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> "Futures markets, in fact, may be quite figuratively Adam Smith's "invisible hand" - a force which surpassed and perhaps defies complete understanding. Yet a force with immeasurable effects and consequences. A force which decides what, when, and where commodities are going to be produced and exchange - whether people are going to eat or go hungry - whether an industry or an entire nation for that matter is going to prosper or fail - and which influences how we live with ourselves and how we live with each other.
> Futures markets are commonly perceived as inconsequential, independent business activities occurring on the fringes of our economic system. A more accurate assessment perhaps is that futures markets are our economic system."

Opening statement of Senator Jepsen, Chairman, in Bradford, C. H., & Galbraith, J. K. (1984). Improving the efficiency of commodity futures markets. Joint Economic Committee, US Congress.

Contents

List of Figures

List of Tables

General Introduction

Contents

Black (1976) compare derivatives contracts to sports bets . Both reflect expectations of the outcome of a future event. If players of a sporting event are not bribed, the outcome is independent of the bets. Derivatives instruments are "*financial contracts whose price is derived from that of an underlying asset such as exchange rate, interest rate, credit risk or commodity*" (Lautier, 2013). There are several kinds of derivatives contracts but this Ph.D. thesis focuses on futures contracts, which are the more common in the organized markets. The latter are standardized agreements between two counterparts. They are traded on organized markets ruled by a clearinghouse. The underlying commodity price is called the spot price. The futures price refers to the price of the futures contract written on the underlying spot price. Black (1976) assumes the spot price is exogenous of derivative prices. When he was writing in the 70s, derivatives markets were tiny. According to Black, the most risk was transferred through corporations and storage stabilized markets. Nonetheless, since the 80s which saw financial liberalization policies and market automatization, the derivatives market has flourished. In 2000, the Commodity Futures Modernization Act (CFMA) enshrined derivatives liberalization sparking an exponential growth of traded volume. The volume of exchange-traded derivatives is roughly thirty times higher than the physical production for metals and four times higher for crude oil in 2005 (Domanski and Heath, 2007). In 2003, the open interest (which is the total number of outstanding futures contracts) of WTI futures was equal to the world oil demand. In 2008, the former became four times higher than the latter (Hache and Lantz, 2013). Black (1976) highlights futures prices guide decisions of economic agents, including storage. Therefore, the circularity between the spot and the futures market becomes an issue. More and more transactions in the commodity derivative markets originate from financial institutions. The futures market is thus exposed to financial shocks nonrelated to the physical market. The latter can become impacted as well because of the circular relationship between the spot and the futures price.

Financial institutions diversify their portfolio by taking positions in the commodity futures market. They become major actors. The hedge fund share of the energy futures open interest rose from 10% to 35% between 2000 and 2008 (Buyuksahin and Robe, 2011). Isleimeyyeh (2017) shows there was a break in the composition of the open interest of commodity futures around 2002. Before this year, the commercials' percentage of open interest is higher than the noncommercials' one[1]. After 2002, the share of noncommercial's positions skyrocketed.

[1] In the Commitments of Traders (COT) reports of the Commodity Trading Futures Commission (CFTC), commercials are operators active in the spot market. While, noncommercials operators are active in the futures market only.

Commodity Futures are an asset class with a market dominated by financial traders. This process is called financialization. Cheng and Xiong (2014) "*highlight understanding the impact of financialization on commodity prices requires a focus on how it affects the economic mechanisms of commodity markets.*" The idea is to study the real effects of the futures market. All the works inside the thesis relax the Black's assumption of a null impact of the futures market on the spot market. This research program established by Cheng and Xiong (2014) includes many axes :

> "The following directions will likely be particularly fruitful for future research. First, future research must update its practice of categorizing trading by hedgers as hedging and trading by speculators as speculation. Systematic modeling of the different trading motives of hedgers and speculators at different times is necessary to uncover the dynamics of risk sharing in commodity futures markets. Second, incorporating informational frictions and the informational role of commodity prices into existing theoretical and empirical frameworks is likely to significantly improve our understanding of the boom and bust cycles of commodity prices. Furthermore, to the extent that commodity markets are an indispensable part of the global economy, it is important to understand how risk reallocation and information transmission from commodity markets affect the real economy and the global financial markets."

These research axes are burning issues now. The commodity trade is the core of the market system. A commodity is vaguely defined such as "*a product that has broad recognition and which trades in markets which have prices based on homogeneous products*" (Gordon et al., 1999). No quality differentiation is possible, so every operator on a commodity market sells similar standardized products. The quality standardization is enforced in the specifications of futures contracts (Lautier, 2013). Ironically, the commodity markets can be considered as the pinnacle of what Marx (1875) calls the "commodity fetishism" where social relationships are mediated through objects, commodities and money, in market exchange. Nonetheless, the social impacts of commodity markets are real even if they are not visible by commodity traders. "*At a deeper level, episodes of sustained volatility generate considerable uncertainty. They spawn increased risks in productive activities and undermine food security and economic growth in developing countries*" (Prakash, 2011). For low-income households in developing countries, a sudden rise in food prices means starvation. Prakash (2011) adds that such a situation increases political insecurity and the risk of internal conflict. In the US, higher energy prices have been associated with higher numbers of heart attacks (Brown et al., 2017). High commodity prices are associated with higher volatility (Deaton and Laroque, 1992). The latter is negatively related to the storage level, which plays the role of buffer. Moreover, inventories increase supply which lowers the spot price. Farer is the maturity of the futures contract, the less the price is sensitive to the news about the disturbances of the spot market (Samuelson, 1965). This phenomenon is called the "Samuelson effect."

Systematic modeling able to explain how prices and quantities vary require a theoretical framework where both the futures and the spot prices are endogenous. The workhorse model of this thesis is from Ekeland et al. (2019).

0.1 Conceptual framework: The Futures-Spot loop

Understanding how financialization works requires both economic and financial modeling. Every chapter focuses on the loop between the futures and the spot market. The first task is to disentangle economic and financial motives. To overcome this issue, I use the theoretical framework of Ekeland et al. (2019). This model shows how speculation and hedging interact through the reciprocal feedbacks between futures and spot prices. Both are endogenous. It is a two-period model with a spot and a futures market. On the spot market, there are spot traders and hedgers. Hedging in this model includes storers who are naturally short and processors who are naturally long. Storage is from the first period to the second period. Processors buy input for their output in the second period, but they can decide to hedge it in the first period. Thus, the hedging pressure, which is the difference between the short and the long hedging positions, can be net short or net long. One key result of this model is that financialization benefits to the dominating side of hedging.

The equilibrium model of Ekeland et al. (2019) is a production economy where there is feedback between the spot and futures prices, which are both endogenous. A production economy is an intertemporal equilibrium where it is possible for agents to transfer. Therefore, the expectation of the spot price at maturity is endogenous too. Ekeland et al. (2019) show that an increasing weight of speculators diminishes the speculation payoff because of the higher competition among them. Their counterparts which are the dominating side of hedging get better off because they pay less for the risk-bearing service. For example, if the hedging pressure is net short, short hedging will become less expensive and will increase with a lower positive risk premium. The well-being of speculators and dominated hedgers decrease while dominating hedgers come out winners.

In the model of Ekeland et al. (2019), there is one commodity, a numéraire, and two markets: the spot market at times t = 1 and t = 2 and a futures market in which contracts are traded at t = 1 and settled t = 2. The model allows for short positions on the futures market. When an agent sells (resp. buys) futures contracts, her position is short (resp. long), and the amount of futures contracts she holds is negative (resp. positive). On the spot market, short positions are not allowed. There is a nonnegative binding constraint on inventories. In other words, the futures market is financial, while the spot market is physical. There are three kinds of operators which make intertemporal decisions:

- *Storers or inventory holders (I)* have storage capacity and can use this capacity to buy the commodity at t = 1 and release it at t = 2. They trade on the spot market at t = 1 and at t = 2. The storers also operate on the futures market. Thus they can hedge the sale of their inventories for the second period on the futures market in the first period. They are naturally long on the spot market.

- *Processors (P)*, or industrial users, use the commodity to produce other goods that they sell to consumers. Because of the inertia of their production process and because all of their production is sold forward, they decide at t = 1 how much to produce at t = 2. They cannot store the commodity, so they have to buy all of their input on the spot market at t = 2. They also trade on the futures market. Thus they can hedge the purchase of their inputs for the second period on the futures market in the first period. They are naturally committed to buying on the spot market.

- *Speculators (S)*, or money managers, use the commodity price as a source of risk to make a profit out of their positions in futures contracts. They do not trade on the spot market. Speculators bear the risk of hedgers. They expect a benefit which is called risk premium.

There is a weight $(N_j)_{j\in\{I,P,S\}}$ for each of the groups described above. Every agent (except the spot traders) is assumed to be a risk-averse inter-temporal utility maximizer. They make their decisions at time t = 1 according to their expectations for time t = 2. Spot traders do not participate in the futures market. For small businesses like farms, learning futures trading and transaction costs can be a significant deterrent to trade futures contracts (Hirshleifer, 1988). Thus, some operators in the spot market renounce to participate in the futures market.

