures prices cannot be rejected for the whole sample, and this is also confirmed by Table 50 reported in Appendix H, which shows indeed that for any of the lags the null hypothesis can be rejected. However, if the sub-period 2015-2023 is considered, the null hypothesis that the change in net positions of non-commercials does not Granger-cause futures prices can be rejected for seven out of twelve lags; instead, in the sub-period 2004-205, the same null hypothesis can be rejected only for three out of twelve lags. These results suggest that the relationship that holds between the change in net positions of non-commercials and spot prices, as well as the one that holds between the change in net positions of non-commercials and futures prices, is more complex than what can be detected from a linear Granger causality test. Perhaps, non-linear (parametric) Granger causality tests (or other kinds of statistical tests) could be more accurate in helping the interpretation of these apparently contrasting results.
For what concerns the Granger-causality relationship from the total open interest to futures prices, the null hypothesis cannot be rejected when considering the whole sample and the AIC-selected lag length (p value of 0.5047). However, combining the results of Table 26 with the ones reported in Table 50, it can be seen that the null hypothesis that total open interest does not Granger-cause futures prices can be rejected for five out of twelve lags for the whole sample (2004-2023), and for seven out of twelve lags for the sub-period 2004-2015.

Table 27 reports the p values obtained from Granger causality tests between volatility of futures returns of soybeans and speculation. For the whole sample (2004-2023), the null hypothesis that the speculation proxy does not Granger-cause volatility is never rejected. Therefore, from the Granger causality tests which use the AIC-selected lag length, no evidence of speculation affecting prices can be found. However, to check the validity and robustness of these results, the analysis has been extended over the AIC-selected lag lengths and more lags have considered, as shown in Table 51 reported in Appendix H. Table 51 shows that the null hypothesis that speculative pressure does not Granger-cause volatility is rejected for four out of twelve lags for the whole sample (2004-2023), for six out of twelve lags for the sub-period 2015-2023, and for three out of twelve lags for the sub-period 2004-2015. In all the three cases, the null hypothesis is rejected for low values of lag length; however, for the whole sample, the AIC suggested a lag length of 7, for which the null hypothesis is not rejected.

			H0: proxy does not Granger cause spot prices	H0: spot prices do not Granger cause proxy
Proxy	Time frame	Lags (AIC)	F-test p value	F-test p value
Ch_NP_NonComm	2004:01-2015:01	4	0.0002***	0.8694
	2015:01-2020:01	4	0.0963*	0.9625
	2020:01-2023:01	11	0.9747	0.5193
	2015:01-2023:01	1	0.0124**	0.4475
	2004:01-2023:01	4	0.0005***	0.8431
Ch_NP_Comm	2004:01-2015:01	4	0.0002***	0.9125
	2015:01-2020:01	4	0.1218	0.8932
	2020:01-2023:01	11	0.8099	0.0902*
	2015:01-2023:01	1	0.0109**	0.6358
	2004:01-2023:01	4	0.0001***	0.8819
Tot_OI	2004:01-2015:01	2	0.5966	0.2575
	2015:01-2020:01	14	0.1145	0.3486
	2020:01-2023:01	11	0.7332	0.0136**
	2015:01-2023:01	2	0.1076	0.1830
	2004:01-2023:01	13	0.5941	0.0607*
T	2004:01-2015:01	2	0.6510	0.0213**
	2015:01-2020:01	13	0.6790	0.5720
	2020:01-2023:01	11	0.7199	0.7207
	2015:01-2023:01	7	0.4638	0.2155
	2004:01-2023:01	8	0.3249	0.0009***
Spec_press	2004:01-2015:01	2	0.3878	0.7587
	2015:01-2020:01	14	0.8834	0.7783
	2020:01-2023:01	11	0.1025	0.7281
	2015:01-2023:01	2	0.5782	0.0742*
	2004:01-2023:01	2	0.3020	0.1894
Hedg_press	2004:01-2015:01	2	0.2074	0.9544
	2015:01-2020:01	15	0.9460	0.2830
	2020:01-2023:01	11	0.1408	0.7319
	2015:01-2023:01	2	0.3794	0.1235
	2004:01-2023:01	2	0.1869	0.6710
S&P GSCI	2004:01-2015:01	9	0.9242	0.2498
	2015:01-2020:01	13	0.0905*	0.1475
	2020:01-2023:01	11	0.6861	0.2655
	2015:01-2023:01	2	0.1701	0.1984
	2004:01-2023:01	13	0.2585	0.0196**

*Table 25: Granger causality test for spot prices of soybeans: p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

			H0: proxy does not Granger cause futures prices	H0: futures prices do not Granger cause proxy
Proxy	Time frame	Lags (AIC)	F-test p value	F-test p value
Ch_NP_NonComm	2004:01-2015:01	4	0.0205**	0.6644
	2015:01-2020:01	2	0.6199	0.4117
	2020:01-2023:01	11	0.7569	0.0829*
	2015:01-2023:01	2	0.1532	0.1038
	2004:01-2023:01	7	0.2210	0.1316
Ch_NP_Comm	2004:01-2015:01	4	0.0218**	0.6080
	2015:01-2020:01	1	0.2693	0.1264
	2020:01-2023:01	11	0.8980	0.1507
	2015:01-2023:01	2	0.1761	0.1600
	2004:01-2023:01	7	0.2049	0.1207
Tot_OI	2004:01-2015:01	1	0.8613	0.0934
	2015:01-2020:01	1	0.4095	0.8751
	2020:01-2023:01	11	0.8477	0.2257
	2015:01-2023:01	2	0.9448	0.0693
	2004:01-2023:01	14	0.5047	0.0001***
T	2004:01-2015:01	2	0.2454	0.0714*
	2015:01-2020:01	15	0.2721	0.0113**
	2020:01-2023:01	11	0.2428	0.3407
	2015:01-2023:01	7	0.3494	0.0000***
	2004:01-2023:01	7	0.0551*	0.0000***
Spec_press	2004:01-2015:01	2	0.4149	0.0024***
	2015:01-2020:01	2	0.0514*	0.0000***
	2020:01-2023:01	11	0.8960	0.2343
	2015:01-2023:01	2	0.7290	0.0000***
	2004:01-2023:01	2	0.3003	0.0000***
Hedg_press	2004:01-2015:01	2	0.0933*	0.0002***
	2015:01-2020:01	2	0.1608	0.0001***
	2020:01-2023:01	11	0.4867	0.4291
	2015:01-2023:01	2	0.5237	0.0000***
	2004:01-2023:01	7	0.4218	0.0000***
S&P GSCI	2004:01-2015:01	7	0.6700	0.4658
	2015:01-2020:01	15	0.2479	0.4911
	2020:01-2023:01	11	0.9637	0.3819
	2015:01-2023:01	2	0.5308	0.0031***
	2004:01-2023:01	13	0.7962	0.1103

*Table 26: Granger causality test for futures prices of soybeans: p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

			H0: proxy does not Granger cause volatility	H0: volatility does not Granger cause proxy
Proxy	Time frame	Lags (AIC)	F-test p value	F-test p value
Ch_NP_NonComm	2004:01-2015:01	1	0.2782	0.7166
	2015:01-2020:01	1	0.6309	0.3022
	2020:01-2023:01	11	0.6165	0.6553
	2015:01-2023:01	1	0.9035	0.1349
	2004:01-2023:01	1	0.4899	0.2323
Ch_NP_Comm	2004:01-2015:01	1	0.3669	0.8595
	2015:01-2020:01	1	0.5247	0.4040
	2020:01-2023:01	11	0.3554	0.5257
	2015:01-2023:01	1	0.8620	0.1738
	2004:01-2023:01	1	0.4967	0.2819
Tot_OI	2004:01-2015:01	1	0.5353	0.9346
	2015:01-2020:01	13	0.3508	0.0786*
	2020:01-2023:01	11	0.0936*	0.2261
	2015:01-2023:01	1	0.0810*	0.0241**
	2004:01-2023:01	10	0.9114	0.0082**
T	2004:01-2015:01	1	0.1709	0.5720
	2015:01-2020:01	15	0.0683*	0.1119
	2020:01-2023:01	11	0.7847	0.0683*
	2015:01-2023:01	8	0.2208	0.7278
	2004:01-2023:01	7	0.4660	0.5975
Spec_press	2004:01-2015:01	7	0.3656	0.0017***
	2015:01-2020:01	2	0.1190	0.8274
	2020:01-2023:01	11	0.4666	0.5897
	2015:01-2023:01	2	0.0230*	0.6278
	2004:01-2023:01	7	0.3094	0.0031***
Hedg_press	2004:01-2015:01	7	0.4310	0.0160**
	2015:01-2020:01	2	0.0698*	0.6170
	2020:01-2023:01	11	0.1961	0.7295
	2015:01-2023:01	2	0.0260**	0.5813
	2004:01-2023:01	7	0.4822	0.0077***

*Table 27: Granger causality test for volatility of futures returns of soybeans: p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

5.2.3 Discussion

The previous analysis assessed, through several Granger causality tests, the relationship that holds between speculation and prices. The tests have been performed in both directions: from prices to speculation, and from speculation to prices.

For what concerns the first direction, evidence of prices affecting speculative activities has been found, especially when futures prices are considered. Thus, it can be broadly stated that (futures) prices affect (in a Granger sense) speculative activities. This is not a surprise, since it is more than reasonable to expect that changes in (futures) prices will cause changes in traders' (both commercial and non-commercial) expectations; this will cause changes in the positions held and, as a consequence, in the overall financial pressure within the futures market. Thereby, the results obtained from this first set of Granger tests refer to a natural and well-known dynamic of trade markets, under which «traders follow prices».

For what concerns the second direction, different - and sometimes contrasting - results have been found, especially when the analysis has been extended from Tables 22-27 to the tables reported in Appendix H.

Starting with corn, the combined analysis suggests that changes in (commercial and non-commercial) net positions Granger-cause spot prices for small values of lag length. The total open interest also seems to Granger-cause spot prices, however, no final conclusion should be drawn, since the null hypothesis is rejected for just six out of twelve lags, and the AIC-selected lag also does not lead to reject the null hypothesis. Conversely, the combined analysis gave strong evidence of the S&P GSCI Granger-causing spot prices during the period 2015-2023. This evidence would not have been found if only the AIC-selected lag length was employed in the analysis; this pins out the first limitation of the statistical model employed, and gives credit to the choice of repeating the test over a range of lags rather than only one: selecting a wrong lag length might lead (or not lead) to overly strong conclusion that might not hold when a greater variety of lags is considered. Conversely, no Granger causality has been found from the S&P GSCI to futures prices. This result does not contradict the relationship found in Section 5.1.2 between spot and futures prices; indeed, for corn it has been observed that futures prices Granger-cause spot prices, and not the contrary. Therefore, this analysis suggests that spot prices can be, and effectively are, significantly Granger-caused by (at least) two different variables: futures prices and the S&P GSCI. Total open interest is found to Granger-cause futures prices as well, with evidence that is stronger than that found for spot prices (the null hypothesis is rejected for eight out of twelve lags, precisely, from lag 5 onwards). Therefore, it can be concluded that if a sufficient number of lags is included as regressors (more than four), the total open interest helps to predict futures prices. Finally, the combined analysis suggests that the total open interest and speculative pressure Granger-cause the volatility of futures returns. This means that the traders' activity affects – to be precise: increases - the extent of futures prices' changes and fluctuations. Big fluctuations of (futures) prices mean less clear information deducible from their trends, which in turn means a decrease in the efficiency of the price discovery function. As a final conclusion, it can be therefore stated that the total open interest and the speculative pressure have an (harmful) effect on price discovery, since they Granger-cause volatility of futures prices for corn.

For soybeans, the combined analysis led us to conclude that the change in both non-commercial and commercial net position Granger-causes spot prices, with evidence that is stronger for non-commercials. The reason for this can be traced back to the "roles" that commercial and non-commercial actors cover in the market, and the main "drivers" of their investments and holdings. Specifically, changes in commercial positions are typically less sudden and drastic, since these market actors are usually taking short positions and hedging on a physical asset. Conversely, non-commercial actors can change their positions more rapidly and frequently, since there is no physical asset driving their decisions, but just personal expectations and risk appetite - which usually vary more often and "randomly" than what can be traced back to market fundamentals' changes. Therefore, the effect of changes in non-commercial net positions is likely to have a more significant effect on prices than the change in commercial net positions. The Granger-causation from changes in non-commercial net positions to prices is not found when futures prices are considered, suggesting that there might be a more complex relationship between these variables, a type of causal relation which is not detectable through linear Granger causality tests. To conclude, the combined analysis suggests that, for small values of lag length (from 1 to 4), the speculative pressure Granger-causes volatility. However, the overall evidence of speculation Granger-causing volatility is less powerful for soybeans than for corn. Conversely, for soybeans, it seems that the relationship goes more often in the opposite direction, with volatility of futures returns Granger-causing the total open interest and the speculative pressure.

Overall, the previous analysis helped to get more evidence about some hypothesized dynamics of futures markets. A part from what has been summarized above, the analysis showed that causalities change from the period 2004-2015 to the period 2015-2023, suggesting that also the market dynamics have changed throughout the years. This can be both due to the continued growth and development of commodity investments from 2003 until today, as well as due to historically-contingent events which affected both prices (through changes in markets' fundamentals), and traders' behaviours and positions. Linear Granger causality tests might help to give a preliminary interpretation on how these three forces (prices, traders and historically-contingent events) relate to and affect each other; however, the relationships might likely be more complex than what can be explained by these tests. Lastly, it is worth to observe that both the periods considered (2004-2015 and 2015-2023) are characterized by big critical events: the first epoch (2004-2015) contains the financial crash, while the second epoch (2015-2023) contains the Covid19 shock and the Ukrainian conflict. All these critical events spread panic among financial markets, however, different dynamics and relationships seem to hold in the two epochs. Further research could be done for what concerns the learning processes of financial investors, that is, the way these actors perceive risk and change their trading behaviours based on the previous market events (especially crises) experienced.

The analysis also reported some inconclusive, ambiguous or contrasting relationships, from which a straightforward conclusion cannot (and should not) be stated. However, these ambiguities are without meaning or totally inconclusive; rather, they give a first insight in the hidden complexity which characterizes the relationships that holds between some of the variables considered, pointing out the limitation of linear Granger causality test of being "too simple".

5.3 Conclusions and limitations

The empirical analysis and the Granger causality tests performed in the previous sections helped to gain additional insights about the food commodity markets' price dynamics. Specifically, the tests confirmed the relationship - based on the price discovery function of futures markets - that links futures and spot prices. Indeed, it has been found that, for corn and soybeans, futures prices Granger-cause spot prices. Furthermore, the tests also helped to develop, expand, and sharpen the discussion on the the potential effects of speculative activities on food prices. Specifically, the tests provided some evidence of speculation influencing the prices' fluctuations and volatility, especially when the total open interest, the change in non-commercial net positions and the speculative pressure were considered as proxies. Thereby, the outcome of the tests, alongside with the visual inspections performed, suggest that speculation cannot and should not be ruled out as one of the influencing forces causing commodity prices' changes.

The employment of the linear Granger causality test over different time periods and different lag lengths also served to test the robustness of the econometric model employed and to point out some important limitations of this model.

First, as any statistical model, also the one employed in these analyses suffers and depends on the quality of data. The data sets used to perform the previous analyses have been retrieved from different websites and repositories and had to be cleaned, prepared, converted and merged before performing the tests. In the process from raw data to cleaned data, there is already a risk that some relevant information gets lost or distorted. Furthermore, to perform the tests, the speculation variable had to be *quantified*. This has been done through the consideration and computation of different proxies. However, every proxy carries its own limitations, and there is not final rule that can tell which one best represents «speculation». The analyses performed in Section 5.2 showed that some proxies revealed evidence of Granger-causality while some others did not; it follows that the choice of proxy for representing speculation is crucial for the outcomes of the analysis. The bottom line of this discussion is that the statistical model already looses some information and accuracy by just "approximately" translating a complex phenomenon such as speculation into a specific index or position.

Second, there are also some limitations related to the linear Granger causality itself, such as the number of lags to select for the test. We have seen that the choice of the lag length is crucial, since in some cases it affects whether or not the null hypothesis is accepted. The AIC might help the choice of the correct number of lags, but there is no guarantee that this approach should be preferred over a more empirical one (Wooldridge, 2015). This is precisely why the tests have also been performed for a range of possible lags (from 1 to 12), and inference has been made based on the "number of times" that the null hypothesis was rejected.

Furthermore, the tests showed that the period selected for the analysis is also crucial for the outcome; for example, the null hypothesis of the S&P GSCI not Granger-causing spot prices of corn was confidently accepted for the period 2004-2015, while it was significantly rejected for the period 2015-2023.

Additionally, the tests also showed that the Granger causality relationship can be bi-directional: this again underscores the fact that Granger-causation should not be confused with a simple cause-effect relationship. In general, this aspect also suggested that the dynamics which dominate prices and markets are likely to be more complex than what a linear model can capture and explain.

Lastly, reminding the outcomes found for the S&P GSCI for spot and futures prices of corn, the analysis showed that one variable (in this case, the spot price of corn) can be Granger-caused with statistical evidence by more than one variable. The implication is that if a significant evidence of Granger causality is found from variable A to variable B, this does not rule out the possibility that other variables are also significantly Granger-causing variable B. There might always be an additional variable - which has not been considered in the model - which is Granger-causing B with high significance. Therefore, while these tests give reasons for considering speculation as one of the factors moving prices, the same tests give no information about the extent to which speculative forces are stronger or weaker than other (not considered) market forces.

For similar reasons, Granger causality test cannot give meaningful indications of the size effect, that is, no meaningful information is given by the coefficients found when regressing the two time series on the selected number of lags. These tests just tell whether is reasonable to assume that variable A helps the forecast of future values of B, however, the *extent* to which future values of B are determined by values of A is out of the tests' power. Granger causality is not simple causality: finding Granger causality from variable A to variable B still does not enable to quantify what for instance, an increase of 10% of variable A causes on variable B. The reason is again because even though we might find that A Granger-causes B with strong statistical evidence, this still does not rule out the possibility that other variables also strongly Granger-cause B. Additionally, the statistical evidence of Granger causation comes from a model which regresses two time series on a specific number of lags, therefore, it might be that in some specific "segments" of the two time series the dynamic correlation between the two series is stronger, while in others is weaker, but then overall the non-Granger causality hypothesis can be rejected. To conclude, the coefficient that can be retrieved from the test are not a good representation of what the actual effects might be (in terms of size and strength). Reminding that linear Granger causality tests only capture first differences relationships (and thus they already miss several potential nonlinear relationships) the coefficients retrieved from those tests would be very poor and inaccurate approximations of a much more complex dynamic.

The aforementioned limitation are precisely the reason why all the results obtained from these tests should be interpreted and weighted carefully. In general, it is more accurate to rely not only on the Granger-causality tests' results, but also on other (statistical or non-statistical) approaches, especially when observing and assessing complex dynamics in which market factors, human sentiments and expectations, crises, wars and shocks all have a role. This is why a multi-method approach is used in this thesis. A multi-method approach helps to develop a level of criticality and expertise which in turn enables to carefully assess, interpret and weight the validity and reliability of the results obtained. By looking at the same phenomenon from different perspectives and analyzing it with different procedures, the multi-method approach forces the researcher to maintain a broader view of the phenomenon under study; it helps to keep an eye on the whole picture, avoiding the risk of relying too much on potentially overly narrow or reductionist tests and jumping to conclusions which might be wrong just because of statistical limitations. The fact that speculation is highly complex and difficult to detect has been stressed and shown already in the first chapters of this thesis. For this reason, it would be unwise and incorrect to develop conclusions based only on a test which not only carries its own statistical limitations, but which also, by its structure, is incapable of fully embracing and representing the real phenomenon in its whole complexity.