Further, the futures and spot markets operate in a sort of partial equilibrium framework:

in the background, there are other sellers of the commodity, and processors as well. These additional agents are referred to as spot traders, and a demand function describes their global effect. I use the notation "˜" for the realized values of the random variables in period 2. All traders make their decisions at time t = 1, conditionally on the information available for t = 2. The timing is as follows:

- For t = 1, the spot and the futures markets are open. Spot traders supply ω_1 and demand $\mu_1 - mP_1$. The spot price is P_1, the futures price is F and m is the elasticity of the spot demand.

- For t = 2, the spot market is open and the futures contract are settled. Spot traders supply $\tilde{\omega}_2$ and demand $\tilde{\mu}_2 - mP_2$. The spot price is P_2. The futures contracts are then settled. I assume that there is a perfect convergence of the basis at the expiration of the futures contract. Thus, at time t = 2, the position on the futures market is settled at price P_2 that is prevailing on the spot market.

This theoretical framework relies on heterogeneous hedging needs. The outcome of the latter is hedging pressure, which enables trading. Otherwise, there would be no risk to transfer. No trade would occur. As Kenneth Arrow casts it, heterogeneity is the mother of trades:

> "One of the things that microeconomics teaches you is that individuals are not alike. There is heterogeneity, and probably the most important heterogeneity here is heterogeneity of expectations. If we didn't have heterogeneity, there would be no trade. But developing an analytic model with heterogeneous agents is difficult.
> Heterogeneity is closely tied to information and how information is diffused through the system. And it is also tied to individuals' limited capacity to process information. This is where complexity theory comes in."
>
> \- Colander et al. (2004)

The literature about the equity market stresses the heterogeneous beliefs of traders (Scheinkman and Xiong, 2004). The latter phenomenon is the cause of disagreements, which generates additional trading volume and both higher asset prices and volatility because agents do not have the same valuation of the asset. With financialization, more and more speculators are active in the commodity futures markets.

The research question of this Ph.D. thesis wonders about the impact of the heterogeneous opinions, of traders engaging in speculative activity on the futures market, over the spot market. Heterogeneous beliefs and information influence prices. The latter change expectations as well, which generates feedback. This circularity goes on the top of the spot-futures loop of the theoretical framework of this thesis. The problem is challenging from both economic and mathematical points of view. Equations become quickly intractable, and there is a lot of economic mechanisms to disentangle.

Chapter 1 considers the informational role of commodity prices. Financial operators bring additional information. Moreover, authorities provide public forecasts to anchor the expectations in fundamentals. In 2011, the G20 created the Agricultural Market Information System (AMIS) to improve the information available to market participants. The issue is how information aggregates to give a more informative price, and if an increasing informativeness enhances how the market works.

Second, this thesis also studies the heterogeneity of beliefs. Overconfident beliefs can even lead to bubbles (Scheinkman and Xiong, 2003). In the commodity markets, technical trading arouses interest in the literature (Joëts, 2015; ter Ellen and Zwinkels, 2010). Technical traders are mostly systematic traders. They follow mechanical rules that rely on the evolution of past prices. From the latter, they try to extrapolate a trend they follow. Their beliefs are self-fulfilling prophecies. If they believe the price will rise, they all buy, which can raise the price. A bubble phenomenon is thus possible. According to the database BarclaysHedge, the assets under management (AUM) of systematic traders grew from \$22.9 billion in 1999 to \$316.4 billion in 2013. At the first semester of 2019, the volume of AUM is \$303 billion. Chapter 2 estimates the impact of trend-followers on the US natural gas. This empirical work looks at evidence of the impact of technical traders on futures prices, and it considers the impact on the spot market through the estimation of the feedback from the futures price to the spot price. Chapter 3 broadens this issue with a theoretical model to figure out the potentially destabilizing impact of technical traders over the spot market.

0.2 Aggregating heterogeneous information

0.2.1 Defining information

Information and beliefs are the two ingredients that make the opinions of human beings. The following definition of information is inspired by Quéré (2000). Information requires a medium. The most common in economic modeling is the signal, which is a message containing a piece of information. The information has a meaning given by constraint which establishes a causal relationship. For example, news of a bigger harvest in a crop market implies a positive supply shock which decreases the price. This example also illustrates that a fact does not give information about itself but about another fact. Here, the harvest gives information about the crop price. Information can be about events remote in space and in time. In a nutshell, information is processed data. Above all, information affects behavior (Quéré, 2000). Signals help agents to make economic decisions. They can be private, known only by a limited group of people. At the opposite, they can be public, meaning they are common knowledge. The most famous public signal is the price. The intuition goes back to Hayek (1945). The price conveys information. They have implications for economic agents under their local knowledge of the economy. For example, a real estate agent knows how one's market works. Therefore, prices spread the information and help economic agents to adjust to each other. Hayek's approach does not rely on rational expectation and is compatible with bounded rationality. Each agent follows a heuristic and transmits information through trading according to Hayek (1945):

> "The whole acts as one market, not because any of its members survey the whole field, but because their limited individual fields of vision sufficiently overlap so that through many intermediaries the relevant information is communicated to all. The mere fact that there is one price for any commodity or rather that local prices are connected in a manner determined by the cost of transport, etc. brings about the solution which (it is just conceptually possible) might have been arrived at by one single mind possessing all the information which is in fact dispersed among all the people involved in the process."

The Hayek vision is different of rational expectation modeling and is nearer of the social action theory of sociologists like Parsons and Luhmann or agent-based modeling which assumes the rationality of the whole system rather than the rationality of individuals (Boldyrev, 2013). At the opposite, this thesis follows the usual method of rational expectations used in economics. Agents are assumed to be consistent by maximizing their utility or their profit with all the information available. This behavior is called "rational." Therefore, the rational expectation of a variable is unbiased and is the best estimation. Agents have the same prior which comes from the knowledge of how the economy works. According to Aumann's agreement theorem, agents with the same priors who get the same information cannot agree to disagree (Aumann, 1976).

Prices are a function of information spread among operators because they trade by taking into account what they know. Thus, prices are functions of agents' signals. Rational agents know the price process so they can use prices to reveal signals of each other. Grossman (1977) shows how in equilibrium with futures trading, traders can use the spot and the futures price to reveal the information spread in the economy fully. In this situation, all the information is transferred from the informed to the uninformed agents. Therefore, they have the same anticipations (Aumann, 1976). Rational expectation equilibrium (REE) captures Hayek's idea of information aggregation by prices. A REE is a set of quantities and price which fulfills market-clearing conditions with no desire of agents to recontract (Grossman, 1981). Nonetheless, the way is different, Hayek (1945) tells prices transmit information to agents who are connected but have partial knowledge of how the economy works. While rational agents have complete knowledge of the price process and fully revealing prices are equivalent to have all the information spread in the economy (Grossman, 1981). The REE framework seems less realistic with representative rational agents, but this model has the advantage of tractability. I choose this kind of modeling to study commodity price informativeness, which is the informative content of prices.

0.2.2 Chapter one: how price informativeness impact futures markets

This chapter looks at how more information affects the net demand on the spot market of hedgers and the risk-bearing activity of speculating agents. This work studies, in particular, the consequences of the redistribution of risk sharing on the well-being of operators. The chapter's approach is theoretical by applying Bayesian theory to an equilibrium model. I introduce information in Ekeland et al. (2019) described in section 0.1. Every group of agents, whatever for speculators, storers or processors, is endowed with a common signal about the net demand at maturity. In this theoretical setting, an efficient market is defined as a Fully-Revealing Rational Expectations Equilibrium (FRREE) (Grossman, 1977). Knowing the price is equivalent to know all the private information. A unique FRREE exists if the hedging pressure is linear. Two theorems from Grossman (1978) and Bray (1981) are extended with a linear hedging pressure to prove the existence and the uniqueness of the equilibrium. I show the FRREE implies the futures price is the unique predictor of the spot price. It is a sufficient statistics. It means it contains all the agents that need to know. In an efficient market, the futures price is a biased but efficient estimator of the spot price at the contract maturity. The bias is the expected payoff of speculation, which is the difference between the expected spot price at maturity and the futures price. The bias in the futures price is called a risk premium. This value is also the income asked by speculating operators as counterparts of the risk sharing.

I distinguish private and public informations. Private information is content which is known only by a share of the population of operators. In this chapter's model, each group (speculators, storers and processors) is endowed with a signal which is common to each of its members. A signal which is known only by a specific group is thus considered as private. At time t = 1, operators receive a signal $(s_j)_{j\in\{I,P,S\}}$ common to the group which they belong. This signal is unbiased such as:

$$\forall\, j \in \{I, P, S\},\ s_j = \tilde{\xi}_2 + \varepsilon_j \quad \text{with } \varepsilon_j \sim N(0, \sigma_j^2) \tag{1}$$

Production of the commodity is inelastic: the quantities ω_1 and $\tilde{\omega}_2$ that reach the spot market at times t = 1 and t = 2 are exogenous to the model. Operators know ω_1 and μ_1 , and share the same prior about $\tilde{\omega}_2$ and $\tilde{\mu}_2$. The operators making intertemporal decisions (storers, processors and speculators) update their decision according to their information set. The latter includes the signal received by the operator according to one's group and public information at time t = 1. I define public information as content known by the whole population of operators. Everyone on the market knows prices. The last ones are endogenous variables which are the results of clearing equations. Prices are the outcome of the positions of the agents based on their information. Thus, operators can infer the private information of the other agents from prices. Therefore, we can write the information set $((\mathcal{F}_j)_{j\in\{I,P,S\}})$ such as :

$$\forall\, j \in \{I, P, S\},\ \mathcal{F}_j = (s_j, F, P_1) \tag{2}$$

First, I show how information can modify the structural relationship between the spot price at maturity (P_2) and the futures price (F). Mathematically, this is represented by a linear equation such as $P_2 = \alpha + \beta\, F + \varepsilon$ which describes a regression. α and β are coefficients while ε is an error term. The futures price bias, which is the conditional risk premium($E[P_2|F] - F$), varies directly through the futures price and indirectly when the equilibrium regime changes. The coefficients of the regression relationship (α and β) vary with the basis and the spread between the futures price of the input and the output price (of the processors). The conditional risk premium and the unconditional risk premium ($E[P_2 - F]$) can be different structurally different. Their equations can be written as such :

$$E[P_2|F] - F = \alpha + (\beta - 1)F \tag{3}$$

$$E[P_2 - F] = E[\alpha] + E[\beta\, F] - E[F] \tag{4}$$

Even if $F = E[F]$, the coefficients may differ. Therefore, estimating the coefficients of the unconditional risk premium to compute the risk premium can be misleading. Moreover, in practice, the spread with the output price is not always known. Therefore, the estimation of the conditional risk premium is harder. The analysis of speculation by Ekeland et al. (2019) still holds. Liquidity increases so the risk premium decreases. This result is consistent with Chinn and Coibion (2014) who shows that the rising liquidity does not improve the efficiency of the futures price as an estimator of the spot price at maturity.

Second, More informative prices increase the elasticity of the hedging pressure to the risk premium, exactly like when the weight of speculators increases. Both intensify competition among speculating agents, so the payoff of a speculative position (or risk premium) decreases. Risk-bearing is less costly and the absolute value of hedging pressure increases.

Last, I shed new light on the conditions which make more precise information harmful for every agent. In this situation, everyone loses because of a decreasing payoff coming from speculation. This last effect is known as the "Hirshleifer effect." More precise information lowers the amount of risk transferred on the futures market for a given amount of hedging positions. The latter becomes less risky. The risk premium earned by speculators decreases. Therefore, higher informativeness can be harmful to all the agents by destroying hedging opportunities. Operators are worse off because they expect to make less money. The public disclosure of information adds a distributive risk which lowers global welfare. Hirshleifer (1971) shows that information has no social value in a pure exchange economy. Therefore, agents in a pure exchange economy with random endowments can be hurt. Better information decreases the amount of risk to share. Thus there is less trading on the risk-sharing market. This phenomenon occurs in financial markets (Goldstein and Yang, 2017). If agents trade fewer goods between them, it means they rather tend to consume their endowments. Thus, the new allocation of risk becomes Pareto inferior to the one with no information. Schlee (2001) shows that one sufficient condition (for the better information to be Pareto inferior in a pure exchange economy) is that "*all agents are risk averse and the economy has a representative* *agent who satisfies the expected utility hypothesis with a concave differentiable von Neumann-Morgenstern utility function.*" In this case, the concavity of the utility function in beliefs makes the agents dislike information in a pure exchange economy. In this chapter, all the agents have a constant-absolute-risk-aversion (CARA) utility function which satisfies the criterion for a representative agent. This implies the equilibrium prices reflect a kind of average of the risk aversions and the conditional variances of each agent according to their information set and preferences (Lintner, 1969). Nonetheless, the equilibrium of the model is not an endowment economy. Storers can transfer an amount of commodities from a period to another. My model is a production economy because storers can carry one unit from the first period to the final one after. Better information can help producers to make better decisions about their output level (Eckwert and Zilcha, 2001). I get two contrary effects: the decrease of the risk-sharing business which harms operators while the improvement of production decisions can improve welfare. Therefore, information can increase or decrease the agents' well-being. Before signals release, traders do not know in which direction prices will move. When the hedging pressure is already very elastic, the increase of the hedged amount is too small to offset any loss caused by a lower risk premium. Thus, a Hirshleifer effect occurs. Everyone's well-being is decreasing.

An interesting extension would be to introduce noise generated by the equity portfolio of speculators. This would generate a Partially Revealing Rational Expectation Equilibrium (PRREE). This property would enable to study more realistically the effect of additional signals. The consequence of the Aumann's agreement theorem is that agents can not disagree in a REE if they have the same information. If the latter is not fully revealed, agents have different anticipations. Nonetheless, they still agree on the underlying model of the economy. There is no room for technical traders (also called "chartists") who follow trends or momentum. The development of electronic trading platforms and computer technology in the 1980s generated a massive arrival of computer-guided technical trading systems (Lukac et al., 1988). The issue is that this "noise trading" can grow with bigger liquidity which could disturb markets by generating excessive volatility (Lautier, 2013). The destabilizing influence of automatic technical trading was the topic of divisive debate in a senate hearing in the 1980s (Bradford and Galbraith, 1984; Brorsen and Irwin, 1987). There is a "*Tinkerbell effect*" of these strategies. Their effects exist because traders believe it. If traders buy when the price is rising, the price will be kept on increasing and vice-versa. Trend-following strategies contribute to volatility and might generate bubble patterns. De Long et al. (1990) show that for stocks, the price can vary irrespective of the fundamental value of the asset. The self-fulfilling prophecy is activated so "*rational destabilizing speculation*" can occur. Tokic (2011) suggested a generalization for futures markets. Rational speculators taking large positions generate a considerable variation of prices. If trend-followers are active on the market, they exacerbate the trend which increases volatility. Moreover, contrarians are forced to give up because of too expensive margin calls. There is a potentially destabilizing effect of different beliefs if some of them can generate trends because of different impulses from a few traders.

0.3 Asset pricing with heterogeneous beliefs: a room for rational destabilization?

0.3.1 Defining what a belief is

The psychologists McGuire and McGuire (1991) suggest that people cope with the situations they encounter in daily life by trying to explain past events and predicting their occurrence in the future (Wyer and Albarracín, 2005). One of these coping strategies is utility-maximization. "*The person's thought about a core event's desirability (often called his or her attitude) is his or her evaluative judgment of how desirable the event's occurrence would be*" (McGuire and McGuire, 1991). The authors add this principle can be sum up in the biblical maxim "*By its fruits, you will know it*" (Matt 7:16). Economics kept only this utility-maximizing strategy to study behaviors. This methodology makes sense in the light of the definition of economics given by Robbins (1932): "*Economics is the science which studies human behaviour as a relation between ends and scarce means which have alternative uses.*" Economic agents look only at the desirability of the outcomes of their actions. Their beliefs are the probabilities of the events which affect the results of their decisions. The probability operator is $P(\cdot)$. For example, speculators on wheat take into account the forecast of the next harvest because it determines the supply and thus the spot price at maturity. The latter is the payoff of a long futures position. A rational agent, endowed with a piece of information I about an event E, updates one's prior belief about the occurrence of the event ($P(E)$) to make a new informed belief ($P(E|I)$). The Bayes' rule describes this updating process:

$$P(E|I) = \frac{P(I|E)P(E)}{P(I)} \tag{5}$$

$P(I|E)$ is the likelihood of the information. The higher is the probability, the likelier the event is going to occur. The likelihood increases the belief of the occurrence of the event E.

At the opposite, the higher is the probability to get this information, the less weight is given to it. Valued information is plausible and rare. (Vives, 2010, p. 79) describes how optimal are rational expectations :

> According to the rational expectations hypothesis, agents anticipate the future according to the true probability distribution of future events. Agents are endowed with their private information and a correct model of the relationship between equilibrium prices and other agents' information. The beliefs of agents influence their actions, which in turn affect the true probability distributions or correct beliefs. A rational expectations equilibrium (REE) is then a fixed-point of a map from beliefs to correct beliefs mediated by the actions of agents. Agents form expectations using optimally the information they have in the context of an equilibrium. Rational expectations are, therefore, just equilibrium expectations.