6 Interviews

To contextualise and expand the analysis and findings of Chapters 2–5, five experts in the field of food commodity markets were interviewed. This chapter reports the main insights gathered from the interviews performed. Specifically, the five interviewees were Jennifer Clapp, Lukas Kornher, Tomaso Ferrando, Jayati Ghosh and Sophie van Huellen.[6]

These scholars are experts in the field of food commodities, and they have been engaged in the topic of speculation of commodities in various, different ways. The approaches and theories adopted to observe, analyze and discuss the topic differ from expert to expert. Some of them work with advanced statistical methods, while others start from a political-economy stance or a theoretical representation of the commodity markets. Some of them have a focus on a specific commodity, market, or country, while others adopt a broader view and look at the global food system as a whole. For this reason, they themselves represent a good sample for constructing a "multi-view" framework, and help gaining knowledge about the same phenomenon from different levels of analysis.

The interviewees were asked a number of general questions that were the same for everyone, plus a number of additional questions specific to their works. Overall, the interviewees gave precious insights on what the current debate on speculation of food commodities looks like, and how it has evolved over time. They also commented on the opportunities and limitations of performing visual inspections and statistical tests as means for the analysis; specifically, they recommended to always keep an eye on the broader framework, thus once again validating and justifying this thesis' decision to adopt a multi-method approach and different layers of analysis. Furthermore, the interviews gave important insights into what concerns the fast development of new financial instruments and, in general, the *social efficiency* of financial innovations. Lastly, the interviewees also gave some suggestions about potential policy actions that could be implemented within the commodity futures exchanges and, in general, the financial sector.

6.1 The debate of speculation on food commodities: who is the black sheep?

As a first general question, the interviewees were asked about their stand on the effect of speculation on commodity prices, and how they view and can explain the controversial and opposing opinions found within the literature. As expected, these questions opened up to some considerations, which are summarized and reported below.

First, a common agreement between the interviewees has been observed for what concerns the effects played by speculation, and more in general by financial trading, on commodity prices. The interviewees all agree that the entry of a growing number of profit-seeking investors in the food commodity futures markets, alongside with the growth of new financial investment tools within such exchanges (which allowed more and more people to capitalize on food prices' changes) had an impact on food prices and their volatility.

Jennifer Clapp, as she also does in her works, points to the change of financial investments' rules as the main factor enabling the financialization of food commodity markets. Furthermore, she blames the financial sector's dynamics for the food price surges experienced today by considering some empirical, historical evidences: both in 2008 and again in February 2022 (after the invasion of Ukraine by Russia), the shooting up of demand in such financial products coincided with a big spike in agricultural commodity prices - it was these new financial investors seeing the prices rise and wanting to capitalize on it, and creating themselves the price bubble. This is also what Jennifer Clapp defines as speculation: financial investors trying to capitalize on rising food prices. Then, both in 2008 and today, it seems like «that spike happened and it left»: it was all those financial investors first moving in, driving prices up, taking profits from it and then leaving the market at the moment in which interest rates started rising and they were then «able to shift their investments to other instruments that would have a higher and more stable return».

[6] We also invited other experts, among them a trading house owner as well. Unfortunately, these experts did not respond.

The interviewee concludes by saying that, even though the two crises (the 2008 one and the present one) look similar on the surface, they are still different for what concerns the interest that moves the investors into these markets. While in 2008 it was mainly commodity trading companies which moved into commodities because of the growth in biofuel demand, today we also see other kinds of investors, such as food retailers, entering the market and gaining power. The interviewee mentions the importance that fertilizers' prices have gained in today's oil-and-food markets' dynamics. In line with what has been discovered in Chapter 4, Jennifer Clapp agrees on the fact that oil and fertilizer prices play a role in driving up food prices. She also states that most economists don't have a precise answer about the extent that each of those factors is actually playing in raising food prices; however, all of them have some kind of role. Therefore, in line with what was found in this thesis, the interviewee claims that «the speculative fervor on commodity futures markets is only one piece of the bigger picture of what's going on».

Lukas Kornher takes into consideration the broader concept of speculation, stating that speculation can be found wherever there is some sort of uncertainty. In food commodity markets, since the harvest happens at one point of the year, there is uncertainty concerning the availability of such food for the whole year; as a consequence, we see speculation in storing commodities (what he defines as *normal* speculation), and not only in the financial market (what he calls *financial* speculation).
Furthermore, he states that speculation (both *normal* and *financial*) can help stabilizing prices as investors can carry risks that farmers and consumers are not willing to bear, thus bringing liquidity to the market. However, in particular and uncommon market situations, the same practices can lead to price spikes and increased volatility. The interviewee defines such situations as historical moments during which «something strange happened in the market».

Second, the challenge of identifying who is a speculator and who is not has been again mentioned by the interviewees as one of the reasons why the debate is still open, and why there is no agreement on whether, and to what extent, these actors play a role in deviating prices from fundamentals.

Sophie van Huellen states that both speculation and hedging are *forward-looking* practices. Both speculators and hedgers participate in the market by taking a position (that is forward-looking) with the hope of gaining profit from it. Additionally, the interviewee claims that since both speculators and hedgers take a view on the market, they both have an effect on prices: the view on the market that any participant takes is reflected in what he/she is willing to pay (or to be paid) for taking that position in the market - it is a simple demand-and-supply condition.
Nevertheless, the interviewee still thinks it's worth differentiating between those who participate in the market because they want to hedge their exposure linked to a physical position, and those who are instead in the market because «they seek to gain from the outright financial position».

To conclude, overall, as confirmed also by Professor Van Huellen, it seems that the debate has evolved from 2008 to today, becoming a bit more *nuanced*: there is a general agreement that speculative trading has an effect on prices in certain periods of time. Therefore, even though the policy sphere, mainly for practical reasons, still seeks for a black-and-white division of things, the academics have moved away from taking extreme positions and nowadays embrace more nuanced, sophisticated and refined positions and arguments. The interviewee takes as an example two famous authors of the fields, Irwin and Sanders. These scholars are experts in agriculture commodity markets, especially the grain market. They investigated the impact of speculation on food commodities by using statistical tests (Granger causality tests as well), and concluded that the role of speculation in rising food prices was minimal, thus speculation could not be blamed for the food price spikes. Professor Van Huellen claims that, at the beginning, their research questions were far too simplistic. However, over time, also by embracing the *micro-structure literature* - which tries to build up a proper theoretical understanding of how traders' positions influence prices to design better empirical strategies - the two authors came up with more weighted, less heated claims on speculation.

6.2 The rationality of traders and the role of public information (media)

A second topic that has emerged from the interviews concerns the rationality that drives investors to participate in food markets, and in general, to take specific positions. Overall, the interviewees agreed upon the fact that the presence of speculative capital in commodity markets is undeniable. The reason for that is because, quoting Tomaso Ferrando, «speculating is what rationally everyone would do». For instance, the fact that traders have been declaring great increases in profits and returns over year 2022 should not be a surprise: they rationally operated and took advantage from a context in which there were signals (coming from futures prices) that they could make profits by investing in food commodities. Furthermore, as pointed by Lukas Kornher, risk-bearing, profit-seeking traders obviously get more attracted by those markets in which good returns are expected, and these are typically markets in which there is volatility, uncertainty and risk you can speculate on.
Nevertheless, the interviewees also remarked the heterogeneity which characterizes the investors' group, stating that there are several mechanisms, different types of *rationality*, which drive investment decisions.

First, the interviewees indicate a new type of investors which is now gaining ground within financial markets, that is, retail investors. Jennifer Clapp describes them as investors who «don't really know what they are doing» by gaining exposure to that market. The reason is that it is usually banks that buy futures on behalf of them: these retail investors are ultimately just searching for ways to diversity their investment portfolio, «they don't even see themselves as betting on hunger». Additionally, the interviewee stated that the number of retail traders increased dramatically during the Covid19 period: grounded by the lockdowns and with nothing much else to do, these people started spending time by trading on commodities through their smartphones.

Second, Sophie van Huellen distinguishes different groups of traders based on their purpose for being in that particular market. For instance, she defines index traders as passive investors, while hedge funds as active investors. However, she states that both types of investors have an effect (sometimes positive, sometimes negative) on prices, just by being in the market, and by doing so she once again remarks the fact that all traders, either hedgers or speculators, affect prices by just taking a view on the market.

Third, Lukas Kornher describes a theoretical aspect which characterizes financial investments. He first introduces the 'efficient financial markets hypothesis' view of financial markets, under which today's price equates the expected price adjusted by a certain discount factor. If that's the case in reality, then there should not be room for speculation to change the prices. However, one might ask how the expected price is formed. Is it completely driven by market fundamentals? The answer that the interviewee gives is no, and the reason for that is again explained by rationality. What the interviewee observes is that financial speculators, investment funds, index traders likely have different incentives, a different *utility function*: this makes them invest in ways that drive prices away from what fundamentals would tell. This is even more evident if we think about the fact that part of the commodity trading is done through high frequency trading and AI-algorithms, that just bet and invest based on stochastic models of previous returns, or based on information and events coming from other markets, or based on a pure diversification strategy: these are clearly investment practices and exposures that are not driven by the fundamentals of the specific commodity market.
Ultimately, this theoretical framework proves that investments are not always driven by market fundamentals' dynamics, and subsequently we should expect prices to not be based on those fundamentals either. Therefore, the author concludes that once this kind of speculation becomes *excessive* - meaning that the share of market actors (or investment technologies) that have a different kind of utility function for their investment decisions becomes bigger - the expectation formation can change significantly and move the expected prices away from what fundamentals would suggest.

To conclude, Jayati Ghosh pointed out that, during the 1990s until 2001 (the year in which the Commodity Futures Modernization Act was enacted in the US), commodity price volatility was relatively low, and global commodity prices mainly tracked changes in supply and demand. However, after the deregulation of commodity markets during 2001-2003, the correlation between global supply and at the weighted average of global prices decreased, commodity price volatility increased, thus changes in volatility became more and more unrelated to changes in supply (or demand). What she means by showing this simple evidence is that, in the current period, there is speculation in commodity markets even though there is no real change in supply or demand, that is: investments have become more and more driven by other factors rather than fundamentals. The interviewee blames media for having exacerbated this phenomenon, especially in the recent period. Media persuaded investors that - because of current market conditions or geopolitical context - prices have to go up, and investors accepted that and acted by taking positions in the market, yet following themselves a pure speculative argument. This is precisely what happened at the beginning of the Ukrainian conflict. Ukraine is known as a big producer of wheat, and Russia as a big producer of fertilizer and a big exporter of oil: the media persuaded investors that the conflict would have affected global prices. Yet, global prices were affected, but it was not because of changes in global supplies (which actually never changed, not even during that price peak period of the invasion and the war), rather, it was because of a self-fulling prophecy started by the media. By just spreading panic on future food shortages and stating that «prices will go up», the media caused the massive entry of investors and speculators in the financial markets. As a consequence, the increasing trading activity drove up prices and created the price bubble itself, without any market-fundamental change experienced in reality. As said by Sophie van Huellen, «the narrative of a future food shortage always results in a lot of speculators going long into food, and that drives up prices and creates a massive bubble». Ultimately, the process was even more heated by food companies which profited from this media noise and raised their prices.

6.3 "Harmful" to whom? The "triple whammy" of developing countries

Another argument that has been brought up by the interviewees concerns the ethical questions such as *How good/bad is speculation? Is speculation harmful?*. In general, the answer depends on whom you ask it. The reason why trading activities are performed by investors is because they all expect to have some sort of advantage from doing it. However, as in every multi-actor game, there are winners and there are losers, as well as opportunities and drawbacks. Concerning speculators, they bring liquidity to the market, and they also contribute to the price formation. This can be either good or bad, depending on which actor you decide to focus on.

What Jayati Ghosh adds to this discussion, is that while in the global market speculation leads to a temporary price increase - and thus one might say that the win-and-lose situation is confined to a small period of time and to those investors who decided to bear the risk - this does not happen in developing countries. Instead, developing countries face a "triple whammy" from the heated trading activities of high-income countries and the subsequent price increases. First, they get impacted by the higher food and fuel prices coming from the crisis: when the global prices go up, there is immediate pressure, and a very fast transmission of global prices to their domestic prices. For food-importing developing countries, the import bill will rise and the trade balance will deteriorate (in response to the increase in global food prices). In many cases, this will lead to a depreciation of their currencies – and such a depreciation will raise the prices of all imports, thus contributing to inflation in these countries. Second, as a consequence of the deteriorated trade balance and exchange rate depreciation, these countries will an increase in financial outflows, and this makes it harder for them to access loans. The financial outflows will lead to a further depreciation of their currencies. Third, to stop the financial outflows and to lower domestic inflation, central banks in the developing countries will raise the interest rate. This will lower domestic investment and economic growth, which will add to the socio-economic costs of the increase in global food prices. If all this happens right when US and EU monetary policies are tightened (as happened during 2022-2023), then it is clear that the impacts of higher global food prices on developing countries and their populations will be long-lasting. Hence, at the moment at which global prices come down again (which typically happens nine months / one year after the beginning of the crisis), the domestic price of food and fuels of such developing countries does not come down: the crisis is not temporary for them. Furthermore, since for the bottom half of the population (and in general for developing countries), food represents more than 50% of their consumption basket, a relatively small food price change has a much bigger impact. If we add the fact that in developing countries people usually have very little social protection, it is not anymore possible to look at the speculation-driven price peaks just as "temporary shocks" with no long-term effects.

6.4 The social efficiency of finance

The previous sections showed that commodity investments are becoming more and more disconnected from the (real) dynamics of demand and supply, that is, speculation no longer reflects real changes in what would affect prices (i.e., supply and demand). As a consequence, prices are deviating away from what fundamentals would tell, and speculation is not stabilizing anymore. There are two interconnected reasons that have contributed to this.

First, there is a growing number of investors who are entering commodity markets with different expectations and purposes; by doing so, they are flushing such markets with liquidity and increasing volatility and uncertainty. As explained above, this triggers a vicious circle in which even more investors get attracted and enter the commodity markets.
Second, there is a growing number of financial tools, practices and platforms which are facilitating and giving the opportunity to trade to a larger number of people – including many traders who enter food commodity markets only motivated by a wish to diversify their financial portfolios.

These two interconnected reasons summarize what is known as the process of *financialization*. Against this background, the interviewees were asked about their opinion about the recent financial innovations which theoretically aim to reduce transaction costs and foster 'financial inclusion'.

Jayati Ghosh states that she is not convinced that these should be seen as "innovations": «[...] innovation is something that makes things better [...] and doesn't just allow a new way of making money by effectively taking money away from someone else».

In line with what was said above, Sophie van Huellen looks at these financial innovations as «clear signs towards further financialization of everyday life», and adds that this «is never a good thing, because it means that you substitute wage with financial income, and that can harm very quickly a lot of people». By saying so, she refers to all those new investors, the so-called retail traders, who massively entered commodity markets during the Covid19 period. Indeed, during the pandemic period, these people had an excess amount of time that they easily spent in trading in commodity derivatives through their smartphones via several trading apps. By doing so, they poured money into commodity markets, and became themselves speculators: they put additional price pressure on food commodities, and contributed to create speculative cycles. Now, what is of concern, is that these retail traders are usually inexpert market participants who trade with their savings. This means that when a price crisis happens, it is not anymore just hedge funds and banks that might be affected by financial losses, but it's also these retail investors who might see their savings wiped out.

The bottom line of this discussion is that opening financial trading to everyone (so that not only rich people can benefit from it) brings several risks, that is, it might lead middle-class and low-income people to bet with their savings and experience harmful losses. Furthermore, it should not be forgotten that the people who remain excluded from financial markets (i.e., the world's poorest including small farmers) will still be affected by the prices' dynamics that arise from them. This is also what brings Sophie van Huellen to conclude that «no one, neither not-rich or super rich, should benefit from rising food prices and the suffering of others».

6.5 Statistical approaches: opportunities and drawbacks

The interviewees were then asked about their stand for what concerns using statistical approaches to evaluate the extent to which speculation affects prices, with a specific focus on the linear Granger causality test used in this thesis.

Sophie van Huellen seemed to be skeptical about the use of Granger causality tests in this field. However, she says that they could still be useful if employed in a proper manner, and if their limitations are carefully considered and acknowledged: «as with any statistical tool, as a researcher it is important to be clear about what that method can achieve, what are the limitations and which answers it can reasonably give evidence for».

To begin, she points out the importance of how you define and quantify speculation: there is no universal correct indicator, but it is undeniable that results might change if you change the indicator. This has also been seen throughout this thesis.

Second, Granger causality tests are based on short-term models: they link first differences of a time series to first differences of another time series. Thereby, any long-run price trend is not detected by these tests.

Third, with Granger causality tests you can, for example, analyze the linkages between changes in positions and changes in prices. However, if you wish to analyze the link between the *level* of positions and the *level* of prices, that's beyond the Granger causality model in itself. The reason is that Granger causality tests require the time series to be stationary, and the time series of the variables in levels are always found to be non-stationary (and therefore, the first differences are usually computed). This is also something that it has been remarked in the previous chapters of the thesis: Granger causality tests give no meaningful indication about the size of the effects, that is, how much a change in variable A changes variable B (once it has been proven that A *G.c.* B).

Fourth, another problem that was highlighted by interviewees with respect to statistical tests in general, is the limitation of data. Indeed, data are not always freely available, and are not always a good representation of reality. This has also been discussed in this thesis by showing that the CFTC reports all have their own limitations and problems when categorizing traders. Furthermore, there is a huge amount of insightful data that, for privacy reasons, is not disclosed by companies and trading commissions, and this makes it even more difficult to quantify and identify the role and impact of trading activities (see for example, for what concerns the oil market, Wilson (2023, May 3) and Sheppard (2023, May 11)).

Lastly, Lukas Kornher points out the importance of the *external validity* of the statistical results obtained. Specifically, he suggest to make conclusions only on the exchange (for example, the Chicago Board of Trade), the commodity and the time period that have been considered in the analysis, without making any further generalization: «be rather parsimonious than elaborate or comprehensive».

Some of the interviewees also made some insightful considerations about the use of statistical approaches to take conclusions about real-life, complex dynamics, thus once again remarking to never lose the focus of the whole picture. After all, the financial sector is a much more complex, blurred environment that can hardly be reduced, summarized and modelled through a couple of time series and tests: to what extent are statistical data capable of grasping the way in which the markets are constructed? How could they grasp the double, blurred role that the traders play as hedgers, but also as speculators?

Tomaso Ferrando is doubtful about what these statistical tests can tell you more than what you can see by just looking at how real things work today: «[...] you talk to any buyer of any commodity, and they will tell you that the process is completely defined by financial investors. So, I don't think that I need a statistic if that's what everyone says. And for every single commodity, that's what they say».

Jayati Ghosh states that «it is possible to make pretty much any argument you want using the data. And the one you choose to highlight depends on your priors». In a similar manner, Jennifer Clapp recalls the following sentence: «statistics measures precisely what we know already, generally». This thesis agrees with these views, and it is precisely for this reason that an impartial, critical, and almost skeptical view has been maintained with respect to all the methods and findings reported. Furthermore, it is also the reason why this thesis has embraced the topic of financial speculation by adopting different levels of analysis.

Lukas Kornher links the statistical evidence to policy actions and makes an interesting consideration about the way statistical tests are typically constructed in this field. Specifically, he observes that these tests usually have as a null hypothesis that there is no effect of speculation, and thus you check for evidence to reject that. However, in the current situation in which there is the risk that speculation drives prices and thereby hunger, shouldn't that hypothesis be turned around? If we say the null is speculation drives prices, then this means that it's time to act and not wait for statistical proof. What the interviewee wants to say is that the topic of commodity speculation is too important with regard to global hunger, and that we should do something beforehand, rather than wait for academic publications and statistical proofs.

To conclude, it should never be forgotten that academics are influenced by how the research is *instrumentalized*, and they all have their verification biases towards a certain hypothesis. This is an additional reason why this thesis has always clearly stated the limitation of its research.

6.6 Policy recommendations

Lastly, the interviewees were asked about potential policy actions which would decrease inequality and reduce the risk of speculative food price peaks.

A first argument on which all the interviewees agreed is that there is a need of more transparency in financial markets. The fact that the media nowadays have such a great influence on investors' decisions and are able to actually trigger self-fulfilling prophecies, brings the urge to reduce the uncertainties, promote clarity and foster good information in the food markets. By doing so, there will be less space for the media's speculative suppositions to trigger such great financial movement. Ultimately, volatility and uncertainty will come down, and the space for profitable speculation within that markets will be reduced.

A second policy action that was mentioned by the interviewees concerned position limits. They all agree that some sort of regulation is necessary to limit abuses in the markets, however, the current available and public information about positions is not accurate enough to say whether those limits are adequate or not. At the moment, the imposed position limits do not capture how several traders take their positions. Indeed, thanks to the advances in technology, today traders can spread their positions across different brokerage services and, by doing so, they can already undercut some of these positions. This underscores once again the importance of turning commodity markets into more transparent environments.

A third policy action mentioned by the interviewees has to do with taxes. Lukas Kornher thinks that taxation might be a good solution, however, it could also lead to an increase in the final price; this increase in price will be quickly passed from speculators to consumers, thus ultimately contributing more to price increases. Therefore, if taxes have to be imposed, the taxation instrument has to be more elaborated, especially since capital can easily move across borders and markets.
Sophie van Huellen claims that financial income should be taxed much more highly, and that goes hand in hand with progressive taxation in general. Whether this will be enough to eliminate excessive speculation in commodities is still unknown. However, it will definitely make it less attractive for individuals to channel a huge amount of their funds into these instruments. Again, the market will eventually become less flushed by liquidity, with positive consequences on price stability.

Finally, the interviewees talked about the exclusion of some specific actors from commodity markets. Jennifer Clapp and Jayati Ghosh agree upon the fact that food commodity markets don't need big banks' new financial investment products and retail investors' investment capital to actually function. The argument that "we need them for liquidity" and that "more liquidity is stabilizing" is simply false: you need enough liquidity to match *real* buyers and seller, and that will still be there even without these big market players. Jayati Ghosh goes even more in detail with her policy recommendations, and states that if only those investors with a clear interest in the commodity could enter the market, and if position limits were set in relation to the investor's extent of interest in that commodity, then the basic reserve requirement to enter the market could be lowered so that small farmers and cooperatives could also have a role in these markets. Instead, what we have at the moment is an exchange market purely dominated by big players which rarely have some clear interest in the commodity: «they are interested in the capital gains/losses to get from that commodity. That changes the game, the commodity becomes another asset class, and then you know, there's so much literature about what happens when you think of something as an asset class».

6.6.1 Rethinking the food system

In his interview, Tomaso Ferrando brings the debate on *what is ethically good or bad in financial markets* to a higher level, questioning *what is the role of finance overall*: do we really need finance entering commodities at all?

For the interviewee, asking whether some financial practices within the commodity markets are desirable or not, implies that we are already assuming and picturing a food system in which finance covers a prominent role. By doing so, it is no longer possible talk about ethical or unethical behaviours: the food system in place right now accepts and welcomes finance, therefore, it automatically creates space for speculative capital of any source, even an *excess* of it. And we cannot blame people for taking advantage and making profits from speculative trading on food, if the system itself gives them the opportunity to do so. Speculation, financial flows and financial capital are a structural component of the food system that is now on play. Therefore, the question is not what kind of behaviours we would like to see or not within the food system, but rather, what kind of food system we want. Depending on the food system that we design and its purposes, there will either be or not be space for speculators.

If we had to design a rights-based food system, which is ecologically sustainable and based on human rights, then there will be automatically little space for speculative capital: at the end, speculators do not have as a priority the protection of the rights of the food system's consumers and small producers. A rights-based food system in which it is no longer just four commodities representing 80% of the global trade, and in which different principles and purposes are pursued, will automatically be incompatible with rewarding speculative capital out of higher prices of food. If we wish to find alternatives to commodity trading and the role that finance plays in food systems, we have to rethink the size of the food system itself.

To conclude, what the interviewee suggests it that we should open even more our view of the phenomenon and embrace the concept of the food system as a whole. We should stop focusing on the very narrow question of what *excessive speculation* is, and open up to more structural questions about what the is impact of finance per se on the system, and whether we accept such system or not.

7 Discussion and Conclusions

This thesis has investigated the role that financial speculation had in rising commodity prices over the years 2004-2023. This has been done by adopting a multi method-approach.

Chapter 2, presented and suggested the challenges and the debates that come with this topic. It gave indications on methods that could be used, as well as suggestions of possible relations between prices and commodities that could be explored and checked.

Chapter 3, by replicating and extending Knittel and Pindyck (2016) econometric model, gave the first evidence of speculation affecting oil prices. Then, by accepting the fact that markets are linked and that oil prices dynamics are easily transmitted to food prices, this evidence also confirmed the fact that speculation in oil markets affects food prices as well.

Chapter 4 continued the research of the "indirect" effects of speculation on food commodities through the oil market by performing linear Granger causality tests. The tests, alongside with the visual assessment of commodity prices' trends and co-movements, suggested a relationship which links oil prices, fertilizer prices and the prices of corn and soybeans. This enforced the argument that any (speculative) position taken in the oil market has an (harmful) effect also on other markets, especially food markets.

Chapter 5 examined the "direct" effect of speculation on food prices by analyzing the speculative activities within the futures markets of corn and soybeans. Specifically, by quantitatively defining speculation and excessive speculation through indexes and proxies, the section performed Granger causality tests between such indicators and the prices (spot, futures and volatility) of corn and soybeans. Even though the evidence was limited to some specific cases and accompanied by all the limitations of the model itself, it could still be concluded that speculation cannot be completely excluded from the factors affecting prices' dynamics. The reason why just some evidence is found has probably to do with the fact that by considering, observing and assessing just the internal dynamics of a specific commodity futures market, we miss all the great contribution of financial speculation that comes from other markets (as proved in the previous chapters) and through different channels and dynamics. As also said by Jenifer Clapp, «the speculative fervor on commodity futures markets it's only one piece of the bigger picture of what's going on».

Chapter 6 gave insightful points of view and suggested some additional critical issues for what concerns the topic of financial speculation and, more in general, financial trading in commodities. Furthermore, some of the arguments made and considerations raised throughout the thesis have also been found in the experts' claims and stands. The fact that the interviewees came from different research traditions and studies, provided us with information and opinions that were coming from different fields and levels of analysis: the interviewees themselves, as a group, represented a valuable sample to develop a multi-view framework of the phenomenon.

7.1 Final considerations and recommendations on employed methods

As a first consideration, the findings that so far emerged provide additional ground to claim that a multi-method, multi-view approach has to be promoted and employed to correctly analyze the topic of speculation in food commodities.

Chapter 2, the literature review, has been fundamental to acquire the proper knowledge concerning commodity futures markets and its dynamics. The review showed that, in order to capture the nature of the discussion and understand the reason why the debate is still open, several aspects should be considered: how is "speculation" defined and identified? What are the assumptions made on the market? Are the theoretical frameworks and the methods applied reasonable and reliable? The literature review taught me to be both critical and precise in the processes of analysis. I learned about the challenges that come with the identification of speculative activities, as well as the concurrent opportunities and drawbacks that such activities bring to the markets. In turn, this prepared me for the next chapters of the thesis: it made me conscious about the limitations that I might encounter by applying a specific model or making a specific assumption.

In Chapter 3, the econometric model of Knittel and Pindyck (2016) has been replicated and extended. As a first step, the model has been thoroughly studied and assessed. Then, the validity of the empirical framework provided by the authors (over which the model has been constructed) has been assessed and re-adapted in line with the current socio-political and market situation. To do so, some updated assumptions on price elasticities had to be made, as well as on other variables that appeared in the model. By working in first person with models and dataset, I learned that the outcome of the results largely depends on such assumptions, as well as on some statistical practices such as the deseasonalization method selected, and that even small changes in such elements can cause results to vary significantly. Therefore, when applying statistical models or making claims based on models' outcomes, I always recommend being as much realistic as possible with the assumptions made, and in any case always stating the importance of such assumptions over the models' results.

In Chapter 4 and Chapter 5 I made a good use of descriptive statistics, visual inspections, and linear Granger causality tests. As a final consideration, I think that these practices have an "ancillary role" within the whole analysis of the phenomenon of commodity price speculation. Therefore, I recommend using them as additional evidence (or counterfactuals) of claims and conjectures that have already been suggested by the assessment of the broader market context, history, and dynamics.
Statistical tests should not be the starting point for developing a claim, rather, I recommend contextualizing and weighting the results based on a socio-economical and market knowledge - which can be acquired by deeply investigating the phenomenon from different perspectives and sources (a literature review is an appropriate way to do it).
On top of that, it is also important to develop a general common sense on how and why price dynamics work in a particular way. Again, statistical tests cannot help in this respect, while a thorough literature review – or, in general, a market investigation – can provide precious information. For example, it has been found that prices Granger-cause open interest: this is totally reasonable if we think about the fact that we are dealing with a phenomenon which considers rational human beings; indeed, changes in prices will affect investors' expectations, who will act accordingly by increasing or decreasing their positions, thus causing changes in the total open interest registered in the market.

I learned that statistical results cannot be taken as stand-alone evidence: they must be contextualized and positioned in a proper theoretical framework. This theoretical framework, in turn, also needs to be justified and explained as much as possible – and this is what I tried to do by building and employing the knowledge acquired throughout the literature review and the subsequent chapters. Without a proper understanding of the market actors, the main dynamics, the historical events, and the socio-political context, it is not possible to assess the validity and reliability of the statistical results.

Finally, by employing statistical tests, I became aware about the limitations of the specific model applied (linear Granger causality tests), as well as of statistical tests in general.
First, as numerical practices necessarily bring their own limitations for what concerns approximations and assumptions, I recommend to always discuss the extent to which these "noises" can be neglected. This is also strongly connected to the quality and availability of data. With respect to commodity prices, average monthly prices have been used, as they were the only ones freely available. For traders' positions, the weekly data provided by the CFTC reports have been transformed into monthly data (to be consistent with the prices' time series). These data cleaning actions and adaptations necessarily brought some additional approximations. For further research, it might be relevant to investigate the same dynamics by using data with higher frequency (for example, daily data), and see whether results change significantly.
Second, the limitations behind the way in which the CFTC classifies and distinguishes types of traders is necessarily not precise, therefore, I also recommend using these datasets wisely.
Third, as with the replicated model of Chapter 3, assumptions cover an important role also with respect to linear Granger causality tests. Specifically, I learned that the choice of the lag length is

crucial for the result. Therefore, I recommend always trying more than one lag length, relying on more than one method to choose the proper lag, and weighting the conclusions accordingly.
Fourth, there are also some limitations related to linear Granger causality test itself: for instance, it can capture just a specific (linear) type of relationship, and it does so by considering the first differences of the time series. For this reason, linear Granger causality tests are blind with respect to non-linear or multiple relationships. Therefore, further research on this field could be done by employing non-linear, parametric Granger causality tests: in this way, more complex and relationships would eventually be identified.

7.2 Is finance socially efficient?

At this point, what can be said about the *social efficiency* of finance? The research of this thesis as well as the insights obtained from the interviews lead us to the conclusion that finance is far from being socially efficient.

When the financial sector was only opened to wealthy investors, big companies, hedge funds and big banks, we were experiencing rich people becoming more rich, and medium/low-income people not only being excluded from this possibility, but also being harmed by the food price changes.
Now that the financial sector is reaching a larger share of the population, we see small retail traders making money, but also extremely harmful losses. Furthermore, the medium- and low- wealth part of the population, even if and when they enter financial markets, still do not experience returns comparable to the ones made by the wealthiest population, since their investment capital comes from a smaller money basket, and they usually have a bigger risk aversion (most of them invest their savings).

In both scenarios, however, we still have a huge amount of people, producers (small farmers), or even entire countries, which are excluded from these financial markets but still are s affected by the pressure that speculative financial activities put on food prices. As said by Tomaso Ferrando, «finance has created a sort of ordering force, a very unequal distribution of power between the actors», and he reported a situation he experienced in which coffee producers were making big losses because coffee traders were not buying the physical commodity, instead, they were just hedging on that commodity in the financial market. The coffee futures markets enabled the traders to create a sort of «financial neutrality» under which they were making profits, while producers struggled.

Financialization has brought unequal benefits to the society. As a result, what we have is a different income growth within the population, in which the top 1% wealth population manages to profit and capitalize way more than others through the financial sector. Is that socially efficient? Is that fair?

Personally, I would say that is arguably fair to have a system such as the financial one which gives unequal opportunities to people to make more money out of it. However, that is how the financial system itself works: someone wins and someone loses and, as in any "betting" game, if you risk more, you have higher potential profits. Thereby, even if I find the financial system unfair because it allows rich people to become richer while poor people are left with either no access or limited possibilities to profit from it, this is how the system is designed.

Having said this, I believe that the financial system becomes definitely unfair and unacceptable when the profits and trading activities of the super-rich translate in bigger losses and hunger of the rest of the population. This is what precisely happens when finance enters commodity markets: wealthy people become richer by gambling on food, thus causing a general increase food price, and poor people – who already start from a weaker point, since they are not able to access the financial market or get the same benefits from it – are harmed and left in starvation.

With the financialization of commodities, it is no longer possible to talk about "own responsibility" to participate in the market, take the risk, and accept profits and losses. In this framework, anyone who is betting is not only determining his own future profits or losses, but is also responsible for affecting prices and increasing uncertainty. By doing so, he is also harming the ones who cannot participate in these bets, but are still deeply dependent on having food commodities at accessible prices.

The fact that the markets are so interconnected and linked led the financialization of food commodities to quickly become a massive problem with fast and very negative consequences on a great part of the world population. That is the reason why, if speculation has to be limited, we should start from food.

Ho to do so? Within the whole thesis, two crucial points have emerged. First, distinguishing speculative practices form hedging practices - and similarly, hedgers from speculators - is far from being easy. Second, all financial investors, by just entering the market and taking a position in it, affect prices: this is at the basis of the process of (futures) price formation.

Problems start to arise when this price formation gets distorted, when it becomes more and more unrelated to real supply and demand factors, and when the price information presents noises. Such phenomenon happens when too much financial pressure is put on prices, that is, when there is an *excessive* level of investments and positions in commodity futures markets. We identify such excess as *excessive speculation*.

We could try - and it has been tried - to measure excessive speculation through indexes, such as the Working (1960) T index; we could try to provide statistical evidences on its effect on prices through Granger causality tests; however, we could - and we should - also just take a step back and look at the broader picture of these financial markets getting more and more rooted in the commodity sphere. By doing so, we will still have enough information to observe, claim and prove that today's commodity markets are much more liquid than what is needed for them to function. The reason is that, due to new financial investment tools and weakened regulations, too many unnecessary, uninterested, inexpert traders entered the market and started trading on commodities for which they had no real interest. They brought and flushed those markets with liquidity, thus increasing volatility and spreading uncertainty.

A volatile, liquid and unpredictable framework obviously attracts more and more risk-taking, profit-seeking traders, who see these volatile prices as means for "profitable bets": after all, it is *rational* that these inventors - speculators - will try to take some advantage and make a profit out of it, if they see the chance to do so. That is totally reasonable. The problem with these market actors is that they follow their own *rationality*, which is based on bets and forecasts on price trends, media's communications, political shocks, and so on. Their investment positions and decisions have therefore little to do with real demand and supply factors, and ultimately have nothing to do with the specific commodity traded. However, their "passive", "uninterested" role within the commodity futures markets has a rather real, damaging consequence on prices. It has been seen in the past crisis and it is can also be seen now: if volatile prices might sound interesting to speculators, they are instead the threat and fear of producers and consumers, who would rather wish to have stable and accessible food prices.

This is why the participation of investors in commodity financial markets should be somehow limited or contained. For commodity markets to function, there is no need for these large numbers of market actors, big financial firms, banks, and funds. The next section provides some policy recommendations that could be implemented to cope with some of the aforementioned problems.

7.3 Policy recommendations

The literature review and the interviews performed showed some of the policy recommendations that have been suggested by scholars and policy makers. What emerged is that these policy actions aim at reducing excessive speculation, i.e., that part of commodity trading which is not beneficial to market liquidity and price formation, but is instead increasing volatility.

In my opinion, excessive speculation could be reduced by policies tackling both trading and market structure.

Reducing excessive speculation at the trader level means identifying and limiting those trading practices which bring no additional benefits to the market, and which would not affect market liquidity if they were to be eliminated. This can be done through several policy actions. First, position limits should be set and based on real supply and demand conditions of the commodity: in this way, futures prices would start to get closer again to what fundamentals suggest. Second, the 'appropriateness rules' applied on financial instruments should be strengthened, allowing only players of the food system to participate in these markets. Thereby, in line with what was said by Jayati Ghosh, I think that position limits based on the traders' commodity (real) interest could cut off a great part of destabilizing liquidity brough into commodity markets. In this framework, all food commodities should be taken out of indexes, so that pure financial investors would eventually limit the volumes of their commodity investments.

Reducing excessive speculation at market level implies revolutionizing the food system in a way that leaves no space for speculative activities. In line with what has been explained by Tomaso Ferrando, I believe that a rights-based food system will drastically reduce unnecessary, harmful, uninterested commodity trading, thus bringing benefits to the food market and ultimately to consumers. However, a rights-based food system requires finance to be deeply re-dimensioned and limited. Therefore, even though such a structure will be able to stabilize and normalize prices, it would be very difficult to implement. In my view, the financialization process cannot be reverted, and finance cannot be taken out from food commodities: todays' markets are way too interlinked, financial practices are too rooted into food producers and consumers as well. In summary, while changing the food system and moving to another paradigm is not a viable option, we can still *improve* the system now in place, and move it into a direction which still sees finance playing a prominent role, but in which abuses are limited, tackled, and reduced.

These two levels of action both require as a starting point a much more transparent market. Market transparency is the basis for a proper, tailored, game-changing, enactment of policy actions. By market transparency I mean that traders' positions should be disclosed and tracked more accurately, and traders' interests should be carefully assessed. Market actors such as big producers should be clear about the (real) availability of supplies, and about their intentions when trading huge volumes of futures. Price uncertainty should be limited, and this could be done if supply and demand levels were transparently available and accessible. Financial innovations should be carefully monitored and regulated as well: to avoid abuses, stricter limits should be set on commodity trading through brokerage apps, and there should be an open communication and data sharing between the different platforms. In this way, investors will no longer be able to spread their investment among such brokerage platforms and undercut some of the position limits.

A (more) transparent market, in which tailored and stricter regulations are properly set, will then leave no space for media to condition people's expectations and spread panic: food companies will no longer be able to take advantage of the panic and raise food prices, and traders will find less attractive to invest in commodities as "everyone knows what the true story is". Additionally, a market in which transparency is fostered and information is shared, will automatically have a smaller price volatility, thus making it less attractive to speculators.