In a REE, operators have the same prior beliefs. According to Aumann's agreement theorem, a PRREE implies different posterior beliefs. This theoretical framework has been fruitful to study the beauty contest (Goldstein and Yang, 2017). Keynes (1936) describes the stock market with an analogy based on a fictional newspaper contest. Winners are those who choose the most popular pictures of faces among all the participants. The gamer has not to choose the best faces according to one's taste. She must guess what others would choose. This logic can be pushed one degree further, to guess what the others think the most popular faces are. It is possible to go even degrees furthers. Financial markets work similarly to Keynes's beauty contest because the trader who guesses the opinion of the market before everyone can make the right move. In the equity market, the issue of the beauty contest on firms' decisions is raised after the dot-com bubble in 2000 (Hirshleifer et al., 2006). Goldstein et al. (2013) show that trading frenzies can occur when there is feedback from the stock price to the firm's real investment. Speculators are incited to rush to trade in the same direction because a higher stock price raises investment, which thus increases the firm's value.

The other intuition of Keynes (1936) about the beliefs in the financial market was what he calls the "*animal spirits.*" This terms refer to the emotions and the feeling of overconfidence which can drive human behaviors. Hirshleifer et al. (2006) show that the presence of irrational investors affect stock prices and companies' investments when there is a feedback from stock prices to cash flows. These traders, who have baseless beliefs, might even generate profit which can be bigger than the one of rational traders. Thus, they deduce "animal spirits" can have lasting financial and real effects. Irrational traders generate fluctuations to fundamentals even when markets are informationally efficient with prices following a random walk. Self-fulfilling dynamics do not only affect the market price but the underlying value itself. This is this issue I want to tackle with my following chapters.

0.3.2 Chapter two: Trend-followers in the US natural gas market

Tokic (2011) highlights 90% of Commodity Trading Advisers (CTA) registered in IASG.com only use technical/quantitative analysis in their trading approaches. CTAs provide individualized advice for customers who want to take positions on commodity futures or options. They can be hired by a Commodity Pool Operator (CPO) to make investment decisions. Both are regulated by the National Futures Association (NFA) and the Commodity Futures Trading Commission (CFTC). The managed future industry became a major actor in the commodity futures markets. Between 2007 and 2015, financial operators represented roughly 60% of the open interest (see chapter 2) in the US natural gas market. The bigger group among them is money managers which weights half of the open interest only. The US natural gas market is quite deregulated, and there is a massive presence of speculators using technical trading techniques. Therefore, it is interesting to study the impact of traders with different beliefs about the trends of the market on the US natural gas pricing.

This chapter follows the approach of the risk premium, which evaluates the different underlying forces that contribute to the US natural gas pricing. Moreover, I look at the feedback of the futures price to the spot price of the US natural gas market. A first intuitive way to look at the pricing is to study fundamentals. Abundant literature exists about the risk premium, which is the payoff of speculators to bear the overall risk of hedgers, which is the hedging pressure. This hedging pressure theory has four implications (Gorton and Rouwenhorst, 2004):

1. The expected payoff of a futures position is the risk premium. The realized payoff is the risk premium plus any unexpected deviation of the future spot price from the expected future spot price
2. A long position in futures is expected to earn positive (excess) returns as long as the futures price is set below the expected future spot price.
3. If the futures price is set below the expected future spot price, the futures prices will tend to rise over time, providing a return to investors in the future.
4. Expected trends in spot prices are not a source of return to an investor in the future.

In this theoretical framework, speculators take the opposite side of hedgers. Speculators offset the net demand implied by the hedging pressure. Thus, the market clears. Therefore, speculators bring liquidity according to this theoretical frame. Indeed, if the hedging pressure is net short, speculators have long positions to clear the market. At the opposite, if the hedging pressure is net long on futures, speculators are short.

Nonetheless, Gorton et al. (2013) find no evidence that the positions of participants predict risk premiums on commodity futures. They find the contemporaneous hedging pressure is positively related to futures returns. However, there is no significant influence of ex-ante hedging pressure on futures returns. Commercials positions become shorter while noncommercials go longer when the futures price increase. Thus, noncommercials behave like momentum traders. Fishe and Smith (2018); Gorton et al. (2013); Kang et al. (2017); Rouwenhorst and Tang (2012) find that non-commercial traders are trend followers and commercial traders are contrarian. The implication is significant because trend-followers ask for risk sharing as well, so they need counterparts. Therefore, two kinds of risk premiums exist on the market, one for hedgers and another one for trend-followers (Kang et al., 2017). This fact completely changes the nature of interactions on the market because commercial traders are the counterpart of a risk-sharing demand coming from speculators who want to bet on futures trends. Roles are reversed. This chapter belongs to this set of literature by confirming these findings. In this chapter, I set up a method to estimate these two kinds of risk premium by modifying the regression of Schwarz (2012) to capture trend-chasing strategies at a weekly frequency. The spot price at maturity is included to capture rational speculation as well, like in Moosa and Al-Loughani (1995).

Commodity prices are barometers of the economy. They convey information. A higher commodity price might be the consequence of higher demand. Therefore, demand could increase because agents anticipate a stronger economy. This informational effect can be high enough to offset the cost effect. Two different cases of the value of price elasticity exist:

1. The classical case of hedging pressure theory when there is no influence of informational effect: the spot demand is decreasing with the price strictly. The informational effect does not offset the cost effect. If there is a financial shock rising the futures price, the spread between the futures price and the spot price (called the *basis*) increases. The effect is different whether the forward curve is in contango or backwardation. When the futures price is increasing with maturity (contango), the storage level increases, which is a positive demand shock on the spot market. Therefore, the spot demand decreases

because of the higher spot price. This last effect mitigates the rise of the spot price. The storage level replaces the spot demand. Thus, the sensitivity of the futures price to the spot price is lesser than one. There is an under-feedback from the futures price to the spot price. For any shock affecting the futures price directly, the spot price will vary less than the futures price. The basis grows. The level of inventories rises. This dynamic generates a positive supply shock at maturity. The release of inventories, at the expiration of the futures contracts, drives the spot price down.

When the futures price is decreasing with maturity (backwardation), the basis remains still negative. Storage is not increasing, but the rising futures price makes hedging costly for long hedgers. The latter reduce their hedging positions, which will translate in a negative demand shock at maturity. The spot price is driven down at maturity as well. Nonetheless, inventories did not vary.

2. The informational effect offsets the cost effect : the spot demand is increasing with the price. The informational effect offsets the cost effect. If there is a financial shock rising the futures price, the temporary higher demand of the storers will push the spot price upward. Therefore, the spot demand increases because of the higher spot price, which deters storage activity. The spot price rises even further. Thus, there is an over-feedback from the futures price to the spot price. For any shock affecting the futures price directly, the spot price will vary more than the futures price. The basis diminishes. The inventory level decreases. It is the situation described by Sockin and Xiong (2015).

Two aims guide this chapter. First, I look at the sensitivity of the spot price to the futures price to check if there is a sign of an informational effect. Second, the sensitivity of the futures price to past values is estimated. In each equation, other variables are put as control.

The regression for the futures price is directly inspired by Schwarz (2012) who focuses on returns however. The cointegration relationship established in subsection 2.3.3 enables to estimate non-differentiated time series in levels. I add a second lag of the explained variable and the spot price at maturity. The latter variable comes from Moosa and Al-Loughani (1995). The aim is to measure the weight of rational speculation, which takes positions according to the expected spot price at maturity. The latter is assumed to be unbiased.

I test the following system :

$$P_t = a_{10} + a_{11} F_{T,t} + a_{12} Q_t + n_t \tag{6}$$

$$F_{T,t} = a_{20} + a_{23} P_T + a_{24} F_{t-\Delta t,T} + a_{25} F_{t-\alpha\Delta t,T} + a_{26} \mathrm{HP}_t + a_{27} \Delta\, \mathrm{HP}_t + v_t \tag{7}$$

P_t is the price of the natural gas on the physical market. $F_{T,t}$ is the natural gas constant-maturity futures price. P_T is the spot price of the day of the expiration of the futures contract. Q_t is the physical traded volume of natural gas on the Henry Hub. HP_t is the Hedging Pressure (HP) which is the difference between the long and short positions of the commercial traders. Δ is the mathematical difference operator. n_t and v_t are error terms. The study looks in particular at these specific values:

- The sensitivity of the spot price to the futures price (a_{11}). If it is higher than one, there is an informational effect offsetting the cost effect with an over-feedback. Therefore, the Sockin-Xiong condition would be fulfilled. The empirical condition for an informational effect is equation (16).

- The sensitivity of the futures price to its value last week (a_{24}) and the week before (a_{25} with $\alpha = 2$). Δt is a variation of one week. A positive coefficient is consistent with the existence of trend-following strategies and short covering. I test two alternative hypotheses for the trend-following positions. The first is based on the difference between the futures price last week and the price the week before, or weekly profit (De Long et al., 1990). a_{24} and a_{25} must be positive. The other one is based solely on the price last week (Koutmos, 1997). a_{24} must be positive only.

- The sensitivity to the hedging pressure (a_{26}). I compute the hedging pressure as the difference between the short and the long position of commercials. According to the risk-premium theory, the hedging pressure becomes shorter when the futures price decreases, and vice versa when hedgers get longer (Bessembinder, 1992). The expected profit of speculation has to be positive. Therefore, if hedgers are net short, the expected profit of a futures position has to be positive for speculators to go long as counterparts of hedgers. I expect a negative value of the coefficient a_{26}.