Appendix A Table of methods and analyses of relevant literature

Author	Test	Indicators for speculation	Other factors analyzed	Commodity	Target variable of the commodity	Data
(Alquist & Gervais, 2013)	Granger causality test	Working's T-index; Open interest; Volume of futures contracts; Open positions; Change in commercial / non-commercial net positions	Real interest rates; demand for oil	Oil	(log) spot prices; (log) future prices; spreads = the future-spot spread	CFTC's weekly Commitments of Trader; International Energy Agency; New York Mercantile Exchange; CFTC's COT and DCOT reports
(Irwin & Sanders, 2010)	Cross-sectional regression test; Time-series tests (Granger causality test and long-horizon regression test)	COT report; DCOT report; SCOT report; IID report. Favorite: IID report. For Granger tests: growth in positions held by the USO and UNG exchange-traded funds (ETFs)		Crude Oil; Natural Gas	Futures returns	CFTC's COT, SCOT and DCOT, IID reports
(Algieri, 2012)	Granger causality test	Proxy indicators for financial speculation: the share of total open interest positions held by non-commercials; the speculative pressure. Proxy indicator for excessive speculation: Working's ESPI index		S&P GSCI commodity index; Maize; Rice; Soybean; Wheat	Historical volatility, obtained from the standard deviation of the logarithmic change in daily or monthly prices. Conditional volatility, obtained through the GARCH(1,1) model.	CFTC's COT report; Commodities and Special Issues Division of the IMF's Research Department, with assistance from the World Bank, UNCTAD, and national sources.
(Robles et al., 2009)	Granger causality test	1. Monthly volume of futures contracts; 2. Monthly open interest of futures contracts; 3. Ratio of volume to open interest (1)/(2) (futures contracts); 4. Ratio of non-commercial positions to total reportable positions (long); 5. Ratio of noncommercial positions to total reportable positions (short); 6. Index traders' net positions (long – short positions)		Wheat; Maize; Soybeans; Rice	(log) Spot prices	Trading activities in the Chicago Board of Trade (CBOT); Food and Agriculture Organization of the United Nations (FAO)
(Hernandez et al., 2010)	Linear (and rolling) and nonlinear (nonparametric) Granger causality test between spot and futures prices.			Corn; Wheat; Soft wheat; Soybeans; Hard wheat	Futures and spot returns; Volatility of spot and futures returns	Food and Agriculture Organization of the United Nations (FAO) International Commodity Prices Database (for spot data); Dataset of the Chicago Mercantile Exchange Group (CME DataMine) and the futures database of the Commodity Research Bureau (CRB Infotech CD) (for futures data)
(Cooke & Robles, 2009)	Granger causality tests	Volume in futures contracts; Open interest; Volume to Open interest ratio; Noncommercial to total trade ratio (=positions in futures contracts by noncomemrcial traders)	Ethanol production; Biodiesel production; Fertilizer prices; Exchange rate; Worldwide real M2; Grains Exports	Corn; Wheat; Soybean; Rice; Oil	(log) spot prices	FAO International Commodity Price Database; Energy Information Administration; USDA & World Bank Commodity Price Database; Federal Reserve Bank of St. Louis Economic Database; IMF's IFS Database; US Census Bureau's Foreign Trade Division, Eurostat Comex, AliceWeb, CanSim, Bank of Thailand, Argentina Secretary of Agriculture; Chicago Board of Trade (CBOT); U.S. Commodity Futures Trading Commission

Author	Test	Indicators for speculation	Other factors analyzed	Commodity	Target variable of the commodity	Data
(Andreasson et al., 2016)	Linear and nonlinear Granger causality test	Working's T-index	Exchange rate (FRED trade-weighted US dollar index for major currencies); stock market dynamics (S&P 500 composite index); implied volatility for the US equity market (CBOE Volatility Index); economic policy uncertainty (US economic policy uncertainty index)	Oil; gas; copper; gold; platinum; silver; cocoa; coffee; corn; cotton; oats; soybeans; wheat	Futures returns	Data for commodity futures prices from Datastream International; Data on speculation from the US CFTC; Data of S&P 500 and the CBOE Volatility index (VIX) from Datastream International; Trade Weight- ed US Dollar Index against seven major traded currencies from the Federal Reserve Economic Data (FRED); US Economic Policy Uncertainty Index, measured by capturing and quantifying newspapers coverage on economic policy, uncertainty on future tax codes and disagreement among economic forecasters.
(Irwin et al., 2009)	Standard Granger causality test	Position changes in commodity futures markets		Wheat; Corn; Soybeans; Soybean oil; Soybean meal; Lean hogs; Live cattle; Feeder cattle	Futures prices (returns) changes	CFTC's COT report

Appendix B Literature Table

The literature review table made for summing up the main findings of all the relevant papers is presented below. For space reasons, the table has been divided in separate tables. Tables 28 and 29 report the author(s), the method applied, the time period considered in the analysis, the commodity selected, the main target and variables of the analysis, and the "yes/no" answer, with the meaning explained in Section 2.3. Tables 30, 31, 32, 33, 34 and 35 report the author(s) together with the main claims, conclusions, and policy recommendations found in the article(s). Most of the sentences reported in the second set of tables are literal information copied from the articles.

Authors	Method	Time period	Commodity market	Prices/target/variables	Does financial speculation affect commodity prices?
(Ghosh, 2010)	Empirical analysis	2007-2008	Multiple	Spot prices	yes
(de Schutter, 2010)	Empirical analysis	2007-2008	Basic food commodities	Volatility of prices. Analysis of spot price commodity index	yes
(IPES-Food, 2022)	Evidences from reports and capital influxes / investors movements in the futures markets	2021-2022	Basic food commodities	Price increases and volatility	yes
(Lagi et al., 2011)	Dynamic model	2004-2011	Multiple	Spot prices	yes
(Bos & van der Molen, 2012)	Non-parametric model	1989 - 2008	Coffee	Impact of futures speculation on spot commodity prices	no
(Masters & White, 2008)	Theoretical model	1990-2010	Multiple	Spot and future prices	yes
(Knittel & Pindyck, 2016)	Simple model of supply and demand	1989-2008	Oil	Spot prices	no
(Tang & Xiong, 2012)	Regression analysis (empirical pattern of greatly increased price co-movements between various commodities)	1998-2011	Multiple	Spot prices	yes
(Ameur et al., 2022)	Nonlinear autoregressive distributed lag (NARDL) framework that considers the asymmetry and nonlinearity in both the long and short run.	2002-2020	Multiple	Spot and future prices	yes
(Robles et al., 2009)	Granger causality test with monthly spot prices	2002-2008	Agricultural commodity markets	Spot prices	no
(Von Witzke & Noleppa, 2011)	Empirical analysis based on a decomposition analysis of isoelastic supply and demand functions.	1950-2010	Wheat, corn and soybeans	Monthly spot prices	no
(Algieri, 2012)	Two batteries of Granger causality tests	1995- 2012	Multiple	Spot prices	yes
(Kim, 2015)	Cross-sectional analysis	1992-2012	Multiple	Daily spot prices, spot price volatility, market quality	no
(Dimpfl et al., 2017)	Cost-of-carry model and the variance decomposition idea of Hasbrouck (1995); cointegration tests and VECM	1992-2013	Major seasonal and non-seasonal agricultural commodities	Relationship between future and spot prices	no
(Andreasson et al., 2016)	Linear (Granger) causality tests and nonlinear causality tests (Diks and Panchenko (2005, 2006) non-parametric causality test); VAR/VECM modeling; GJR-GARCH model	1990-2014	Multiple	Futures prices and the potential drivers: Working's T-Index; FRED trade-weighted US dollar index; S&P 500 index; US economic policy uncertainty index; CBOE Volatility Index.	no
(Wimmer et al., 2021)	Meta-granger analysis	\	\	2106 manually collected p-values from Granger causality (GC) tests reported in 54 prior studies	no
(Borgards & Czudaj, 2022)	Dynamic model	2006-2020	Multiple	Open interest of futures as a proxy for sentiment; spot prices; long/short futures contracts; commodity's log returns in long, short or neutral sentiment periods	no
(Adämmer & Bohl, 2015)	Momentum threshold autoregressive (MTAR) approach; Augmented Dickey–Fuller (ADF) test and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test.	1993-2002 and 2003-2012	Corn, soybean and wheat; real crude oil prices and real exchange rates	Monthly observations of spot prices	Depends on the commodity

Table 28: Literature review table: "yes / no"

Authors	**Method**	**Time period**	**Commodity market**	**Prices/target/variables**	**Does financial speculation affect commodity prices?**
(Alquist & Gervais, 2013)	Bivariate Granger causality tests	1993-2012 and also two subsamples (2003M1-2008M6 and 2003M1-2010M12).	Oil	Spot and futures prices	no
(Gilbert, 2010)	Simple econometric methods (Granger non-causality tests); Autoregressive Distributed Lag (ADL) model	1972-74; 2005-08	Multiple	Spot prices	Only for a short period of time; the major foucs should be on index investors.
(Aulerich et al., 2014)	Bivariate Granger causality tests; seemingly unrelated regression (SUR) is used to estimate lead-lag dynamics	2000-2009	12 agricultural futures markets	Non-public daily data from the Large Trader Reporting System (LTRS) maintained by the U.S. Commodity Futures Trading Commission (CFTC); futures prices	little impact on futures prices, and somehow beneficial in the long run
(Fattouh et al., 2013)	Empirical analysis, literature review	\	Oil	Literature	yes / no
(Kilian & Murphy, 2014)	Structural vector autoregressive (VAR) model; structural regression model	2003-2008	Oil	Spot prices; inventories level; short-run price elasticity of oil demand; "4 shocks"	no
(Irwin & Sanders, 2012)	Cross-sectional regression framework vs time-series tests; Fama–MacBeth tests; Granger causality and long-horizon regression tests	2006-2011	Multiple	Spot prices, index investments	no
(Irwin & Sanders, 2010)	Granger causality tests; Working's speculative T-Index	2006-2009	Multiple	Price volatility	not responsible for price volatility
(Sanders et al., 2010)	Working's T analysis	1954-2008	Multiple	Weekly spot prices	not responsible for price increases
(Irwin et al., 2009)	Literature review; empirical tests: Granger causality tests.	2006-2008	Multiple	Index investments; spot prices	no
(Sanders & Irwin, 2010)	Literature review; empirical tests: Granger causality tests.	2006-2008	Multiple	Long-only index funds	no
(Brunetti et al., 2016)	4 measures of daily realized volatility measures (calculated from datasets); Granger causality tests	2005-2009	Multiple	Daily spot price changes and volatility	no
(Brunetti & Buyuksahin, 2009)	Simple multivariate framework, realized volatility, Granger-causality tests	2005-2009	Multiple	Daily prices and volatility in futures markets	they reduce price volatility
(Hamilton, 2009)	Empirical research	1968-2012	Oil	Spot prices	no
(Hamilton & Wu, 2015)	A simple model in which an increased volume of buy orders could affect futures prices by changing the equilibrium risk premium. The model is used to measure the impact of index-fund investing on commodity futures prices.	2006-2009	12 commodities covered by the Supplemental Commitment of Traders and Oil	Daily futures prices (relation between the notional value of commodity futures contracts held on behalf of index-fund investors and expected returns on futures contracts)	no
(Juvenal & Petrella, 2015)	Static economic model	2006-2008	Oil	Spot prices, 4 shocks from Kilian & Murphy + additional shocks	yes, but small role
(Singleton, 2014)	Model framework that accommodates risk aversion and heterogeneity among market participants. Adapted models.	2006-2010	Oil	CIT traders, weekly and monthly futures prices	yes
(Smith, 2009)	Theoretical model	1973-2008	Oil	Spot and futures prices	no
(Clapp & Isakson, 2018a)	Theoretical model / literature review	\	Agricultural markets	Spot prices	yes
(Martin & Clapp, 2015)	Theoretical model / literature review	\	Agricultural markets	Spot prices	yes
(Clapp, 2014)	Theoretical model / literature review	\	Agricultural markets	Spot prices	yes
(Clapp & Isakson, 2018b)	Theoretical model	2007-2008	Agricultural markets	Spot prices	yes
(Tilton et al., 2011)	Conceptual examination of the key mechanisms in spot and futures markets	\	Commodity markets	Spot and futures prices	yes
(Gulley & Tilton, 2014)	Empirical test	1994–2011	Copper	Spot and futures prices	yes

Table 29: Literature review table: "yes / no" ctd.

Authors	Role of speculation / Claim	Policy recommendations
(Ghosh, 2010)	"The dramatic rise and fall of world food prices in 2007-08 was largely a result of speculative activity in global commodity markets, enabled by financial deregulation measures in the US and elsewhere" (Ghosh, 2010). "International commodity markets increasingly began to develop many of the features of financial markets, in that they became prone to information asymmetries" (Ghosh, 2010, p. 10).	"Effective state intervention for food price stability and food security requires fiscal resources" (Ghosh, 2010, p. 20)..
(de Schutter, 2010)	"A significant portion of the increases in price and volatility of essential food commodities can only be explained by the emergence of a speculative bubble" (de Schutter, 2010, p. 1).	"States should ensure that dealing with food commodity derivatives is restricted as far as possible to qualified and knowledgeable investors who deal with such instruments on the basis of expectations regarding market fundamentals, rather than mainly or only by speculative motives" (de Schutter, 2010, p. 1).
(IPES-Food, 2022)	"Commodity speculation as key factor in turning the current shocks into a full-blown food price crisis; price shocks are clearly being exacerbated by commodity speculation" (IPES-Food, 2022, p. 2).	"Provide financial assistance and debt relief to vulnerable countries; Crack down on commodity speculation; Build regional grain reserves and a global food aid apparatus fit for the protracted crises we face; Diversify food production and trade systems; Rebuild resilience and cut harmful dependencies through diversity and agroecology" (IPES-Food, 2022).
(Lagi et al., 2011)	"The dominant causes of price increases are investor speculation and ethanol conversion" (Lagi et al., 2011, p. 1).	"Both causes of price increase, speculative investment and ethanol conversion, are promoted by recent regulatory changes—deregulation of the commodity markets, and policies promoting the conversion of corn to ethanol. Rapid action is needed to reduce the impacts of the price increases on global hunger" (Lagi et al., 2011, p. 1).
(Bos & van der Molen, 2012)	"Speculation is not the most important factor that explains prices" (Bos & van der Molen, 2012, p. 1). The effect of speculation on the coffee price is spiky.	
(Masters & White, 2008)	"The Master's hypothesis": "Traditional Speculators were not completely banned from the commodities futures markets was because they provide beneficial liquidity to the markets" (Masters & White, 2008, p. 10). "Index Speculators lean only in one direction - long - and they lean with all their weight. The result is that they push prices in only one direction - up" (Masters & White, 2008, p. 11). "Index speculators damage the price discovery function" (Masters & White, 2008, p. 11) and because of them future prices of different commodities become correlated.	"To repair the damage to the price discovery function and to bring food and energy prices down to levels that more accurately reflect supply and demand, Congress should take action to undo the changes made to speculative position limits. "[...] 1. Re-Establish Federal Speculative Position Limits for All Speculators in All Commodities in All Markets; 2. Define Excessive Speculation Numerically; 3. Eliminate (or Severely Restrict) Index Speculation (Masters & White, 2008)."
(Knittel & Pindyck, 2016)	"Speculation had little, if any, effect on oil prices" (Knittel & Pindyck, 2016, p. 85).	
(Tang & Xiong, 2012)	"As a result of the financialization process, the price of an individual commodity is no longer determined solely by its supply and demand. Instead, prices are also determined by the aggregate risk appetite for financial assets and the investment behaviour of diversified commodity index investors" (Tang & Xiong, 2012, p. 72).	(from the trade-off): policy makers need to be cautious about imposing constraints on commodity index investment because such constraints also limit the potential risk-sharing benefit. For this reason, "simply improving the public's awareness of the increased correlations of commodities with each other and with stocks is likely to slow the rapid growth of commodity index investment and reduce the adverse volatility spill- over effect" (Tang & Xiong, 2012, p. 72).
(Ameur et al., 2022)	"Changes in commodity prices appear first in the futures market, as informed investors and speculators prefer trading on this market that is characterized by low costs and a high-leverage effect. Then, the information is transmitted from the futures to the spot market through arbitrageurs' activity, which explains the nonlinearity of the relationship" (Ameur et al., 2022, p. 171). "Our results highlight bidirectional feedback between both markets, but the lead of the futures market on the spot returns is greater than the contrary. This confirms the leadership of the futures commodity market in the process of price discovery. Changes in commodity prices appear first in futures markets and then the information is transmitted to spot markets through arbitrageurs' trades. This result shows that speculation is an important determinant of commodity prices rather than market fundamentals. The arbitrageurs' activity and transaction costs characterizing the functions of the commodity market explain the nonlinear relationship" (Ameur et al., 2022, p. 187).	
(Robles et al., 2009)	"Speculative activities might have been influential, but the evidence is far from conclusive" (Robles et al., 2009, p. 5). "The results show that speculative activities might have been influential. The analysis also tested the extent to which selected indicators for speculative activity can help forecast spot price movements, producing evidence that some speculation indicators affect current commodity prices of wheat, rice, maize, and soybeans" (Robles et al., 2009, p. 7).	"Appropriate global institutional arrangements for preventing such market failures are missing. [...] The incentives for speculation in food commodities could be reduced by (1) changing regulatory frameworks to limit the volume of speculation versus hedging, (2) making delivery on contracts or portions of contracts compulsory, (3) imposing capital deposit requirements when each futures transaction is made, or all three. A new global institutional arrangement encompassing a "virtual reserve" could be an alternative solution. Each country would commit to supplying funds, if needed, for intervention in the futures market. The innovative concept behind the virtual reserve is the signal that it would give to markets, including speculators. Although its presence alone would likely divert speculators from entering this market, the virtual reserve must be ready to trade grain when necessary. This concept could provide the kind of global collective action that is needed to facilitate well-functioning grain markets and to reduce the harm that can result from excessive price spikes" (Robles et al., 2009).

Table 30: Literature review table: claims and policy recommendations

Authors	Role of speculation / Claim	Policy recommendations
(Von Witzke & Noleppa, 2011)	"Price volatility is all about supply and demand and not caused by speculation" (Von Witzke & Noleppa, 2011, p. 13). "There is no reason to assume that speculation has driven the price spike of 2007-08. In fact, based on monthly data, it is possible to explain the price spike in agricultural commodities in 2007-08 entirely by changes in key supply and demand determining factors" (Von Witzke & Noleppa, 2011, p. 16) especially non-agricultural supply-side variables.	
(Algieri, 2012)	"While speculation and volatility influence reciprocally each other, or tendentially speculation follows price volatility, excessive speculation tends to Granger-cause price volatility, i.e. speculators become shepherds" (Algieri, 2012, p. 28). "It is not speculation that matters for destabilising markets, but excessive speculation" (Algieri, 2012, p. 29).	
(Kim, 2015)	"My analysis finds no evidence that speculators destabilize the commodity spot market. Instead, speculators contribute to lower price volatility, enhanced price efficiency, and better liquidity in the commodity markets. More importantly, I show that speculators either have no effect or stabilize prices during periods of large price movement. My findings suggest speculators have had a significant and in fact positive influence on the commodity market during the recent "financialization" period, implying that restricting speculative trading in the futures market is not an efficient way to stabilize the commodity market" (Kim, 2015, p. 696)	
(Dimpfl et al., 2017)	"There is only very limited impact of the futures market on the permanent price and thus on the spot price of important agricultural commodities. It is predominantly the spot market—governed by supply and demand forces—that determines the efficient price of the agricultural commodities. The contribution of futures markets— and in particular potential futures speculation—to the long-run efficient price is, therefore, rather limited" (Dimpfl et al., 2017, p. 61). "in the short-run, futures prices are decoupled from fundamentals (possibly due to speculation) and therefore have only very little impact on the price discovery" (Dimpfl et al., 2017, p. 61). "The main conclusion from our analysis is that the long-run efficient price of agricultural commodities is determined on the spot market. This result deviates to some extend from prior findings which generally identify a dominant role of the futures market in price discovery" (Dimpfl et al., 2017, p. 61). "Our findings can be interpreted as support for the conclusions that futures speculation is not a key factor in determining commodity prices as the futures markets contribute little to the efficient commodity price. Ultimately, supply and demand forces determine the efficient price of the good, influenced by rain, drought, or population growth. In the short-run, however, price distortions which might be caused by speculation in the futures market, are possible" (Dimpfl et al., 2017, p. 61).	
(Andreasson et al., 2016)	"We find evidence of unidirectional linear and non-linear causality links from commodities to excess speculation in the majority of the considered commodities" (Andreasson et al., 2016, p. 126). "This is true for all commodity classes, which may well serve as evidence against claims that speculation drives food prices. The investigation of nonlinear causality reveals a strong lead dependence from cocoa and coffee to speculation indices" (Andreasson et al., 2016, p. 126). "It would have been expected that as speculators forecast that the prices of the underlying commodities will go up, they act on that and buy more commodity futures contracts, probably even creating market bubbles. Interestingly, what emerged from our empirical investigation is that commodity futures' speculators will not speculate if they anticipate the reserve situation because price declines do not attract much new agents with opposite price predictions, namely volatility is much greater when prices are on the upward side than on the down side. Therefore, speculation could be one of the reasons for volatility asymmetry" (Andreasson et al., 2016, p. 127).	
(Wimmer et al., 2021)	"Our results indicate that studies published in higher ranked journals present significantly less evidence for speculation to drive commodity prices" (Wimmer et al., 2021, p. 1). "The results reveal that the hypothesis of Granger non-causality between speculation and commodity prices cannot be rejected at standard significance levels when assuming a best choice study design and various variations of it. We conclude that either there is no genuine overall speculation effect in agricultural, energy and metal markets, or the research design of the frequently applied GC testing is not powerful enough to detect those effects" (Wimmer et al., 2021, p. 1).	
(Borgards & Czudaj, 2022)	"We dynamically model the equidirectional trading of long and short commodity futures of long-short speculators as a proxy for their market sentiment. We find evidence that the sentiment period returns are considerably positive and differ significantly from neutral sentiment periods for all commodities, which underlines the sentiment's relevance. In line with the empirical literature, we can reject the argument of price manipulation as the price continues to develop into the direction of the sentiment period although long-short speculators trade non-directionally in the following" (Borgards & Czudaj, 2022, p. 1). "We clearly reject the argument of manipulating commodity prices, we conclude that long-short speculators ethical correctly invest in agricultural commodities, representing the most essential food resources of our planet" (Borgards & Czudaj, 2022, p. 17).	"Since long-short speculators aim to enter directional trades based on their information, their sentiment serves as an observable proxy for the value of their information" (Borgards & Czudaj, 2022, p. 17). "We would suggest to concentrate more on the behaviour of long-short speculators as they represent the trader group of the CFTC reports that probably have the clearest investment intentions" (Borgards & Czudaj, 2022, p. 17).

Table 31: Literature review table: claims and policy recommendations ctd.

Authors	**Role of speculation / Claim**	**Policy recommendations**
(Adämmer & Bohl, 2015)	"Our empirical results support the hypothesis that speculative bubbles are present in wheat prices between 2003 and 2013. For corn and soybeans, however, our empirical results are inconclusive" (Adämmer & Bohl, 2015, p. 67). "For corn and soybeans our findings are unable to confirm previous results since we do not find a robust long-run relation between agricultural prices and fundamentals" (Adämmer & Bohl, 2015, p. 75).	"The investigation of speculative bubbles in agricultural commodity markets is, compared to equity markets, still underdeveloped in the economic literature. The recent price turmoils have increased the interest in this subject, considering the appearances of empirical papers. One of the major challenges remaining is the determination of fundamental impact factors on commodity prices. Future research should focus on alternative models to determine intrinsic values of commodity prices, while different testing strategies can be used to shed further light on this relatively new subject" (Adämmer & Bohl, 2015, p. 75).
(Alquist & Gervais, 2013)	"The T-index remained high even after the price of oil collapsed in late 2008, indicating that there was no substantial change in speculative pressure during that period"" (Alquist & Gervais, 2013, p. 42). "The ability to hold oil inventories links the spot and futures markets, and this link implies that the effect of financial speculation, if any, should be reflected in the physical market of oil" (Alquist & Gervais, 2013, p. 44). "however, non-commercial net open interest did not lead the futures-spot spread" (Alquist & Gervais, 2013, p. 44). " [...] Macroeconomic fundamentals (real interest rates and global demand conditions), and not financial speculation, can explain the 2003-08 increase in the price of oil. Financial speculation seems to have played a modest role at best. Our own analysis suggests that there is no evidence to support the view that there is a strong relationship between the positions of speculators and price changes" (Alquist & Gervais, 2013, p. 50).	
(Gilbert, 2010)	"The rise in food prices over 2007 and the first half of 2008 should be seen as part of the wider commodity boom which is largely the result of rapid economic growth in China and throughout Asia in a context of loose money and in which, because of previous low investment, supply was inelastic. The demand for grains and oilseeds as biofuel feedstocks was the main cause of the price rise but macroeconomic and financial factors explain its extent. The futures market may be an important monetary transmission mechanism, but it is commodity investors, not speculators, who, by investing in commodities as an asset class, may have generalized prices rises across markets" (Gilbert, 2010). "[...] Economic growth and changes in the world money supply have played an important role in moving agricultural prices. [...] weaker evidence that the oil price and the level of futures market activity have also been important [...]. Exchange rate changes have not been important" (Gilbert, 2010, p. 3). "[...] There is some evidence for speculative bubbles in agricultural food commodity prices although these probably persist only for short periods of time. However, the major focus should be on commodity investors (i.e., index-based investors), not on speculators. Index based investors may have generalized price increases across markets and increased price correlations across markets, both within the agricultural sector and between agriculture and other sectors" (Gilbert, 2010, p. 29)."	"we need to move beyond market-specific factors and consider macroeconomic and financial factors which operate across large numbers of markets" (Gilbert, 2010).
(Aulerich et al., 2014)	"Buying pressure from financial index investment in recent years did not cause massive bubbles in agricultural futures prices. The Masters Hypothesis is simply not a valid characterization of reality. This is not to say that the large influx of index investment did not have any impact in agricultural futures markets. We find some evidence that index investment may have resulted in a very slight upward pressure on futures prices before expiration and contributed to a small narrowing of price spreads during the period when index investors roll trades across futures contracts. The upward pressure on agricultural futures prices before expiration can be explained as either a temporary order flow impact (Henderson, Pearson, and Wang, 2012) or a re-pricing of risk (Hamilton and Wu, 2012). The narrowing of spreads is likely due to a "sunshine trading effect" (Admati and Pfleiderer, 1991) where the preannouncement of CIT rolling activities coordinates the supply and demand of liquidity and reduces trading costs. [...] index investment may have several long-lasting and beneficial economic impacts, including a decrease in the cost of hedging for traditional physical market participants, a dampening of price volatility, and better integration of agricultural futures markets with financial markets. [...] the results of this study do not rule out the possibility of small and short-lived bubble components in agricultural futures prices which are not associated with commodity index investment" (Aulerich et al., 2014, p. 37).	"The Masters Hypothesis is not valid. First, new limits on speculation in agricultural futures markets are not grounded in well-established empirical findings and could impede the price discovery and risk- shifting functions of these markets. Second, the focus on speculation has wasted precious time, attention, and effort that could be more productively directed towards the multiple challenges that global agriculture will face in the coming decades. The recent effort to put these challenges on the political agenda of international organizations such as the G-20 is an encouraging start (Blas, 2012)" (Aulerich et al., 2014, p. 37).
(Fattouh et al., 2013)	"We find that the existing evidence is not supportive of an important role of speculation in driving the spot price of oil after 2003. Instead, there is strong evidence that the co-movement between spot and futures prices reflects common economic fundamentals rather than the financialization of oil futures markets" (Fattouh et al., 2013, p. 7). "There is no compelling evidence that changes in financial traders' positions predict changes in the price of oil futures. Results are conflicting". [...] "Contrary to widely held beliefs that increases in oil futures prices precede increases in the spot price of oil, there is no evidence that oil futures prices significantly improve the out-of-sample accuracy of forecasts of the spot price of oil". [...] "The simple static model that has been used to explain how an influx of financial investors may cause an increase in the spot price of oil is inconsistent with dynamic models of storage" (Fattouh et al., 2013). [...] "Structural VAR models provide strong evidence of speculation in 1979, 1986, 1990 and late 2002, but are not support of speculation being an important determinant of the real price of oil from 2003 to mid-2008"	"More careful attention to the role of heterogeneous expectations and allowing for limits to arbitrage may help improve theoretical models of oil markets" (Fattouh et al., 2013, p. 30)). [...] "The ostensive aim of recent regulatory changes in oil futures markets is to reduce price volatility, when increased oil price volatility was never the problem, but the persistent increases in the price of oil after 2003. In fact, the literature has shown that the presence of index funds has, if anything, been associated with reduced price volatility. What has been missing in the literature has been a systematic effort to quantify the social welfare costs of speculation. Addressing this concern will require the development of more fully articulated economic models than the current generation of theoretical and empirical models" (Fattouh et al., 2013, p. 30).

Table 32: Literature review table: claims and policy recommendations ctd.

Authors	Role of speculation / Claim	Policy recommendations
(Kilian & Murphy, 2014)	"The estimates of the model show that there were several historical episodes in which speculation moved the real price of oil including 1979, 1986, 1990 and late 2002. However, regard to the surge in the real price of oil between 2003 and mid-2008, the model estimates unambiguously show that there is no evidence to support the notion that this surge was caused by speculation" (Kilian & Murphy, 2014). "The 2003-08 oil price surge was caused by fluctuations in the flow demand for oil driven by the global business cycle (i.e., shifts in the global flow demand for oil). There is evidence, however, that speculative demand shifts played an important role during earlier oil price shock episodes including 1979, 1986, and 1990. [...] even after accounting for the role of inventories in smoothing oil consumption, our estimate of the price elasticity of oil demand is not close to zero and much higher than traditional estimates from dynamic models that do not account for price endogeneity. This eliminates speculation as an explanation of the 2003-08 oil price surge" (Kilian & Murphy, 2014). "[...] On average, fluctuations in oil inventories mainly reflect speculation, but there also is an important element of production smoothing by refiners in response to oil supply shocks. This contrasts with a much larger role of flow demand shocks in explaining the variability of the real price of oil. For example, in the long run, 85% of the variation in the real price of oil can be attributed to flow demand shocks, compared with 9% due to speculative demand shocks and 4% due to flow supply shocks" (Kilian & Murphy, 2014)."	"The run-up in the real price of oil between 2003 and mid-2008 was caused almost entirely by shifts in the global flow demand for oil. This implies that the real price of oil is expected to rise, as the global economy recovers from the financial crisis, creating a policy dilemma, unless energy consumption can be reduced or new energy sources can be found. In contrast, additional regulation of oil traders is unlikely to prevent the price of oil from rising again in the future" (Kilian & Murphy, 2014).
(Irwin & Sanders, 2012)	"Fama–MacBeth tests using the CFTC's quarterly IID find very little evidence that index positions influence returns or volatility in 19 commodity futures markets. Granger causality and long-horizon regression tests also show no causal links between daily returns or volatility in the crude oil and natural gas futures markets and the positions for two large energy exchange-traded index funds. Overall, the empirical results of this study offer no support for the Masters Hypothesis" (Irwin & Sanders, 2012, p. 256)	"The evidence strongly suggests that index funds—while a sizable participant—did not in fact harm price discovery in commodity futures markets. From this vantage point, recent regulatory plans to impose speculative position limits on index fund investors in all U.S. commodity futures markets appear to be ill-conceived" (Irwin & Sanders, 2012, p. 256).
(Irwin & Sanders, 2010)	"While the increased participation of index fund investments in commodity markets represents a significant structural change, this has not generated increased price volatility, implied or realised, in agricultural futures markets. Based on new data and empirical analysis, the study finds that index funds did not cause a bubble in commodity futures prices. There is no statistically significant relationship indicating that changes in index and swap fund positions have increased market volatility. [...] the weight of evidence clearly suggests that increased index fund activity in 2006-08 did not cause a bubble in commodity futures prices" (Irwin & Sanders, 2010, p. 1).	"Lack of convergence between spot and futures prices in certain markets, however, does raise a number of issues about the functioning of these markets and possible role of index funds. Further research is needed to understand better these recent structural changes in futures marks and how they may impact on the dynamics of price formation. [...] limiting the participation of index fund investors could unintentionally deprive commodity futures markets of an important source of liquidity and risk-absorption capacity at times when both are in high demand" (Irwin & Sanders, 2010, p. 1).
(Sanders et al., 2010)	"Traditional speculative measures do not show any material shifts over the sample period. In most markets, the increase in long speculative positions was equaled or surpassed by an increase in short hedging" (Sanders et al., 2010, p. 77). "Working's speculative index suggests that long-only index funds may in fact be beneficial in markets dominated by short hedging pressure. That is, they improve the adequacy of speculation by helping the market to "carry" unbalanced short hedging. The relatively normal level of speculation over the sample period raises some doubt as to whether index funds are behind recent commodity price increases" (Sanders et al., 2010, p. 92).	"Proposals are once again surfacing to curb "harmful" speculation in futures markets. Such policy decisions aimed at curbing speculation may well be counterproductive in terms of price levels or market volatility. In particular, these policy initiatives could severely compromise the ability of futures markets to accommodate hedgers and facilitate the transfer of risk" (Sanders et al., 2010, p. 92).
(Irwin et al., 2009)	"The entry of index funds into commodity futures markets did not disturb a sterile textbook equilibrium of pure risk–avoiding hedgers and pure risk–seeking speculators, but instead the funds entered a dynamic and ever changing 'game' between commercial firms and speculators with various motivations and strategies" (Irwin et al., 2009, p. 380). [...] "There is little evidence that the recent boom and bust in commodity prices was driven by a speculative bubble. If speculation by long–only index funds did impact commodity futures prices, it is not evident in the empirical evidence available to date. Economic fundamentals, as usual, provide a better explanation for the movements in commodity prices. The main factors driving prices up in the energy markets included strong demand from China, India, and other developing nations, a leveling out of crude oil production, a decrease in the responsiveness of consumers to price increases, and U.S. monetary policy (Hamilton, 2008)" (Irwin et al., 2009, p. 388).	"Legislative proposals currently being considered may in fact curtail speculation—through reduced volume of trade—but the initiatives could severely compromise the ability of commodity markets to accommodate the needs of firms to manage price risks. In particular, limiting the participation of index fund investors would rob the markets of an important source of liquidity and risk–bearing capacity at a time when both are in high demand. The net result is that commodity futures markets will become less efficient mechanisms for transferring risk from parties who don't want to bear it to those that do, creating added costs that ultimately get passed back to producers in the form of lower prices and back to consumers as higher prices" (Irwin et al., 2009, p. 389).
(Sanders & Irwin, 2010)	"The results suggest that index fund positions across futures markets have no impact on relative price changes across those markets. The empirical results provide no evidence that long-only index funds impact commodity futures prices" (Sanders & Irwin, 2010, p. 1).	

Table 33: Literature review table: claims and policy recommendations ctd.

Authors	Role of speculation / Claim	Policy recommendations
(Brunetti et al., 2016)	Focus on two kinds of speculators: hedge funds and swap dealers in futures markets. "We find little evidence that speculators destabilize financial markets. To the contrary, hedge funds facilitate price discovery by trading with contemporaneous returns while serving to reduce volatility. Swap dealer activity, however, is largely unrelated to both contemporaneous returns and volatility. Our evidence is consistent with the hypothesis that hedge funds provide valuable liquidity and largely serve to stabilize futures markets. [...] we find that speculative position changes do not amplify volatility during the crisis and so do not impede the functioning of futures markets" (Brunetti et al., 2016, p. iii). "[...] the links between real economic activity and commodity prices remain intact during the recent financial crisis. While economic conditions are significantly linked to commodity price volatility prior to the financial crisis, economic uncertainty drives commodity price volatility after July 2008. These robust connections cast doubt on conjectures that increased "financialization" of commodity markets has altered the dynamics of commodity markets during the recent financial crisis. Rather, during the crisis, position changes and volatility are both driven by macroeconomic uncertainty, and position changes per se do not cause volatility" (Brunetti et al., 2016, p. 20). "[...] Although we do not rule out the possibility that traders might attempt (or actually succeed) to move prices and magnify volatility over short time intervals (such as minutes or hours), we find no evidence of this phenomenon during various months-long run-ups or declines that characterize recent commodity prices. Our tests show that there has been no systematic, deleterious link between the trades of hedge funds or swap dealers and either returns or volatility during recent years" (Brunetti et al., 2016, p. 21).	"The trades of relatively unconstrained traders who primarily process fundamental information can reduce market volatility by taking positions opposite to commercial entities with hedging needs. For policy-makers, these results show that hedge fund participation can benefit financial markets, and they highlight the benign influence of the growing commodity index positions in futures markets. Our results should give pause to those who seek to limit speculative trading based on the observation that positions have been growing" (Brunetti et al., 2016, p. 21).
(Brunetti & Buyuksahin, 2009)	"Speculative trading in futures markets is not destabilizing. In particular, speculative trading activity reduces volatility levels" (Brunetti & Buyuksahin, 2009, p. 1) "We find evidence that swap dealer and hedge fund activities Granger-cause volatility. We, therefore, analyze impulse response functions and find that swap dealer and hedge fund activity reduces volatility" (Brunetti & Buyuksahin, 2009, p. 4) "Therefore, speculators, in general, and hedge funds, in particular, should not be seen as sinful agents. In fact, we find that speculative trading activity has beneficial effect on markets" (Brunetti & Buyuksahin, 2009, p. 23).	
(Hamilton, 2009)	"Whereas previous oil price shocks were primarily caused by physical disruptions of supply, the price run-up of 2007–08 was caused by strong demand confronting stagnating world production" (Hamilton, 2009, p. 215) "it is hard to deny that the price of oil rose too high in July 2008 and that this miscalculation was influenced in part by the flow of investment dollars into commodity futures contracts. It is worth emphasizing, however, that the two key ingredients needed to make such a story coherent—a low price elasticity of demand, and the failure of physical production to increase—are the same key elements of an explanation of the same phenomenon based only on fundamentals. I therefore conclude that these two factors, rather than speculation per se, should be construed as the primary cause of the oil shock of 2007–08" (Hamilton, 2009, p. 240).	
(Hamilton & Wu, 2015)	"Index-fund investing seems to have had little impact on futures prices in these markets" (Hamilton & Wu, 2015, p. 3). There is no relation between "the notional value of commodity futures contracts held on behalf of index-fund investors and expected returns on futures contracts" (Hamilton & Wu, 2015, p. 28). "Our overall conclusion is thus consistent with most of the previous literature - there seems to be little evidence that index-fund investing is exerting a measurable effect on commodity futures prices" (Hamilton & Wu, 2015, p. 29). "Even if one could demonstrate an effect of index-fund buying on commodity futures prices, it would be a separate challenge to explain how this could also end up changing the equilibrium spot price" (Hamilton & Wu, 2015, p. 29).	
(Juvenal & Petrella, 2015)	Global demand has been the main driver of oil prices surge after 2003, explaining about 40 percent of the oil price increase (Juvenal & Petrella, 2015, p. 2). "Speculation was the second-largest contributor to oil prices and accounted for about 15 percent of the rise. The effect that speculation had on oil prices over this period coincides closely with the dramatic rise in commodity index trading" (Juvenal & Petrella, 2015, p. 2). "On balance, the evidence does not support the claim that a sudden explosion in commodity trading tectonically shifted historical precedent: Global demand remained the primary driver of oil prices from 2000 to 2009. That said, one cannot completely dismiss a role for speculation in the run-up of oil prices of the past decade. Speculative demand can and did exacerbate the boom-bust cycle in commodity prices. Ultimately, however, fundamentals continue to account for the long-run trend in oil prices" (Juvenal & Petrella, 2015, p. 2).	
(Singleton, 2014)	"Index-fund buying affect oil futures prices. Growth in positions of index investors and managed-money accounts had significant positive effects on return in oil futures markets around the 2008 boom/bust in oil prices, after accounting for stock returns in the United States and emerging economies, open interest and lagged futures returns" (Singleton, 2014).	