- The price pressure (a_{27}). If hedging is driving trade, an increase in short hedging drives the futures price downward. This liquidity effect is temporary. In this situation, the value of the coefficient a_{27} should be negative. Afterward, this temporary effect would be reversed (De Roon et al., 2000). Otherwise, if the coefficient is positive, the hedging pressure is not driving prices. Thus, hedgers are contrarian and provide risk-sharing to speculators who are trend-following (Kang et al., 2017).

Therefore, I expect the system meets the following constraints if the hedging pressure theory is verified :

$$a_{11} \leq 1 \quad (8)$$

$$a_{24} = 0 \quad (9)$$

$$a_{25} = 0 \quad (10)$$

$$a_{26} > 0 \quad (11)$$

$$a_{27} < 0 \quad (12)$$

At the opposite, if technical traders impact the pricing and drive the risk-sharing demand as described by Kang et al. (2017), the coefficients for the variation of hedging pressure and past returns are positive. Therefore, the following conditions are met :

$$a_{24} \in]0,1[\quad (13)$$

$$a_{25} \in [0,1[\quad (14)$$

$$a_{27} > 0 \quad (15)$$

Such a situation means commercials act as contrarian and prices depend positively of their past values. Therefore, such a result implies there is positive feedback trading among non-commercial operators.

The presence of information frictions, as defined by Sockin and Xiong (2015), implies :

$$a_{11} \geq 1 \quad (16)$$

If the sensitivity of the spot to the futures price is higher than one, the demand is increasing with the spot price. An increasing futures price raises even more the spot price. Thus, both prices can rise at the same time with a constant or a decreasing storage level. This analysis is possible because of the cointegration of regression variables and the instruments.

I estimate the influence of trend-followers on the Nymex, the US gas natural futures markets, and the feedback from the latter on Henry Hub, the physical market, from February 2000 to July 2015. The data set is split into two subperiods. The first one is from 2000 to 2008, including the period before and during the spike. The second one is after the spike from 2009 to 2015. Results are consistent with the existence of an impact of the trend-following strategies on the US natural gas futures and spot markets.

The estimation of the parameters of the futures equations show a dominating role of trend-following speculation for weekly variations on the Henry Hub and Nymex from February 2000 to July 2015. The result is consistent with a significant influence of the trend-followers on the US natural Gas futures market.

The feedback effect from the futures market to the spot market is confirmed. 2008 has been a pivotal year. The period 2000-2008 exhibits a sensitivity of the spot price to the futures price lesser but close to one. After 2008, there is not a stable relationship anymore between the spot and the futures prices.

My findings are consistent with speculation exacerbating trends on the futures market and generating feedback to the spot market. This situation can lead the US natural gas prices to spike and crash as in 2008 or 2014.

Further studies are needed to investigate the existence of an informational effect, in particular around 2008. Moreover, it would be interesting to look at methodologies able to capture the time-varying aspect of the sensitivity of the spot price to the futures price.

0.3.3 Chapter three: Rational destabilization

The managed futures industry has been growing exponentially since the 1980s, as shown in figure 1. In 1980, the futures managed industry weighted \$0.31 billion. In 2018, it was \$355.1 billion. The volume takes off in particular after 2000 which is the year of the ratification of the Commodity Futures Modernization Act (CFMA).

As said earlier, the CTA (which compose the managed futures industry) are adept of technical trading techniques. They follow trends which can be impulsed by destabilizing behaviors. De Long et al. (1990) show how rational speculators can impulse trends exacerbated by trend-followers on the stock market. Tokic (2011) elaborated a theory for the commodity markets but there is no modeling. The aim of this chapter is thus to fill a hole in the literature. This work evaluates if the spot market can be destabilized by the activity of technical traders on the futures market. This chapter is theoretical and has been written with a co-author, David Batista Soares, who is Ph.D. student at the University of Caen and Agro-Paris Tech. In this chapter, we propose a model of a spot and futures commodity market that offers new perspectives on analyzing the impact of technical traders on volatility and market efficiency. Among some result, this work can contribute to the explanation of the 2008 commodity price spike and the 2014 energy price crash. We contribute to the literature by creating the first

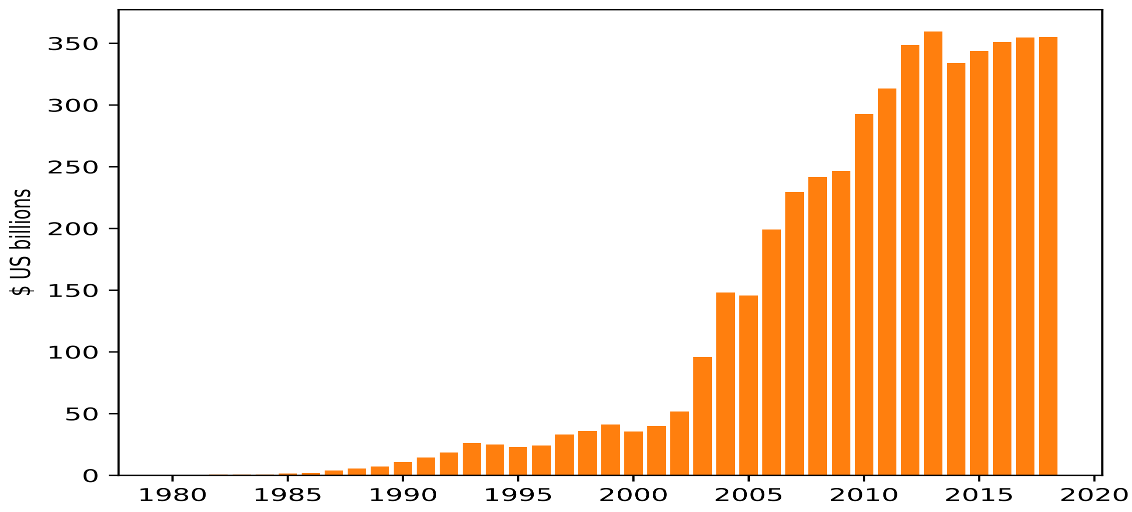

Figure 1: Assets Under Management - Futures Managed Industry. Source: Barclays

model which shows how technical traders on the futures market can impact the spot market for a given commodity indirectly. We define price stabilization by a lower price variability. If price variability decreases when a variable x increases, the variable x has a stabilizing effect on the price. For the opposite outcome on the price, the variable x is said to have a destabilizing effect. We consider both destabilizations of the futures and spot prices by the weight of technical traders among operators on the futures market. We show technical traders destabilize the spot market, and they have an ambiguous effect on the futures market.

The model we present is an extension of the model introduced by Ekeland et al. (2019), with its main advantages. This framework unifies in a simple way the storage theory and the hedging pressure theory. Both futures and spot prices are endogenous in a rational expectations equilibrium (REE). We introduce an intermediate period where technical traders enter the market according to the first-period price.

Hence, our model is a (finite-horizon) dynamic self-fulfilling REE. Therefore, "*as shown by Spiegel (1998),when equilibrium exists, it is generically not unique. Multiplicity arises because of the circularity involved by the dynamic rational expectations loop: the price function depends upon the expectation of the price function*" (Biais et al., 2010). Spiegel (1998) explains that agents need price series which match their belief systems. If several price series are consistent with the equilibrium definition, we get multiple equilibria. This result is well-known of the overlapping-generation literature (Biais et al., 2010; Ganguli and Yang, 2009; Spiegel, 1998; Watanabe, 2008) which completes the work of Lucas (1978). The latter shows a general equilibrium that generates asset prices, which are a function of the expected product of the payoff and a discount factor. In a dynamic setting, the payoff of the next asset in the next period includes the price at the next period. The payoff of a futures contract before each maturity is its price only[2]. If there is no basis risk, the final payoff is the spot price at maturity. When futures positions are revised within the cash market holding period, the dynamics described by Lucas (1978) works. There is a relationship between the futures price in the first period and the expected one for the second period. While like in the one-period case, the futures price in the first period depends on the expected payoff at maturity. We get the two rational expectations loops exhibited by overlapping-generation models. Our model does not exhibit agents with lives overlapping. However, positions for a given futures contract are overlapped because they can be initiated at different periods but they expire at the same time, maturity.

Our model even exhibits a third rational expectations loop. The underlying and so its expectation are endogenous in our model. The two loops described above impact the futures price so physical operations through hedging decisions. Therefore, we have the spot and the futures market intertwined through three rational expectations loop. Therefore, financial activity on the futures market has consequences on the spot price and so on economic activity. We present a three periods model. There is an initial period ($t = 1$), an intermediate one ($t = 2$) and a final one ($t = 3$). There are two markets: one spot market and an associated futures market with only one maturity with respective prices P_t and F_t at time t. All effective random values will be denoted with the symbol $\sim$. At the period $t \in \{1, 3\}$, spot traders generate an exogenous random supply ω_t. Their demand depends positively on an exogenous random variable (η_t) and negatively on the spot price (P_t). The spot market is under a constraint of positive inventories. In the futures markets, a contract can be opened at the initial or the intermediate period. The futures market is the only one open at the intermediate period. We justify this assumption in two different ways. The first one, following Working (1953), is that futures contracts "*(...) serve primarily to facilitate hedging and speculation by promoting exceptional convenience and economy of the transactions*". Hence, having more frequent futures market clearing does not seem to be a restrictive hypothesis. Furthermore, futures positions are revised within cash market holding periods, as in Anderson and Danthine (1983a). The implications of the latest are crucial if there is feedback from the futures market to the spot market : revising futures positions impact the final payoff at maturity of the spot market. They are settled in the final period. When traders sell (buy) futures contracts, their position is short (long), and the number of futures contracts they hold

[2]Unlike shares, there is no dividend.

is negative (positive). There is no basis risk, so at time 3, $P_3 = F_3$. Three kinds of operators make inter-temporal decisions. The two first one are physical operators. They hedge their activity on the spot market with futures contracts. The last kind is the speculators. They only trade in the futures market. We have two myopic groups who act for one period only: the exogenous spot traders at each period and the technical traders who are active at the intermediate period on the futures market only. Therefore, we extend Ekeland et al. (2019) in two ways: we add period, with the futures market open, and by introducing technical traders. This extension is quite similar to Anderson and Danthine (1983b) where hedgers, endowed with a non-stochastic technology, choose their physical positions to hedge in the first period and a second period with the possibility to change futures positions.

At time $t = 2$, we introduce changing investment opportunities (Breeden, 1979,8; Merton, 1971,7). Active operators on the futures market take into account the relationship between the payoff of the positions taken at the first period and of the ones taken at the second period, to select their positions. All realized values are common knowledge for all kinds of agents. Let μ be additional news about the harvest at time $t = 3$ which is revealed at time $t = 2$. There are two effects of this quantity news on investment opportunities. First, this additional harvest information has a negative impact on the spot price at maturity (P_3). Second, $\text{Cov}[\mu, \xi_3] = 0$, with ξ_t being equal to the exogenous net demand for the commodity at time t (see below). $\tilde{\mu}$ is an independent news shock that brings information on the exogenous net demand at maturity. This feature links spot prices between them through every period.

This chapter shows that the existence of equilibrium is determined by a fixed-point equation, which is a second-degree polynomial. Therefore, there is a potential multiplicity of equilibria, which is a source of instability. The variance in the expected utility requires to solve an endogenous moment of order two (Spiegel, 1998). Thus, the resolution of the market-clearing conditions collapses in a second-order polynomial with two roots for the intertemporal speculative pressure which is the covariance between the payoff of a long position in the first period and the profit of positions taken in the second period[3]. These two solutions can be valid equilibria.

Intertemporal Speculative Pressure (ISP) is the covariance between the spot price at maturity and the profit of the positions written in the second period. ISP measures how the profit from speculation in the second period varies with the spot price at maturity. Agents adjust their speculative positions by taking into account the ISP in the first period. For example, if

[3]If ISP were a squared matrix of dimension K, the second-order polynomial would give 2^K solutions. This would be the case if there were K securities available to speculators (Spiegel, 1998).

ISP is negative (which seems to be the rule as we will see further), the profit of the speculative positions written at the second period and the spot price at maturity are negatively correlated. Speculative positions in the first period go longer because speculators expect the profit of a long position to be positive in the intermediate period and negative at maturity. All positions are marked-to-market. Thus, rational agents expect to go short in the intermediate period. Positive feedback trading amplifies this phenomenon. Higher is the weight of technical traders, more negative is ISP, longer are rational agents in the first period, and higher is the upward pressure on the futures price in the second period. Therefore, rational destabilization is at play. In the chapter's model, the futures market generates feedback on the spot market. This bullish dynamic on futures price is not without consequence for the spot price maturity.

The second-order polynomial of the fixed-point equation of ISP exhibits two roots. If both solutions are equilibria, they stand for a high and a low regime of covariance between the profit of the speculative positions written in the second period and the spot price at maturity. Rational agents can believe either ISP is negative a little bit or very much. Both match their belief system and are self-fulfilling prophecies. The variation of the futures price in the second period does not vary in the same way according to the regime of ISP and the levels of spot prices differ.

This chapter shows how the risk management of technical trading by rational operators modify market fundamentals. Chartists decrease the covariance between the spot price at maturity and the profit of the positions taken in the second period. Speculating agents go longer at the initial period in reaction to this expected additional risk at the next period. The longer speculative pressure at the first period drives futures price upward, which hurts long hedging and incites short hedging. This dynamic raises the spot price too in the first period. The shorter hedging pressure generates a negative net demand shock at maturity. Therefore, spot prices at maturity decrease. Finally, spot price variability increases with the rising weight of technical traders.

We also show empirical measures of hedging pressure and speculation are not always accurate. Technical traders generate a second kind of risk premium. Commercials can act as contrarians providing risk-bearing to chartists. Empirical measures of hedging pressure and Working's T exhibit caveats.

This chapter focuses on intertemporal speculative pressure and sets the intertemporal aspects of commercials' hedging decisions aside. Including revisions of hedging decisions would shed new light on the spot-futures loop. Furthermore, an extension to an infinite period would tell about dynamic evolution paths.

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Chapter 1

Does better price informativeness enhance the functioning of the commodity markets?

Contents

Introduction

Commodities futures have become increasingly popular as an asset class for portfolio managers in the first decade of the third millennium. This process is called «financialization» (Cheng & Xiong, 2014). In this context, governments consider information quality as a critical stake to guide agents' expectations. To witness, the G20 has launched the Agricultural Market Information System (AMIS) in 2011. One of the aims of the AMIS is to improve information about wheat, maize, rice, and soybeans. To fulfill this purpose, the AMIS provides analysis, by investigating topical issues, and forecasts of short-term supply and demand at both national and international levels.

An arising issue is who benefits from this policy and also who are the losers. It is possible that everyone's well-being improves or at the opposite, the global welfare decreases. This situation, when everyone loses, is labeled as a "Hirshleifer effect." More precise information lowers the amount of risk transferred on the futures market for a given amount of hedging positions. The latter becomes less risky. The risk premium earned by speculators decreases. Therefore, higher informativeness can be harmful to all the agents by destroying hedging opportunities. Operators are worse off because they expect to make less money. The public disclosure of information adds a distributive risk which lowers global welfare. I study how new public information, about net demand on the spot market at maturity, impacts risk sharing. I look in particular the consequences of the redistribution of risk sharing on the well-being of operators.

A question arising quite immediately is how the differences of information among agents affect the functions of the derivative markets. An efficient market gathers sufficient information in the price, which thus becomes the best estimator of the payoff. The issue becomes more about the quality of the aggregated information rather than the differences of information among operators. This chapter focuses on the futures only among the derivatives products because it is the most used kind of contracts in commodities markets. Besides, the futures markets have essential economic functions. The contract prices for different maturities will give information about the anticipated spot prices at maturity (Lautier, 2013). This function is called price discovery. Another important feature of futures markets is storage, which is directly impacted by prices. If the forward curve[1] is upward sloping, the level of inventories will be high because it is profitable to hold stocks to sell them later. At the opposite, a downward sloping forward curve implies a low level of storage because the higher spot price gives

[1]The forward curve defines the prices of futures contracts according to their maturity.

the incentive to sell the commodity on the physical market immediately. The forward curve reveals the anticipations of the market traders. Anticipations depend on the available information heavily. The price revelation of the information is a key feature of efficient markets. A market is strongly efficient if all the information is revealed, including private information.

My approach is theoretical. I apply Bayesian theory to an equilibrium model. I introduce information in Ekeland, Lautier, and Villeneuve (2019). This model shows how speculation and hedging interact through the reciprocal feedbacks between futures and spot prices. Both are endogenous. It is a two-period model with a spot and a futures market. On the spot market, there are spot traders and hedgers. Hedging in this model includes storers who are naturally short and processors who are naturally long. Storage is from the first period to the second period. Processors buy input for their output in the second period, but they can decide to hedge it in the first period. Thus, the hedging pressure, which is the difference between the short and the long hedging positions, can be net short or net long. One key result of this model is that financialization benefits to the dominating side of hedging. Every group of agents (whatever for speculators, storers or processors) is endowed with a common signal about the net demand at maturity. In this theoretical setting, an efficient market is defined as a Fully-Revealing Rational Expectations Equilibrium (FRREE) (Grossman, 1977). Knowing the price is equivalent to know all the private information. A unique FRREE exists if the hedging pressure is linear. Two theorems from Grossman (1978) and Bray (1981) are extended with a linear hedging pressure to prove the existence and the uniqueness of the equilibrium. I show the FRREE implies the futures price is the unique predictor of the spot price. It is a sufficient statistics. It means it contains all the information agents need to know. In an efficient market, the futures price is a biased but efficient estimator of the spot price at the contract maturity. The bias is the expected payoff of speculation, which is the difference between the expected spot price at maturity and the futures price. The bias in the futures price is called a risk premium. This value is also the income asked by speculating operators as counterparts of the risk sharing.