Table 34: Literature review table: claims and policy recommendations ctd.

Authors	Role of speculation / Claim	Policy recommendations
(Smith, 2009)	Futures prices changes do not affect spot prices: "because futures contracts settle for cash, futures trading by hedge funds, commodity index funds, speculators, or anyone else—even if they rush into the futures market with lots of money— does not increase the demand for oil. Because those who trade futures contracts do not take possession or make delivery of crude oil, their trades lack any conduit that could affect the physical market or the spot price" (Smith, 2009, p. 158). [...] "The world oil market operates subject to the familiar laws of supply and demand, and market fundamentals are the dominant influence on price. The market is subject to shocks, and when these shocks are taken together with short-run rigidities and high costs of adjustment, the resulting price volatility is largely inherent, rather than contrived by speculators, cunning producers, or anyone else" (Smith, 2009, p. 162).	
(Martin & Clapp, 2015)	"[. . .] the regulations sought to prevent 'excessive' speculation that might result in market manipulation and sudden sharp price shifts. [. . .] Heightened and excessive speculation in the sector can result in increased volatility in agricultural and land prices" (Martin & Clapp, 2015, p. 553).	
(Clapp, 2014)	"[. . .] the growing role of financial speculation on agricultural commodity futures markets as one of the contributing causes of those price trends" (Clapp, 2014, p. 799). "[. . .] Most analysts agree that there is some link between the recent rise of financial speculation in commodity markets and food price trends. But because distancing has obscured the precise lines of cause and effect, the extent to which financial speculation is viewed as central cause of food price volatility or a marginal force is highly contested. In other words, distancing has fuelled uncertainty about cause, effect and responsibility, giving rise to competing discourses about the issue" (Clapp, 2014, p. 807).	
(Clapp & Isakson, 2018b)	"We conclude with an explanation of how the recent burst of financial speculation on agricultural commodities is linked to growing price volatility in the markets for actual food, including the food price spikes of 2007–08, and describe the uneven social impacts of those price swings" (Clapp & Isakson, 2018b).	
(Tilton et al., 2011)	"[...] prices in futures and spot markets are closely linked when these markets are in strong contango, as is typically the case when spot markets are depressed. In such circumstances, investors play a useful role in financing inventories by buying spot and simultaneously selling futures to take advantage of the arbitrage. The result is an increase in stocks and a reduction in the spread between futures and spot prices. In contrast, when commodity markets are in weak contango or backwardation, spot prices are mostly governed by current rather than future conditions. Changes in futures prices may have some influence on spot prices by altering the convenience demand of consumers for stocks and hence the spot consumer demand curve. However, their influence is much looser than during period of strong contango" (Tilton et al., 2011, p. 194)	"[...]the shortcomings of the available data and the conflicting conclusions reached by the empirical analyses of these data suggest that strong public policies to rein in investor activity are premature. Such policies could well lead to unintended consequences impairing the way markets function, for example, by constraining market liquidity. Rather, strong policy action should be preceded by additional efforts to perfect the available data, to collect additional information on investor activity, and to conduct further empirical work on the influence of investor demand on commodity prices" (Tilton et al., 2011, p. 194).
(Gulley & Tilton, 2014)	"This study provides an empirical test of this hypothesis using daily changes in LME average copper prices over the 1994–2011 period. It finds that the correlation coefficients between day-to-day changes in spot and futures prices are quite close to 1 during periods of strong contango. During periods of backwardation and weak contango, the correlations are positive but lower. These findings provide empirical support for the hypothesis advanced by Tilton et al. (2011) that investor demand on futures markets affects spot and futures prices similarly when the markets are in strong contango but somewhat less so when they are in weak contango or backwardation" (Gulley & Tilton, 2014, p. 109)	

Table 35: Literature review table: claims and policy recommendations ctd.

Appendix C Knittel and Pindyck "Simple Economics"

C.1 Replication of the epoch analysis

Table 36 comes from Knittel and Pindyck's (2016) work. The table reports the results of the epoch analysis the authors performed for four periods, specifically: 2007:1-2008:7, 2009:2-2011:4, 2009:2-2010:4, and 2010:9-2011:4. The change in log price due to speculation ($\Delta \ln P_T^S$) and the change in log convenience yield due to speculation ($\Delta \ln \psi_T^S$) have been calculated according to the formulas:

$$\Delta \ln P_T^S = \frac{1}{\eta_S - \eta_D}(\ln(X_T/Q_T) - \ln(X_0/Q_0))$$

$$\Delta \ln \psi_T^S = \frac{1}{\eta_S - \eta_D}(\ln(X_T/Q_T) - \ln(X_0/Q_0)) - (1/\eta_N)(\ln N_T - \ln N_0)$$

While ψ_0, ψ_T have been calculated following equation 9.

To eliminate the seasonality in demand that shows up in the inventories' data, the authors have de-seasonalized inventories by using a set of 11 dummy variables as regressors and subtracting to the inventories the coefficient associated with the regression model (Knittel & Pindyck, 2016). As a consequence, consumption (Q) is also de-seasonalized by construction.

Table 37 reports the results obtained from the replicated epoch analysis. The aim of this replication is to test the robustness of the authors' model, when changes in dataset and methods are made. The replicated model has collected the datasets of prices, exports, imports, production and inventories from the Energy Information Administration (EIA), with the aim of obtaining a starting dataset which was the same as the one used by the authors. However, when de-seasonalizing inventories, a different approach has been used. Specifically, the de-seasonalization has been done through Python, by calling the following formula:

```
from statsmodels.tsa.seasonal import seasonal_decompose

decomposition = seasonal_decompose(series['Stocks'], model='additive', period=12)
decomposition.seasonal
deseason_stocks = series['Stocks'] - decomposition.seasonal
```

Figure 26: De-seasonalization through Python

The differences between the outcomes of Tables 36 and 37 come precisely from the fact that the de-seasonalization method of Python is different from the one used by the authors. However, these differences are small and do not change the interpretation, especially for what concerns the change in log price due to speculation. For what concerns the change in log convenience yield due to speculation, the differences are more marked (even though the overall analysis and interpretation still lead to the same conclusion). The reason for this is that the formula for the change in log convenience yield due to speculation directly uses the inventories and takes the log difference; by applying the logarithm, even a small variation is amplified. However, since the overall discussion remains the same, it can be concluded that the model is sufficiently robust with respect to the de-seasonalization method selected.

Epoch	(1) 2007:1-2008:7	(2) 2009:2-2011:4	(3) 2009:2-2010:4	(4) 2010:9-2011:4
Beginning price (P_0)	54.51	39.09	39.09	75.24
Ending price (P_T)	133.37	109.53	84.29	109.53
Beginning F3 price (F_0^3)	56.16	45.47	45.47	78.08
Ending F3 price (F_T^3)	134.52	111.01	87.05	111.01
Beginning X (X_0)	582867	484570	484570	521087
Beginning Q (Q_0)	577514	481923	481923	509951
Ending X (X_T)	566539	519262	535992	519262
Ending Q (Q_T)	562038	518881	537916	518881
Change in log price due to speculation (ΔlnP_T^S)	-0.31%	-1.19%	-2.27%	-10.43%
Ending inventories (N_T)	286800	346500	343220	346500
Actual inventory build up over entire epoch (ΔN_T)	-37750	-7490	-10760	-20980
Beginning convenience yield (ψ_0)	3.52	-1.5	-1.5	1.69
Ending convenience yield (ψ_T)	3.89	3.04	1.77	3.04
Change in log conv. yield due to speculation ($\Delta ln\psi_T^S$)	12.05%	0.95%	0.82%	-4.56%

Table 36: Epoch analysis - Knittel and Pindyck's results. From Knittel and Pindyck (2016).

Epoch	(1) 2007:1-2008:7	(2) 2009:2-2011:4	(3) 2009:2-2010:4	(4) 2010:9-2011:4
Beginning price (P_0)	54.51	39.09	39.09	75.24
Ending price (P_T)	133.37	109.53	84.29	109.53
Beginning F3 price (F_0^3)	56.16	45.47	45.47	78.08
Ending F3 price (F_T^3)	134.52	111.01	87.05	111.01
Beginning X (X_0)	582928	484526	484526	521312
Beginning Q (Q_0)	577834.9998	482899.6122	482899.6122	511394.625
Ending X (X_T)	566441	518003	536443	518003
Ending Q (Q_T)	561325.2788	518172.1154	538411.1154	518172.1154
Change in log price due to speculation (ΔlnP_T^S)	0.07426%	-0.92218%	-1.75610%	-9.76679%
Beginning inventories (N_0)	314583.0743	342030.4621	342030.4621	352856.7377
Ending inventories (N_T)	276422.9044	328781.6063	327003.6063	328781.6063
Actual inventory build up over entire epoch (ΔN_T)	-38160.16987	-13248.85577	-15026.85577	-24075.13141
Beginning convenience yield (ψ_0)	3.516331742	-1.850715425	-1.850715425	1.688199143
Beginning convenience yield (ψ_0) truncation (if needed)	3.516331742	1.5	1.5	1.688199143
Ending convenience yield (ψ_T)	3.890191949	3.036425805	1.771590986	3.036425805
Ending convenience yield (ψ_T) truncation (if needed)	3.890191949	3.036425805	1.771590986	3.036425805
Change in log conv. yield due to speculation ($\Delta ln\psi_T^S$)	13.00589%	3.02843%	2.73676%	-2.69995%

Table 37: Epoch analysis - replicated model.

Variable	**Value**
η_S - η_D epochs 1,2,3	0.4
η_S - η_D epoch 4	0.2
η_N	1
k_T	1.5
k_N	1

Table 38: Variables.

Appendix D Some computations and Python commands

D.1 Augmented Dickey–Fuller (ADF) tests, Akaike information criterion (AIC) and Granger causality tests on Python

Figure 27 shows how the Augmented Dickey–Fuller (ADF) tests and linear Granger causality tests have been performed on Python for corn. The Akaike information criterion (AIC) has been selected for defining the number of lags for the Granger causality tests.

```
#ADF test for futures prices
from statsmodels.tsa.stattools import adfuller
adfTest= adfuller(corn["Futures price"], autolag='AIC')
adfTest[1] #pvalue of test

#pvalue is 0.5995548659168248. The time series is non-stationary.
```

```
# new column: compounded return, i.e., the logarithmical changes in consecutive daily prices
corn['Compounded_return_futures'] = np.log(corn['Futures price']/corn['Futures price'].shift(1))
corn['Compounded_return_spot'] = np.log(corn['Spot price']/corn['Spot price'].shift(1))
corn.head()
```

```
#ADF test for compounded return of futures prices
from statsmodels.tsa.stattools import adfuller
adfTest = adfuller(corn["Compounded_return_futures"], autolag='AIC')
adfTest[1] #pvalue of test

#pvalue is 8.499379866167053e-18. The time series is stationary!
```

```
# Define the number of lags: VAR model.
# The VAR class assumes that the passed time series are stationary. Non-stationary or trending data can
# often be transformed to be stationary by first-differencing or some other method.
# There is no hard-and-fast-rule on the choice of lag order. It is basically an empirical issue.
# However, it is often advised to use the AIC in selecting the lag order with the smallest value.

from statsmodels.tsa.api import VAR

model = VAR(corn[['Spot price','Futures price']])
for i in [1,2,3,4,5,6,7,8,9,10,11,12,13,14,15]:
    result = model.fit(i)
    print('Lag Order =', i)
    print('AIC : ', result.aic)

#preferred number of lags: 3
```

```
#perform Granger-Causality test between spot and futures compounded returns
from statsmodels.tsa.stattools import grangercausalitytests
result = grangercausalitytests(corn[['Compounded_return_spot','Compounded_return_futures']].dropna(), maxlag= [3])
#pvalue is 0.0000. Compounded returns of futures prices Granger-cause compounded returns of spot prices.
```

Figure 27: Python commands for preparing and computing Granger-causality tests

D.2 Historical (or realized) volatility: computation

The volatility of futures returns has been computed following the methodology proposed by Algieri (2012) for historical (or realised) volatility, which «involves calculating the historical average variance or standard deviation of log price returns (growth rate)» (Algieri, 2012). Specifically, historical daily data on WTI crude oil futures prices has been collected from investing.com. Through Python, the data have been cleaned, ordered and prepared. Let P_i be the futures price of WTI crude oil on day i. As a first step, the daily (compounded) return for every day i of the data set has been computed as follows:

$$\text{Compounded return on day } i = r_i = \ln \frac{P_i^{day}}{P_{i-1}^{day}} \tag{10}$$

Then, the monthly historical volatility of (compounded) returns - which is, for a generic month, the standard deviation of the daily (compounded) returns of such month - has been computed. Specifically, the dataset on daily compounded returns has been grouped by month, and the standard deviation has been calculated for each month of the dataset. Figure 28 shows the commands executed on Python:

```
# new column: compounded return, i.e., the logarithmical changes in consecutive daily prices
# (= difference in the logged commodity price index)
fut['Compounded_return'] = np.log(fut['Futures price']/fut['Futures price'].shift(-1))

# take variance values for every month
volat_oil = fut.groupby(pd.PeriodIndex(fut['Date'], freq="M"))['Date', 'Futures price', 'Compounded_return'].std()
```

Figure 28: Python commands for computing monthly historical volatility from daily futures prices

Appendix E Granger causality tests between spot and futures prices of WTI crude oil

Table 39 reports the p values obtained from the bidirectional, linear Granger causality tests executed on spot and futures prices of WTI crude oil. The tests have been used to determine whether futures prices forecast spot prices, or if the opposite relation holds. The outcome of ADF test signalled that the time series (of spot and futures prices) were not stationary; therefore, compounded returns (i.e., the changes in consecutive logarithmical prices) have been computed for each variable (see equation 10 in Appendix D.2). For each couple of time series, the test has been computed for the whole sample (2004:01-2023:01) as well as for sub-samples. For each test, the number of lags reported refers to the one selected through the AIC; however, the same tests have also been repeated for a range of lags, varying from 1 to 12. The p-values for these set of tests are reported in Table 40. From the results reported in the two Tables, it can be stated that futures prices of oil significantly Granger-cause spot prices of oil. Indeed, the null hypothesis is rejected with great statistical significance for almost all periods, and especially for the whole sample (the most statistically powerful one). Conversely, the null hypothesis that spot prices do not Granger-cause futures prices cannot be rejected in almost all cases. Therefore, it can be stated that futures prices of oil Granger-cause spot prices of oil. The relationship found between spot and futures prices has some implications and consequences on the futures markets' dynamics, which will be discussed in Section 5.1, where the same tests will be executed for corn and soybeans.

Null Hypothesis	Time frame	Lags (AIC)	F-test p value	Decision
Futures prices do not Granger-cause spot prices	2004:01-2015:01	3	0.0000***	reject
	2015:01-2020:01	2	0.0000***	reject
	2020:01-2023:01	11	0.8068	do not reject
	2015:01-2023:01	2	0.0000***	reject
	2004:01-2023:01	3	0.0000***	reject
Spot prices do not Granger-cause futures prices	2004:01-2015:01	3	0.0314**	reject
	2015:01-2020:01	2	0.6625	do not reject
	2020:01-2023:01	11	0.7609	do not reject
	2015:01-2023:01	2	0.4897	do not reject
	2004:01-2023:01	3	0.1244	do not reject

*Table 39: Granger causality test for futures and spot prices of WTI crude oil. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

	Time frame: 2004-2015			Time frame: 2015-2023			Time frame: 2004-2023	
	H0: spot prices do not granger cause futures prices	H0: futures prices do not granger cause spot prices		H0: spot prices do not granger cause futures prices	H0: futures prices do not granger cause spot prices		H0: spot prices do not granger cause futures prices	H0: futures prices do not granger cause spot prices
Lags	F-test p value	F-test p value	Lags	F-test p value	F-test p value	Lags	F-test p value	F-test p value
1	0.0061***	0.0000***	1	0.3246	0.0000***	1	0.6392	0.0000***
2	0.0164**	0.0000***	2	0.4897	0.0000***	2	0.0935*	0.0000***
3	0.0314**	0.0000***	3	0.5271	0.0000***	3	0.1244	0.0000***
4	0.0587*	0.0000***	4	0.7311	0.0000***	4	0.3111	0.0000***
5	0.1388	0.0000***	5	0.8397	0.0000***	5	0.4347	0.0000***
6	0.1156	0.0000***	6	0.8183	0.0001***	6	0.4661	0.0000***
7	0.1633	0.0000***	7	0.9179	0.0001***	7	0.5823	0.0000***
8	0.2532	0.0000***	8	0.9329	0.0006***	8	0.5751	0.0000***
9	0.3227	0.0000***	9	0.8743	0.0006***	9	0.7678	0.0000***
10	0.1080	0.0000***	10	0.7524	0.0006***	10	0.8448	0.0000***
11	0.1568	0.0000***	11	0.6012	0.0004***	11	0.6702	0.0000***
12	0.1565	0.0000***	12	0.7491	0.0016***	12	0.8493	0.0000***

*Table 40: GC tests for WTI crude oil: relation between spot and futures prices on different periods and different number of lags; p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance. The lag length selected through the AIC is marked in red.*

Appendix F Pearson's unconditional correlation (r): p-values

Tables 9, 10, and 11 of Section 4.2 report the Pearson correlation coefficient (r) for each pair of variables, which is the most common method used for measuring a linear correlation between two variables. Tables 41, 42, and 43 below report the p-values of such coefficients. The tables are symmetric.

	S&P GSCI	WTI crude oil: futures price	Food Price Index	Soybeans: futures price	Corn: futures price
S&P GSCI	0	6.728e-17	0.0393	0.497	0.401
WTI crude oil: futures price		0	8.773e-31	4.270e-27	3.658e-32
Food Price Index			0	6.144e-90	5.984e-75
Soybeans: futures price				0	1.518e-86
Corn: futures price					0

Table 41: Pearson's r p-values. Period: 2004-2023

	S&P GSCI	WTI crude oil: futures price	Food Price Index	Soybeans: futures price	Corn: futures price
S&P GSCI	0	0.001	0.212	0.110	0.527
WTI crude oil: futures price		0	4.019e-40	4.347e-25	1.162e-22
Food Price Index			0	1.926e-54	1.625e-44
Soybeans: futures price				0	3.191e-47
Corn: futures price					0

Table 42: Pearson's r p-values. Period: 2004-2015

	S&P GSCI	WTI crude oil: futures price	Food Price Index	Soybeans: futures price	Corn: futures price
S&P GSCI	0	4749e-41	1.815e-19	1.007e-12	1.295e-16
WTI crude oil: futures price		0	2.640e-27	2.285e-17	4.803e-21
Food Price Index			0	9.985e-46	2.449e-46
Soybeans: futures price				0	5.723e-44
Corn: futures price					0

Table 43: Pearson's r p-values. Period: 2015-2023

Appendix G Granger causality tests between spot and futures prices of corn and soybeans: more lags

The lag length selected through the AIC is marked in red.