Moreover, noisy information makes the futures price stochastic. Thus, the difference of information among agents implies a stochastic risk premium even in an efficient market. The distribution of the conditional risk premium, the value of the risk premium according to the information included in the futures price, is determined by its unconditional moments. Therefore, the hedging pressure is stochastic as well. Both signs of the basis and the spread between the futures price of the input and the scaled forward price of the output vary with the variation of the signals. It modifies the coefficients of the linear relationship of the spot price at maturity on the futures price randomly. In this framework, an increasing weight of the speculators decreases the cost of risk sharing but does not improve the precision of the signals. I define here the precision as the inverse of the variance.

Finally, I show that the higher price informativeness about the net demand at maturity increases the elasticity of the risk-bearing capacity. This outcome is similar to financialization. The cost of risk sharing decreases. In an efficient market, an additional signal improves the precision of the sufficient statistics revealed by the futures price in the first period. Therefore, the conditional variance of the spot price decreases in the second period. This lower volatility means a less risky investment so an incentive to speculate. The operators who are risk-bearers accept at a lesser cost. In other words, they get a smaller risk premium. The effect on welfare is ambiguous. The utility arising from speculation decreases because of the diminishing risk premium coming from speculation but increases with the higher price precision. Nonetheless, empirical simulations show that when the price precision is low, an additional signal can increase global welfare by rising utilities both from speculation and hedging. When the prices are very noisy, the AMIS improves global welfare by increasing the expected profit of speculation. At the opposite, this policy may generate a «Hirshleifer effect» because more precise information is harmful when the expected gains of risk-sharing decrease, such as the utility of every operator decreases.

The paper is organized as follows. Section 1.1 reviews the literature about information aggregation mainly in the commodity markets. Section 1.2 describes the settings of the model. The main equations are in part 1.3. Section 1.4 characterizes the equilibrium showing its existence and its uniqueness. Section 1.5 shows how information makes stochastic asset pricing. Last, section 1.6 discussed the policy implications of this article.

1.1 Literature review

The equilibrium model of Ekeland et al. (2019) is a production economy where there is feedback between the spot and futures prices, which are both endogenous. Therefore, the expectation of the spot price at maturity is endogenous too. Consequently, this setting enables studying how information impacts production and speculation decisions through the interaction of prices and expectations. I show a more informative futures price decreases the absolute value of the risk premium as financialization does. Ekeland et al. (2019) show a lower absolute risk premium favors the dominating side of hedging. For example, if the hedging pressure is net short, short hedging will become less expensive and will increase with a lower positive risk premium. Nonetheless, we have an additional effect on welfare in comparison to Ekeland et al. (2019). More precise information decreases the conditional variance meaning speculation is less risky. This effect is opposite to the decline of the payoff highlighted by Ekeland et al. (2019). If the impact of the diminishing risk is stronger, everyone wins. At the opposite, everyone can lose because the declining payoff of speculation is a burden on the welfare of every operator. Otherwise, the outcome is the situation highlighted by Ekeland et al. (2019). The decreasing payoff is hurting speculators and the dominated of hedging but which does not offset the hedging gains of the dominating side.

The approach of this article is complementary to Sockin and Xiong (2015), which tackles informational frictions, which offset the cost effect on price. In their model, information is about the strength of the global economy. They show how the macroeconomic aspects can shape the asset pricing of futures contracts. While in mine, information is about the supply side, more precisely about the net demand of the commodity at maturity. I focus on microeconomic aspects while the approach of Sockin and Xiong (2015) is more macroeconomic. Both approaches are complementaries. Both are models with a rational-expectations equilibrium (REE) under asymmetric information as defined by Grossman (1981). The agents have rational expectations; i.e., traders know how the economy works. They gather all the available information, and they can compute the state of the economy through the set of prices directly. I thus assume traders use the correct model. Sockin and Xiong (2015) highlight the importance of informational frictions. Each good producer observes a private signal about a common productivity factor. The authors have a macroeconomic approach. The productivity shock of end-users is a macroeconomic factor. Informed agents convey their information about the macroeconomic situation to the commodity prices. This informational effect can be so strong that it can offset the cost effect meaning there is a commodity demand increasing with the spot price. For more realism, they refuse normal distribution for the parameters. Their variables are log-normal, and at the end, the informational effect can offset fundamental values. Their key message is that speculators have an indirect effect on commodity supply and demand through the feedback of futures price. The latter can impact the commodity demand and the spot price. If the informational effect offsets the cost effect, a rising futures price will counter-intuitively decreases the basis and thus the storage level.

Although this chapter's model is an extension of Ekeland et al. (2019), the structure is similar to Goldstein and Yang (2017a). The producers of the authors' model are equivalent to the storers modeled in this chapter. They have the same maximization program (their linear cost parameter plays the same role than the spot price in period 1 for storers). Moreover, when the futures price increases under the influence of speculators, farmers or storers get incentives to increase the supply in the next period. Therefore, a higher futures price drives down the spot price in contango. At last, their model relies on a strong assumption. Speculators have perfect information about the commodity demand shock, but they bring noise because of their security portfolio hedging in Goldstein and Yang (2017a). Therefore, the increasing weight of speculators has an ambiguous effect on the price informativeness and the risk premium. A similar effect is generated when there are strategic complementarities in the acquisition of information.

A key feature of this chapter's model is a common error for each group. This assumption can be interpreted as a biased consensus. More speculators with no new information bring liquidity only, consistent with Chinn and Coibion (2014). The literature highlighted the existence of an optimistic biased consensus among analysts (Knill, Minnick, & Nejadmalayeri, 2006). They notice that speculators can get information about oil and gas producers through analysts. The issue is their forecast of corporate earnings are often too optimistic. In their empirical analysis, "a measure of aggregate earnings surprise for the industry" is used as a proxy for information asymmetry. The later is considered as proportional to the former. Their results show a "large degree of information asymmetry" on the futures markets for oil and gas. Moreover, errors are not distributed identically and independently among speculators. The analysts' forecasts can be biased in the same direction. An explanation with rational agents has been brought (Lim, 2001). Analysts in an uncertain information environment and who are reliant on the management access as a primary source are more likely to make optimistic bias forecasts about the companies' earnings. Nonetheless, the signal in this chapter's model is not about earnings but the net demand in the next period. It is hard to say if forecasts about net demands are biased. For example, the forecasts errors of the U.S Department of Agriculture (USDA) about harvests of corn, soya bean, and wheat have been associated mostly with structural changes. There is no evidence that they are biased systematically toward leniency or pessimism (Isengildina-Massa, Karali, & Irwin, 2013).

Some speculators can be informed. For example, Hau (2001) studies the electronic trading system Xetra of the German Security Exchange, which provides data source on the equity trades of 756 professional traders located in 23 different cities and eight European countries.

He showed that traders located outside Germany in non-German-speaking cities exhibit lower proprietary trading profit in comparison to local German traders. In commodity markets, there is the same kind of concentration in towns like Geneva, Singapore, or Houston. Thus, it is reasonable to suppose that informed speculators exist.Khoury and Martel (1989) assume speculators are more informed than hedgers:

> « These speculators can exploit economies of scale and of specialization in order to have access to a continuous flow of additional relevant information concerning future supply and demand conditions in the spot ,and futures markets at a much lower cost than hedgers (Khoury and Martel 1985, 1986) [...] Moral hazard and/or the loss of lucrative trading opportunities by speculators hamper the transfer of the needed information to hedgers; and the cost (in terms of time and money) to hedgers of acquiring this information on their own generally exceeds the benefit to them. »

Khoury and Martel (1989) show how information asymmetry can lead to a positive storage level when the futures price is lower than the spot price. If the basis is negative, stockholders expect the futures price to decrease enough, such as the profit on the futures hedge exceeds the loss from the storage activity. A high discount rate and a low cost of storage reinforce this effect. Therefore, they provide an alternative explanation to convenience yield, which is the benefit associated with holding a physical good (Kaldor, 1939). When the forward curve is decreasing, the market is said in "backwardation". Nonetheless, Khoury and Martel (1989) remain quite ad hoc, and their alternative explanation did not replace the convenience yield to model storage in a backwardated market. I do not get a similar result in this chapter's model.

Other authors have made different assumptions. The involved agents in the physical commodity trading as the storers or the processors can exploit their information for speculation (Cheng & Xiong, 2014). For example, their knowledge of the local physical market enables them to exploit information frictions. Therefore, they get informational advantages that they can use. According to Vives (2010), the informed speculators are the producers while the processors are uninformed hedgers:

> « The private information of producers cannot help the production decisions because it comes too late, but allows them to speculate in the futures market where uninformed speculators (market makers) and other hedgers operate. This will tend

> to diminish the hedging effectiveness of the futures market and consequently diminish the output of risk-averse producers (since they will be able to hedge less of their production). The adverse selection is aggravated with more precise information. Adverse selection is eliminated if the signal received by producers is made public. However, more public information may decrease production because it destroys the insurance opportunities ».