CORN

	Time frame: 2004-2015			Time frame: 2015-2023			Time frame: 2004-2023	
	H0: spot prices do not granger cause futures prices	H0: futures prices do not granger cause spot prices		H0: spot prices do not granger cause futures prices	H0: futures prices do not granger cause spot prices		H0: spot prices do not granger cause futures prices	H0: futures prices do not granger cause spot prices
Lags	**F-test p value**	**F-test p value**	**Lags**	**F-test p value**	**F-test p value**	**Lags**	**F-test p value**	**F-test p value**
1	0.0759	0.0000***	1	0.7367	0.0000***	1	0.0748*	0.0000***
2	0.8482	0.0000***	2	0.5980	0.0000***	2	0.6632	0.0000***
3	0.7545	0.0000***	3	0.3969	0.0000***	3	0.2585	0.0000***
4	0.4813	0.0000***	4	0.3369	0.0000***	4	0.0995*	0.0000***
5	0.1594	0.0000***	5	0.4622	0.0000***	5	0.0252**	0.0000***
6	0.1426	0.0000***	6	0.7358	0.0000***	6	0.0436**	0.0000***
7	0.1080	0.0000***	7	0.6026	0.0000***	7	0.0299**	0.0000***
8	0.1709	0.0000***	8	0.6352	0.0000***	8	0.0371**	0.0000***
9	0.1542	0.0000***	9	0.5191	0.0000***	9	0.0403**	0.0000***
10	0.2350	0.0000***	10	0.5726	0.0000***	10	0.0900*	0.0000***
11	0.2793	0.0000***	11	0.6379	0.0000***	11	0.1183	0.0000***
12	0.1931	0.0000***	12	0.7210	0.0000***	12	0.0691*	0.0000***

*Table 44: GC tests for corn: relation between spot and futures prices on different periods and different number of lags; p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

SOYBEANS

	Time frame: 2004-2015			Time frame: 2015-2023			Time frame: 2004-2023	
	H0: spot prices do not granger cause futures prices	H0: futures prices do not granger cause spot prices		H0: spot prices do not granger cause futures prices	H0: futures prices do not granger cause spot prices		H0: spot prices do not granger cause futures prices	H0: futures prices do not granger cause spot prices
Lags	**F-test p value**	**F-test p value**	**Lags**	**F-test p value**	**F-test p value**	**Lags**	**F-test p value**	**F-test p value**
1	0.0075***	0.0000***	1	0.3844	0.0000***	1	0.0018***	0.0000***
2	0.1413	0.0000***	2	0.9710	0.0000***	2	0.1324	0.0000***
3	0.2523	0.0000***	3	0.7647	0.0000***	3	0.1905	0.0000***
4	0.3422	0.0000***	4	0.5519	0.0000***	4	0.1315	0.0000***
5	0.5467	0.0000***	5	0.6417	0.0000***	5	0.3181	0.0000***
6	0.6974	0.0000***	6	0.9580	0.0000***	6	0.4873	0.0000***
7	0.6853	0.0000***	7	0.5197	0.0000***	7	0.4147	0.0000***
8	0.4247	0.0000***	8	0.6410	0.0000***	8	0.2425	0.0000***
9	0.9210	0.0000***	9	0.7204	0.0000***	9	0.6740	0.0000***
10	0.6560	0.0000***	10	0.7825	0.0000***	10	0.4007	0.0000***
11	0.8926	0.0000***	11	0.2669	0.0000***	11	0.5828	0.0000***
12	0.5636	0.0000***	12	0.5072	0.0000***	12	0.2167	0.0000***

*Table 45: GC tests for soybeans: relation between spot and futures prices on different periods and different number of lags; p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

Appendix H Granger causality tests between speculation and prices: more lags

The lag length selected through the AIC is marked in red.

H.1 Corn, spot prices

		Time frame: 2004-2015			Time frame: 2015-2023			Time frame: 2004-2023	
		H0: proxy does not granger cause spot prices	H0: spot prices do not granger cause proxy		H0: proxy does not granger cause spot prices	H0: spot prices do not granger cause proxy		H0: proxy does not granger cause spot prices	H0: spot prices do not granger cause proxy
Proxy	**Lags**	**p value**	**p value**	**Lags**	**p value**	**p value**	**Lags**	**p value**	**p value**
Ch_NP_NonComm	1	0.0255**	0.6629	1	0.1243	0.3664	1	0.0094***	0.6605
	2	0.0475**	0.7671	2	0.4753	0.5316	2	0.0452**	0.6555
	3	0.0729*	0.9208	3	0.6418	0.8372	3	0.0620*	0.9675
	4	0.1275	0.9710	4	0.8339	0.8964	4	0.0909*	0.9871
	5	0.2644	0.0111**	5	0.4819	0.6728	5	0.1258	0.0142**
	6	0.5325	0.0485**	6	0.5627	0.8954	6	0.2253	0.0567*
	7	0.3949	0.0131**	7	0.5799	0.9088	7	0.1281	0.0386**
	8	0.5509	0.0223**	8	0.5944	0.8016	8	0.2899	0.0549*
	9	0.5746	0.0231**	9	0.4902	0.7689	9	0.3174	0.0584*
	10	0.6790	0.0466**	10	0.5407	0.7952	10	0.2928	0.0993*
	11	0.6766	0.1021	11	0.3515	0.9751	11	0.1827	0.3107
	12	0.7133	0.0142**	12	0.4867	0.9881	12	0.2524	0.0945*
Tot_OI	1	0.4483	0.0013***	1	0.7427	0.0000***	1	0.4119	0.0000***
	2	0.7430	0.0107**	2	0.4400	0.0000***	2	0.5493	0.0000***
	3	0.7416	0.0325**	3	0.5190	0.0000***	3	0.5515	0.0000***
	4	0.6503	0.0495**	4	0.5593	0.0000***	4	0.3872	0.0000***
	5	0.3440	0.0659*	5	0.2609	0.0000***	5	0.0824*	0.0000***
	6	0.2545	0.0137**	6	0.2604	0.0001***	6	0.0493**	0.0000***
	7	0.2895	0.0416**	7	0.2833	0.0002***	7	0.0513*	0.0000***
	8	0.4017	0.0515*	8	0.3499	0.0001***	8	0.0725*	0.0000***
	9	0.5030	0.1013	9	0.4352	0.0009***	9	0.1196	0.0000***
	10	0.5632	0.0570*	10	0.4413	0.0023***	10	0.1597	0.0000***
	11	0.2453	0.1112	11	0.1529	0.0043***	11	0.0066***	0.0000***
	12	0.3491	0.1209	12	0.0484**	0.0121**	12	0.0043***	0.0001***
T	1	0.5482	0.5923	1	0.0461**	0.0430**	1	0.5146	0.0826*
	2	0.6875	0.7707	2	0.1257	0.0419**	2	0.6265	0.2243
	3	0.6754	0.6329	3	0.1115	0.0436**	3	0.6048	0.2080
	4	0.6509	0.3491	4	0.1281	0.0728*	4	0.4067	0.0443**
	5	0.8349	0.3502	5	0.0448**	0.0999*	5	0.4369	0.0371**
	6	0.8445	0.3482	6	0.0879*	0.0691*	6	0.4529	0.0251**
	7	0.9099	0.3680	7	0.4176	0.0404**	7	0.6793	0.0137**
	8	0.9400	0.3555	8	0.3046	0.0724*	8	0.6321	0.0189**
	9	0.9560	0.1782	9	0.4602	0.1114	9	0.7121	0.0229**
	10	0.9734	0.2596	10	0.6264	0.2075	10	0.7887	0.0424**
	11	0.9784	0.2135	11	0.5670	0.2504	11	0.6958	0.0383**
	12	0.9949	0.0382**	12	0.7066	0.2317	12	0.8521	0.0058***
Spec_press	1	0.6764	0.0006***	1	0.2672	0.0002***	1	0.3184	0.0000***
	2	0.6868	0.0263**	2	0.4510	0.0697*	2	0.5707	0.0287**
	3	0.6431	0.0504*	3	0.4355	0.5469	3	0.4939	0.0463**
	4	0.5512	0.0726*	4	0.4913	0.3395	4	0.4849	0.0551*
	5	0.8068	0.0625*	5	0.5135	0.4019	5	0.6932	0.0188**
	6	0.9034	0.1218	6	0.6039	0.5624	6	0.7617	0.0458**
	7	0.7866	0.1379	7	0.5862	0.6013	7	0.4823	0.0444**
	8	0.7882	0.0686*	8	0.8642	0.8649	8	0.5748	0.0919*
	9	0.8319	0.0149**	9	0.7155	0.9295	9	0.5964	0.0287**
	10	0.8141	0.0504*	10	0.8241	0.9313	10	0.6247	0.0895*
	11	0.8349	0.0392**	11	0.8691	0.9055	11	0.5199	0.0809*
	12	0.9333	0.0173**	12	0.9217	0.9511	12	0.6607	0.0046***
S&P GSCI	1	0.2346	0.0764*	1	0.0314**	0.2281	1	0.0281**	0.0272**
	2	0.0503*	0.1147	2	0.0222**	0.4468	2	0.0416**	0.0558*
	3	0.0968*	0.1925	3	0.0756*	0.5918	3	0.1035	0.1257
	4	0.1576	0.2773	4	0.1425	0.5291	4	0.1758	0.2057
	5	0.1924	0.2806	5	0.0236**	0.6927	5	0.2082	0.2019
	6	0.1312	0.3890	6	0.0113**	0.8251	6	0.2369	0.3135
	7	0.2615	0.1178	7	0.0197**	0.8543	7	0.3361	0.1514
	8	0.2485	0.1903	8	0.0406**	0.9282	8	0.5677	0.2366
	9	0.2485	0.0941*	9	0.0616*	0.7281	9	0.4881	0.0527*
	10	0.1602	0.1278	10	0.0705*	0.7305	10	0.2889	0.0662*
	11	0.2292	0.2377	11	0.0960*	0.3485	11	0.3518	0.0407**
	12	0.2141	0.2213	12	0.0658*	0.4045	12	0.3566	0.0662*

*Table 46: Granger causality test from 1 to 12 lags for spot prices of corn: p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

H.2 Corn, futures prices

		Time frame: 2004-2015			Time frame: 2015-2023			Time frame: 2004-2023	
		H0: proxy does not granger cause futures prices	H0: futures prices do not granger cause proxy		H0: proxy does not granger cause futures prices	H0: futures prices do not granger cause proxy		H0: proxy does not granger cause futures prices	H0: futures prices do not granger cause proxy
Proxy	**Lags**	**p value**	**p value**	**Lags**	**p value**	**p value**	**Lags**	**p value**	**p value**
Ch_NP_NonComm	1	0.0416**	0.1204	1	0.9063	0.0188**	1	0.2533	0.0191**
	2	0.2984	0.1826	2	0.9016	0.1178	2	0.8175	0.0538*
	3	0.5035	0.2192	3	0.6640	0.0282**	3	0.7734	0.0261**
	4	0.4528	0.1803	4	0.9175	0.0180**	4	0.8054	0.0146**
	5	0.7371	0.1389	5	0.9472	0.0414**	5	0.8860	0.0238**
	6	0.6978	0.0534*	6	0.6754	0.0192**	6	0.7539	0.0033***
	7	0.5886	0.0975*	7	0.6767	0.0526*	7	0.6665	0.0084***
	8	0.6161	0.0302**	8	0.7849	0.1591	8	0.7550	0.0040***
	9	0.7712	0.0425**	9	0.8292	0.0666*	9	0.9430	0.0051***
	10	0.8828	0.0734*	10	0.8647	0.0507*	10	0.9476	0.0117**
	11	0.7741	0.1330	11	0.7277	0.2102	11	0.7666	0.0441**
	12	0.7915	0.1625	12	0.3703	0.2899	12	0.7395	0.0712*
Tot_OI	1	0.4372	0.0000***	1	0.9591	0.0105**	1	0.3095	0.0000***
	2	0.8453	0.0000***	2	0.4813	0.0062***	2	0.7089	0.0000***
	3	0.4211	0.0000***	3	0.1443	0.0001***	3	0.1276	0.0000***
	4	0.5137	0.0002***	4	0.1782	0.0001***	4	0.1866	0.0000***
	5	0.1849	0.0002***	5	0.3668	0.0002***	5	0.0372**	0.0000***
	6	0.1445	0.0005***	6	0.5289	0.0000***	6	0.0354**	0.0000***
	7	0.0921*	0.0008***	7	0.4916	0.0001***	7	0.0461**	0.0000***
	8	0.0411**	0.0018***	8	0.3328	0.0013***	8	0.0245**	0.0000***
	9	0.0904*	0.0037***	9	0.2015	0.0011***	9	0.0836*	0.0000***
	10	0.1178	0.0039***	10	0.2231	0.0026***	10	0.0220**	0.0000***
	11	0.0286**	0.0065***	11	0.0743*	0.0064***	11	0.0064***	0.0000***
	12	0.0542*	0.0067***	12	0.1440	0.0804*	12	0.0034***	0.0000***
T	1	0.0957*	0.0003***	1	0.4554	0.0000***	1	0.3780	0.0000***
	2	0.4457	0.0013***	2	0.5077	0.0000***	2	0.8815	0.0000***
	3	0.3999	0.0019***	3	0.4259	0.0000***	3	0.8007	0.0000***
	4	0.5364	0.0007***	4	0.5934	0.0000***	4	0.7202	0.0000***
	5	0.7562	0.0009***	5	0.9359	0.0000***	5	0.8709	0.0000***
	6	0.5398	0.0015***	6	0.8809	0.0001***	6	0.7458	0.0000***
	7	0.5959	0.0026***	7	0.8106	0.0001***	7	0.7269	0.0000***
	8	0.5751	0.0033***	8	0.8469	0.0005***	8	0.7439	0.0000***
	9	0.3913	0.0083***	9	0.6981	0.0012***	9	0.5745	0.0000***
	10	0.5189	0.0085***	10	0.8412	0.0045***	10	0.6821	0.0000***
	11	0.4346	0.0120**	11	0.8630	0.0083***	11	0.5159	0.0000***
	12	0.5935	0.0186**	12	0.4671	0.0125**	12	0.5080	0.0000***
Spec_press	1	0.6873	0.0000***	1	0.8544	0.0000***	1	0.6338	0.0000***
	2	0.3072	0.0000***	2	0.5055	0.0000***	2	0.3317	0.0000***
	3	0.3914	0.0000***	3	0.5810	0.0000***	3	0.6355	0.0000***
	4	0.3212	0.0000***	4	0.7763	0.0000***	4	0.6993	0.0000***
	5	0.5241	0.0000***	5	0.8547	0.0000***	5	0.8656	0.0000***
	6	0.6741	0.0000***	6	0.6235	0.0000***	6	0.9069	0.0000***
	7	0.5691	0.0000***	7	0.3136	0.0000***	7	0.6800	0.0000***
	8	0.6420	0.0000***	8	0.3718	0.0002***	8	0.6933	0.0000***
	9	0.7381	0.0000***	9	0.3669	0.0007***	9	0.8352	0.0000***
	10	0.5975	0.0000***	10	0.3163	0.0009***	10	0.6069	0.0000***
	11	0.5139	0.0000***	11	0.4362	0.0025***	11	0.4052	0.0000***
	12	0.6579	0.0000***	12	0.1984	0.0036***	12	0.4300	0.0000***
S&P GSCI	1	0.7377	0.8360	1	0.0352**	0.7841	1	0.3841	0.7841
	2	0.1708	0.1601	2	0.1351	0.4304	2	0.2298	0.4304
	3	0.3389	0.2391	3	0.1728	0.6291	3	0.3983	0.6291
	4	0.2676	0.2043	4	0.2036	0.4040	4	0.2445	0.4040
	5	0.3606	0.1508	5	0.2352	0.6426	5	0.2603	0.6426
	6	0.1554	0.2104	6	0.2512	0.7679	6	0.2318	0.7679
	7	0.1684	0.2324	7	0.3981	0.7943	7	0.3642	0.7943
	8	0.2655	0.1568	8	0.4877	0.8462	8	0.4337	0.8462
	9	0.3048	0.0742*	9	0.3593	0.9272	9	0.4745	0.9272
	10	0.3986	0.0994*	10	0.4449	0.6972	10	0.5270	0.6972
	11	0.3884	0.1609	11	0.3923	0.5674	11	0.5413	0.5674
	12	0.3890	0.2365	12	0.3612	0.4497	12	0.4129	0.4497

*Table 47: Granger causality test from 1 to 12 lags for futures prices of corn: p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

H.3 Corn, volatility of futures returns

		Time frame: 2004-2015			Time frame: 2015-2023			Time frame: 2004-2023	
		H0: proxy does not granger cause volatility	H0: volatility does not granger cause proxy		H0: proxy does not granger cause volatility	H0: volatility does not granger cause proxy		H0: proxy does not granger cause volatility	H0: volatility does not granger cause proxy
Proxy	Lags	p value	p value	Lags	p value	p value	Lags	p value	p value
Ch_NP_NonComm	1	0.3020	0.6311	1	0.9791	0.6254	1	0.8344	0.5165
	2	0.4722	0.8850	2	0.9791	0.6971	2	0.8801	0.6234
	3	0.6822	0.7232	3	0.3887	0.8545	3	0.2722	0.7874
	4	0.7839	0.6880	4	0.5823	0.8932	4	0.4395	0.7858
	5	0.8724	0.7809	5	0.6412	0.9472	5	0.4969	0.8819
	6	0.9381	0.8204	6	0.7105	0.9436	6	0.5469	0.8808
	7	0.9712	0.7416	7	0.8406	0.8887	7	0.7112	0.7955
	8	0.8343	0.8313	8	0.8634	0.9419	8	0.7217	0.8721
	9	0.7929	0.8512	9	0.9119	0.9514	9	0.7922	0.8669
	10	0.7175	0.8208	10	0.8124	0.9750	10	0.7632	0.9140
	11	0.7490	0.8301	11	0.8189	0.9829	11	0.8020	0.9267
	12	0.8148	0.7790	12	0.7164	0.9918	12	0.6475	0.9566
Tot_OI	1	0.1306	0.0407**	1	0.0502*	0.0391**	1	0.2218	0.5855
	2	0.0665*	0.0475**	2	0.0844*	0.0086***	2	0.0018***	0.4125
	3	0.0593*	0.1859	3	0.2542	0.0172**	3	0.0035***	0.1980
	4	0.1586	0.3077	4	0.3832	0.0582*	4	0.0073***	0.2164
	5	0.2379	0.3499	5	0.5737	0.0333**	5	0.0078***	0.1990
	6	0.2921	0.1213	6	0.1639	0.0882*	6	0.0111**	0.0115**
	7	0.4328	0.1547	7	0.1098	0.0365**	7	0.0309**	0.0152**
	8	0.2496	0.2558	8	0.0652*	0.0608*	8	0.1184	0.0256**
	9	0.2121	0.2718	9	0.0541*	0.1037	9	0.1828	0.0226**
	10	0.2221	0.2281	10	0.0459**	0.1531	10	0.0112**	0.0402**
	11	0.0917*	0.3067	11	0.0103**	0.2104	11	0.0268**	0.0311**
	12	0.1372	0.4155	12	0.0370**	0.0103**	12	0.0076***	0.1428
T	1	0.8800	0.0429**	1	0.5366	0.0051***	1	0.7137	0.4262
	2	0.8790	0.0274**	2	0.5876	0.0073***	2	0.6410	0.2686
	3	0.2012	0.0495**	3	0.5723	0.0228**	3	0.7995	0.2960
	4	0.3975	0.1636	4	0.8109	0.0921*	4	0.9404	0.2675
	5	0.3835	0.2156	5	0.6574	0.1644	5	0.8347	0.3613
	6	0.3764	0.2832	6	0.6693	0.0641*	6	0.8756	0.2270
	7	0.3951	0.3731	7	0.7726	0.1317	7	0.7724	0.3207
	8	0.4890	0.4400	8	0.7987	0.2137	8	0.6914	0.3931
	9	0.7406	0.4620	9	0.3950	0.2661	9	0.4084	0.4784
	10	0.7571	0.4196	10	0.5926	0.4078	10	0.5174	0.5009
	11	0.8408	0.5147	11	0.6957	0.5013	11	0.4520	0.4883
	12	0.8471	0.5406	12	0.5171	0.5669	12	0.4089	0.6168
Spec_press	1	0.0843*	0.7720	1	0.0067***	0.6177	1	0.0015***	0.8254
	2	0.0855*	0.8525	2	0.0640*	0.2455	2	0.0101**	0.5476
	3	0.1768	0.7596	3	0.0394**	0.2806	3	0.0119**	0.7422
	4	0.2474	0.8874	4	0.0440**	0.4349	4	0.0224**	0.8492
	5	0.3081	0.9489	5	0.0420**	0.5950	5	0.0244**	0.9167
	6	0.3791	0.9564	6	0.0396**	0.6149	6	0.0433**	0.8703
	7	0.3772	0.9273	7	0.0292**	0.7719	7	0.0357**	0.8255
	8	0.4307	0.9345	8	0.0902*	0.8629	8	0.0800*	0.9072
	9	0.5078	0.9148	9	0.0983*	0.8230	9	0.1330	0.6944
	10	0.5966	0.7726	10	0.1314	0.8654	10	0.1042	0.5592
	11	0.6939	0.8385	11	0.2011	0.9445	11	0.1628	0.6780
	12	0.7611	0.8991	12	0.0818*	0.9823	12	0.1279	0.8200

*Table 48: Granger causality test from 1 to 12 lags for volatility of futures returns of corn: p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

H.4 Soybeans, spot prices

		Time frame: 2004-2015			Time frame: 2015-2023			Time frame: 2004-2023	
		H0: proxy does not granger cause spot prices	H0: spot prices do not granger cause proxy		H0: proxy does not granger cause spot prices	H0: spot prices do not granger cause proxy		H0: proxy does not granger cause spot prices	H0: spot prices do not granger cause proxy
Proxy	**Lags**	**p value**	**p value**	**Lags**	**p value**	**p value**	**Lags**	**p value**	**p value**
Ch_NP_NonComm	1	0.0006***	0.1577	1	0.0124**	0.4475	1	0.0003***	0.2167
	2	0.0011***	0.4434	2	0.0161**	0.7554	2	0.0005***	0.4908
	3	0.0004***	0.6172	3	0.0320**	0.7211	3	0.0003***	0.6484
	4	0.0002***	0.8694	4	0.0957*	0.7584	4	0.0005***	0.8431
	5	0.0011***	0.9595	5	0.1528	0.5865	5	0.0029***	0.8440
	6	0.0022***	0.8452	6	0.1711	0.4899	6	0.0027***	0.5887
	7	0.0009***	0.8667	7	0.2961	0.4928	7	0.0022***	0.5640
	8	0.0024***	0.6890	8	0.4386	0.6561	8	0.0035***	0.5979
	9	0.0033***	0.8835	9	0.4716	0.7001	9	0.0030***	0.6997
	10	0.0042***	0.9189	10	0.5206	0.6916	10	0.0026***	0.7987
	11	0.0058***	0.9379	11	0.5330	0.8763	11	0.0036***	0.9122
	12	0.0074***	0.7776	12	0.5365	0.8856	12	0.0064***	0.8327
Tot_OI	1	0.7329	0.5046	1	0.2211	0.0660*	1	0.1525	0.3076
	2	0.5966	0.2575	2	0.1076	0.1830	2	0.2781	0.0706*
	3	0.0199**	0.3607	3	0.2235	0.4452	3	0.0682*	0.2398
	4	0.0312**	0.3322	4	0.3468	0.6295	4	0.0440**	0.1539
	5	0.0696*	0.6043	5	0.2803	0.4806	5	0.1284	0.2660
	6	0.1244	0.3881	6	0.2802	0.6583	6	0.2286	0.0588*
	7	0.2235	0.4285	7	0.2744	0.4516	7	0.2422	0.0429**
	8	0.3504	0.2724	8	0.4190	0.4198	8	0.5123	0.0138**
	9	0.4321	0.7097	9	0.5717	0.4306	9	0.5786	0.1573
	10	0.5232	0.4969	10	0.7349	0.5277	10	0.6125	0.2014
	11	0.4076	0.8111	11	0.8185	0.5886	11	0.3449	0.3733
	12	0.4392	0.1041	12	0.5503	0.6780	12	0.4051	0.0501*
T	1	0.6218	0.1855	1	0.4836	0.0987*	1	0.8799	0.0568*
	2	0.6510	0.0213**	2	0.5518	0.1187	2	0.9056	0.0028***
	3	0.8201	0.0232**	3	0.4558	0.2289	3	0.9887	0.0028***
	4	0.7760	0.0413**	4	0.5109	0.4538	4	0.9869	0.0047***
	5	0.8803	0.0465**	5	0.3064	0.1707	5	0.9722	0.0087***
	6	0.0156**	0.0134**	6	0.3550	0.0998*	6	0.0358**	0.0013***
	7	0.0249**	0.0020***	7	0.4638	0.2155	7	0.0663*	0.0003***
	8	0.0899*	0.0032***	8	0.6303	0.3298	8	0.3249	0.0009***
	9	0.1199	0.0061***	9	0.5118	0.2536	9	0.3683	0.0014***
	10	0.1658	0.0114**	10	0.4903	0.2375	10	0.4542	0.0019***
	11	0.2014	0.0071***	11	0.4128	0.2200	11	0.4951	0.0021***
	12	0.2044	0.0011***	12	0.5451	0.2254	12	0.6429	0.0005***
Spec_press	1	0.6926	0.0023***	1	0.5188	0.0003***	1	0.4728	0.0000***
	2	0.3878	0.7587	2	0.5782	0.0742*	2	0.3020	0.1894
	3	0.4991	0.5531	3	0.7939	0.1647	3	0.5148	0.2156
	4	0.1988	0.8339	4	0.9761	0.1970	4	0.4510	0.3458
	5	0.4699	0.7504	5	0.8128	0.3265	5	0.9005	0.4118
	6	0.5874	0.8926	6	0.9148	0.3246	6	0.9428	0.3452
	7	0.0894*	0.6294	7	0.5785	0.2986	7	0.1579	0.1745
	8	0.4185	0.3598	8	0.7908	0.3901	8	0.5076	0.1324
	9	0.5079	0.4605	9	0.2997	0.2288	9	0.4751	0.2306
	10	0.4677	0.4574	10	0.2580	0.3867	10	0.5251	0.1926
	11	0.2499	0.2171	11	0.3508	0.2865	11	0.4838	0.1900
	12	0.3439	0.2647	12	0.4848	0.3255	12	0.5236	0.0374**
S&P GSCI	1	0.7287	0.3817	1	0.0489**	0.2127	1	0.1971	0.1428
	2	0.4681	0.1281	2	0.1701	0.1984	2	0.2490	0.0264**
	3	0.5741	0.2016	3	0.1746	0.3032	3	0.2439	0.0386**
	4	0.6709	0.1320	4	0.2612	0.3293	4	0.3197	0.0277**
	5	0.8267	0.2716	5	0.3292	0.3812	5	0.4573	0.0521*
	6	0.7073	0.4010	6	0.3353	0.4710	6	0.1905	0.0848*
	7	0.8115	0.2103	7	0.2421	0.6010	7	0.2336	0.0319**
	8	0.9581	0.3960	8	0.6134	0.4735	8	0.3432	0.0573*
	9	0.9242	0.2498	9	0.4807	0.5706	9	0.4252	0.0245**
	10	0.9147	0.1760	10	0.2774	0.4161	10	0.3377	0.0118**
	11	0.9565	0.3122	11	0.3299	0.5131	11	0.4088	0.0140**
	12	0.3926	0.3959	12	0.3464	0.4888	12	0.1777	0.0166**

*Table 49: Granger causality test from 1 to 12 lags for spot prices of soybeans: p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

H.5 Soybeans, futures prices

		Time frame: 2004-2015			Time frame: 2015-2023			Time frame: 2004-2023	
		H0: proxy does not granger cause futures prices	H0: futures prices do not granger cause proxy		H0: proxy does not granger cause futures prices	H0: futures prices do not granger cause proxy		H0: proxy does not granger cause futures prices	H0: futures prices do not granger cause proxy
Proxy	Lags	p value	p value	Lags	p value	p value	Lags	p value	p value
Ch_NP_NonComm	1	0.0317**	0.3743	1	0.2160	0.0523*	1	0.2244	0.5419
	2	0.1403	0.3979	2	0.1532	0.1038	2	0.7063	0.4748
	3	0.0074***	0.4551	3	0.2182	0.0949*	3	0.1462	0.5334
	4	0.0205**	0.6644	4	0.0510*	0.1758	4	0.1054	0.4464
	5	0.1115	0.8308	5	0.1020	0.2742	5	0.4363	0.6387
	6	0.1360	0.7262	6	0.0209**	0.0143**	6	0.3642	0.2249
	7	0.1147	0.6862	7	0.0437**	0.0307**	7	0.2210	0.1316
	8	0.1593	0.7723	8	0.0619*	0.0617*	8	0.3019	0.1813
	9	0.3076	0.8406	9	0.0500**	0.0659*	9	0.4679	0.1037
	10	0.3915	0.8962	10	0.0642*	0.0940*	10	0.4890	0.1650
	11	0.2963	0.9372	11	0.1371	0.1883	11	0.3207	0.3343
	12	0.3520	0.9677	12	0.0567*	0.3031	12	0.3640	0.4124
Tot_OI	1	0.8613	0.0934*	1	0.7707	0.1669	1	0.9959	0.0566*
	2	0.0425**	0.2314	2	0.9448	0.0693*	2	0.0656*	0.1555
	3	0.0098***	0.0054***	3	0.9351	0.0973*	3	0.0318**	0.0005***
	4	0.0167**	0.0053***	4	0.9755	0.2384	4	0.0426**	0.0016***
	5	0.0368**	0.0153**	5	0.9576	0.3204	5	0.0733*	0.0063***
	6	0.0382**	0.0225**	6	0.5205	0.2609	6	0.0982*	0.0031***
	7	0.0556*	0.0160**	7	0.7677	0.1819	7	0.1801	0.0007***
	8	0.0996*	0.0114**	8	0.6075	0.1987	8	0.2323	0.0002***
	9	0.2516	0.0349**	9	0.6846	0.2031	9	0.5061	0.0025***
	10	0.2511	0.0356**	10	0.7163	0.2131	10	0.5621	0.0044***
	11	0.2225	0.0768*	11	0.7007	0.1711	11	0.4968	0.0105**
	12	0.2548	0.0130**	12	0.7957	0.1962	12	0.4828	0.0027***
T	1	0.1071	0.0332**	1	0.6540	0.0000***	1	0.1792	0.0001***
	2	0.2454	0.0714*	2	0.6619	0.0000***	2	0.4765	0.0001***
	3	0.3425	0.0356**	3	0.1991	0.0000***	3	0.4419	0.0001***
	4	0.4706	0.0679*	4	0.4845	0.0000***	4	0.5108	0.0001***
	5	0.5378	0.0919*	5	0.7392	0.0000***	5	0.5239	0.0002***
	6	0.0446**	0.0982*	6	0.4972	0.0000***	6	0.0762*	0.0000***
	7	0.0219**	0.0452**	7	0.3494	0.0000***	7	0.0551*	0.0000***
	8	0.0404***	0.0242**	8	0.1480	0.0001***	8	0.1156	0.0000***
	9	0.0739*	0.0158**	9	0.1533	0.0002***	9	0.2466	0.0000***
	10	0.1315	0.0249**	10	0.2478	0.0007***	10	0.3155	0.0000***
	11	0.1199	0.0254**	11	0.1832	0.0013***	11	0.2240	0.0000***
	12	0.1418	0.0082***	12	0.2095	0.0009***	12	0.3543	0.0000***
Spec_press	1	0.8950	0.0000***	1	0.6968	0.0000***	1	0.9287	0.0000***
	2	0.4149	0.0024***	2	0.7290	0.0000***	2	0.3003	0.0000***
	3	0.4274	0.0128**	3	0.7373	0.0000***	3	0.2658	0.0000***
	4	0.4137	0.0282**	4	0.7366	0.0000***	4	0.3217	0.0000***
	5	0.8022	0.0360**	5	0.6480	0.0000***	5	0.6368	0.0000***
	6	0.7695	0.0830*	6	0.1592	0.0000***	6	0.4912	0.0000***
	7	0.5111	0.0135**	7	0.3407	0.0000***	7	0.3232	0.0000***
	8	0.6090	0.0174**	8	0.4325	0.0000***	8	0.4392	0.0000***
	9	0.8881	0.0248**	9	0.1019	0.0000***	9	0.4861	0.0000***
	10	0.9547	0.0193**	10	0.1607	0.0001***	10	0.5845	0.0000***
	11	0.8433	0.0486**	11	0.2600	0.0001***	11	0.4956	0.0000***
	12	0.8354	0.0991*	12	0.1994	0.0004***	12	0.5517	0.0000***
S&P GSCI	1	0.4154	0.1847	1	0.2834	0.4447	1	0.2078	0.3730
	2	0.3259	0.3644	2	0.5308	0.0031***	2	0.2126	0.3543
	3	0.4846	0.2503	3	0.2952	0.0118**	3	0.2012	0.1993
	4	0.5938	0.1121	4	0.4204	0.0299**	4	0.3205	0.0766*
	5	0.2943	0.1493	5	0.5595	0.0448**	5	0.1189	0.0826*
	6	0.3849	0.3246	6	0.5568	0.0853*	6	0.1869	0.1198
	7	0.6700	0.4658	7	0.8123	0.1274	7	0.4675	0.2273
	8	0.7928	0.4281	8	0.9396	0.1685	8	0.6259	0.2538
	9	0.8184	0.3856	9	0.4683	0.3388	9	0.7972	0.1098
	10	0.8610	0.3096	10	0.5323	0.3838	10	0.8576	0.0869*
	11	0.9280	0.5268	11	0.7238	0.0953*	11	0.8151	0.0810*
	12	0.7045	0.6410	12	0.8611	0.1413	12	0.7600	0.1136

*Table 50: Granger causality test from 1 to 12 lags for futures prices of soybeans: p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

H.6 Soybeans, volatility of futures returns

		Time frame: 2004-2015			Time frame: 2015-2023			Time frame: 2004-2023	
		H0: proxy does not granger cause volatility	H0: volatility does not granger cause proxy		H0: proxy does not granger cause volatility	H0: volatility does not granger cause proxy		H0: proxy does not granger cause volatility	H0: volatility does not granger cause proxy
Proxy	**Lags**	**p value**	**p value**	**Lags**	**p value**	**p value**	**Lags**	**p value**	**p value**
Ch_NP_NonComm	1	0.2782	0.7166	1	0.9035	0.1349	1	0.4899	0.2323
	2	0.4926	0.8860	2	0.5549	0.0534*	2	0.7608	0.3229
	3	0.3867	0.9673	3	0.8588	0.0736*	3	0.7760	0.4481
	4	0.4130	0.9877	4	0.9053	0.1319	4	0.7118	0.5040
	5	0.5634	0.7557	5	0.9045	0.1855	5	0.8345	0.5019
	6	0.7326	0.7036	6	0.6647	0.1997	6	0.8393	0.3189
	7	0.7125	0.6199	7	0.7893	0.2834	7	0.8899	0.3626
	8	0.7473	0.7399	8	0.9094	0.4257	8	0.9172	0.4927
	9	0.7424	0.8772	9	0.5549	0.4677	9	0.9509	0.6331
	10	0.8495	0.8374	10	0.4184	0.4980	10	0.9850	0.6949
	11	0.9111	0.5926	11	0.1018	0.5439	11	0.9758	0.7331
	12	0.8138	0.7050	12	0.1120	0.5566	12	0.9645	0.7574
Tot_OI	1	0.5353	0.9346	1	0.0810*	0.0241**	1	0.2039	0.0073***
	2	0.7378	0.5769	2	0.1382	0.0109**	2	0.4686	0.0056***
	3	0.3614	0.6711	3	0.3726	0.0600*	3	0.1048	0.0235**
	4	0.5133	0.6613	4	0.4936	0.0021***	4	0.1166	0.0029***
	5	0.8435	0.9049	5	0.4034	0.0380**	5	0.2169	0.0156**
	6	0.9235	0.3993	6	0.2334	0.0292**	6	0.2644	0.0353**
	7	0.9575	0.5645	7	0.3896	0.0556*	7	0.4391	0.0261**
	8	0.9206	0.5372	8	0.1694	0.0578*	8	0.6837	0.0532*
	9	0.9496	0.7031	9	0.1948	0.0319**	9	0.8941	0.0178**
	10	0.9439	0.7090	10	0.1821	0.0845*	10	0.9114	0.0082***
	11	0.8128	0.4362	11	0.1866	0.1069	11	0.7809	0.0147**
	12	0.8724	0.0900*	12	0.1370	0.0052***	12	0.6541	0.0041***
T	1	0.1709	0.5720	1	0.9341	0.1833	1	0.2561	0.1998
	2	0.2310	0.5484	2	0.9845	0.4610	2	0.4290	0.4325
	3	0.1856	0.5926	3	0.6037	0.3321	3	0.4327	0.3273
	4	0.3079	0.7090	4	0.8491	0.5592	4	0.5963	0.4565
	5	0.5177	0.5025	5	0.5875	0.6974	5	0.5446	0.4488
	6	0.5069	0.3264	6	0.3482	0.9003	6	0.4579	0.5471
	7	0.4197	0.3501	7	0.2723	0.8613	7	0.4660	0.5975
	8	0.5516	0.4580	8	0.2208	0.7278	8	0.6350	0.7193
	9	0.4957	0.5605	9	0.0027***	0.7086	9	0.4063	0.7869
	10	0.6332	0.6254	10	0.0023***	0.4637	10	0.5564	0.7956
	11	0.7573	0.6377	11	0.0025***	0.5989	11	0.6503	0.8619
	12	0.8206	0.2976	12	0.0023***	0.6270	12	0.6537	0.4161
Spec_press	1	0.2803	0.0893*	1	0.0037***	0.4443	1	0.0311**	0.0675*
	2	0.0514*	0.5322	2	0.0230**	0.6278	2	0.0265**	0.4242
	3	0.0622*	0.6161	3	0.0322**	0.2369	3	0.0593*	0.3934
	4	0.0807*	0.8424	4	0.0490**	0.2368	4	0.0922*	0.4164
	5	0.1277	0.1544	5	0.1120	0.3758	5	0.1743	0.0838*
	6	0.2447	0.2110	6	0.1005	0.4739	6	0.2310	0.1492
	7	0.3656	0.0017***	7	0.1351	0.5844	7	0.3094	0.0031***
	8	0.4350	0.0006***	8	0.1106	0.7124	8	0.3454	0.0040***
	9	0.4076	0.0020***	9	0.2588	0.7922	9	0.4881	0.0091***
	10	0.4842	0.0030***	10	0.1593	0.7865	10	0.5999	0.0136**
	11	0.5623	0.0034***	11	0.0329**	0.9313	11	0.5901	0.0218**
	12	0.6802	0.0042***	12	0.0256**	0.9631	12	0.7284	0.0178**

*Table 51: Granger causality test from 1 to 12 lags for volatility of futures returns of soybeans: p-values. * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; *** = reject Null Hypothesis at 1% significance.*

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