The last effect is the "Hirshleifer effect". When all the information is released, it can lead to a no-trade situation such as the utility of the agents can decrease. The risk-sharing activities between the agents create insurance opportunities. New information modifies risk sharing and thus how operators trade among them on the futures market. Operators can be impacted negatively by this redistribution of risks. Therefore, information release adds a distributive risk to technological risk. J. Hirshleifer (1971) shows information has no social value in a pure exchange economy. Therefore, agents in a pure exchange economy with random endowments can be hurt. Better information decreases the amount of risk to share. Thus there is less trading on the risk-sharing market. This phenomenon occurs in financial markets (Goldstein & Yang, 2017b). If agents trade fewer goods between them, it means they rather tend to consume their endowments. Thus, the new allocation of risk becomes Pareto inferior to the one with no information. Schlee (2001) shows that one sufficient condition (for the better information to be Pareto inferior in a pure exchange economy) is that «*all agents are risk averse and the economy has a representative agent who satisfies the expected utility hypothesis with a concave differentiable von Neumann-Morgenstern utility function.*» In this case, the concavity of the utility function in beliefs makes the agents dislike information in a pure exchange economy. In this article, every agent has a CARA utility function which satisfies the criterion for a representative agent. This setting implies equilibrium prices reflect a kind of average of the risk aversions and the conditional variances of each agent according to their information set and preferences (Lintner, 1969).

Nonetheless, this chapter's equilibrium is not an endowment economy. Storers can transfer a given amount of commodities from a period to another. This chapter's model is a production economy because storers can carry one unit from the first period to the final one after. Better information help producers to make better decisions about their output level (Eckwert & Zilcha, 2001). I get two contrary effects: the decrease of the risk-sharing business which harms operators while the improvement of production decisions can improve welfare. Therefore, information can increase or decrease the agents' well-being. Before signals release, traders do not know in which direction prices will move. Sulganik and Zilcha (1996) study an equilibrium with competitive risk-averse firms that hedge the foreign exchange risk of their production they sell abroad. They show that more information is not always beneficial on futures markets for foreign exchange. The futures price can change in a disadvantageous direction for traders, specifically when there is a positive risk premium.

The empirical literature, in agricultural economics, finds a positive informative value of crop reports, in particular for the USDA's ones (Karali, Isengildina-Massa, Irwin, Adjemian, & Johansson, 2019; Mattos & Silveira, 2016)[2]. Crop prices vary with reports, which shows the markets surprise. Gouel (2018) evaluates the public benefits of news forecasts in the soybean market with a rational expectation storage model. He shows that welfare gains are about 2% of the storage costs. However, his model looks only at physical operations (consumption, production and storage), and does not take into account the Hirshleifer effect. Therefore, the advantages of public forecasts could be smaller than what the empirical literature in agricultural economics tells.

The other issue is the bias in the futures price, also called risk premium. If the equilibrium is fully revealing, the futures price can be a sufficient statistics meaning that it includes all the necessary information to get the best estimate. However, it can be a biased statistics. Moosa and Al-Loughani (1994) tested both unbiasedness and efficiency of the futures price of WTI crude oil for the period from January 1986 to July 1990. Their time series are monthly. They find a bias when they regress monthly spot returns on monthly futures returns. Moreover, they find autocorrelated residuals, which mean that the futures price is not an efficient forecaster. Last, they find a time-varying risk premium which they fit adequately with a GARCH-M(1,1) process. Chinn and Coibion (2014) run the tests for four different types of commodity prices: energy, agricultural products, precious metals, and base metals. For energy, they include petroleum, natural gas, gasoline, and heating oil. Corn, soybeans, and wheat are the three agricultural commodities in their sample. For precious metals, they consider gold and silver while their set of base metals consists of aluminum, copper, lead, nickel, and tin. Their monthly data cover the period from 1990 to 2012. They find evidence of unbiasedness for energy but not for other commodities. However, they find that increasing liquidity did not reduce bias. It did not improve efficiency either. They noticed an increased comovement among commodity futures and that since the 2000s, the basis tended to lose forecasting power, meaning the predictive content of commodity prices declined.

[2] The literature review about the informative value of crop reports is quite exhaustive in Mattos and Silveira (2016).

Vives (2010) elaborated a two-period model of asymmetric information in a futures market. There are on one hand speculators who are whether informed or uninformed. The informed speculators have a signal on the future spot price in the next period. In the Vives model, the spot price is exogenous to the futures price. On another hand, hedgers are informed about an individual endowment shock. This endowment is the quantity that the hedger, who is a processor, will sell on the manufactured good markets. The model is quite complicated to solve with substantial limitations such as the exogeneity of the spot price and the quantities of manufactured goods. The issue is the same for Perrakis and Khoury (1998), where their spot price is also exogenous in their asymmetric information model. In their model, the spot price is a martingale process. Thus, they test their model on three commodities markets of the Winnipeg Commodities Exchange's (WCE), the Canadian futures market of commodities, between 1982 and 1994. At this time, the WCE was the only futures market for canola and barley. As a benchmark, they tested their model on the wheat market. Wheat is exchanged in Chicago too. They found nonsignificant results for wheat markets, but they get a significantly Fully-Revealing Rational Expectations Equilibrium (FRREE) for the barley and canola markets. The authors acknowledge that the assumption of an exogenous price is reasonable for small markets like canola and barley at the time of the WCE. However, it seems less consistent for financialized markets. The activities of hedgers present in both markets may have consequences on the spot market. It is right in particular for storers. If the futures price is high, they will buy more commodities in the spot market. Therefore, the demand increases in the spot market, so the spot price increases.

I show that it is possible to have a very tractable model with endogenous spot prices and quantities of manufactured goods with asymmetry on the net spot demand. Traders have different information. Private information is revealed to traders through signals which are known only by the recipients. Each group of operators is endowed with a common signal. Thus, financial traders get their own signal common to their whole group. They include this information in their set of knowledge to take their positions. Therefore, they influence, through their positions, the future price which does affect the hedging pressure and thus the stored quantities and the processors' demand.

I observe a «Hirshleifer effect» in some cases, which is quite similar to Sulganik and Zilcha (1996), with prices moving in a disadvantageous direction for traders. Nonetheless, this effect exists for both positive and negative risk premium.

1.2 The settings of the model

I extend the two-period rational expectations equilibrium model of Ekeland et al. (2019) to introduce the additional feature of information asymmetry à la Grossman (1977). Therefore, the description of the model is mostly inspired by the paper of the core model (Ekeland et al., 2019). The model is based on three periods. In t=0, the markets are not open yet and there is no information. I call this period of market *ex-ante*. The unconditional moments are computed.

There is one commodity, a numéraire, and two markets: the spot market at times t = 1 and t = 2 and a futures market in which contracts are traded at t = 1 and settled at t = 2. The model allows for short positions on the futures market. When an agent sells (resp. buys) futures contracts, her position is short (resp. long), and the amount of futures contracts she holds is negative (resp. positive). On the spot market, short positions are not allowed. There is a nonnegative binding constraint on inventories. In other words, the futures market is financial, while the spot market is physical. There are three kinds of operators which make intertemporal decisions:

- *Storers or inventory holders (I)* have storage capacity and can use this capacity to buy the commodity at t = 1 and release it at t = 2. They trade on the spot market at t = 1 and t = 2. The storers also operate on the futures market. Thus they can hedge, on the futures market in the first period, the sale of their inventories for the second period. They are naturally long on the spot market.

- *Processors (P)*, or industrial users, use the commodity to produce other goods that they sell to consumers. Because of the inertia of their production process and because all of their production is sold forward, they decide at t = 1 how much to produce at t = 2. They cannot store the commodity, so they have to buy all of their input on the spot market at t = 2. They also trade on the futures market. Thus they can hedge the purchase of their inputs in the second period on the futures market at the first period. They are naturally committed to buying on the spot market.

- *Speculators (S)*, or money managers, use the commodity price as a source of risk to make a profit out of their positions in futures contracts. They do not trade on the spot market. Speculators play a role of liquidity providers in the futures market (Vives, 2010). They share risk with hedgers. Market-making or risk-bearing is a source of benefits.

There is a weight $(N_j)_{j\in\{I,P,S\}}$ for each of the groups described above. I assume that all agents (except the spot traders) are risk-averse, inter-temporal utility maximizers. They make their decisions at time t = 1 according to their expectations for time t = 2. Spot traders do not participate in the futures market. For small businesses like farms, learning futures trading and transaction costs can be a significant deterrent to trade futures contracts (D. Hirshleifer, 1988). Thus, some operators in the spot market renounce to participate in the futures market.

Further, the futures and spot markets operate in a sort of partial equilibrium framework: in the background, there are other sellers of the commodity, and processors as well. These additional agents are referred to as spot traders. A demand function describes their global effect. I will use the notation "˜" for the realized values of the random variables in period 2. All traders make their decisions at time t = 1, conditionally on the information available for t = 2. The timing is as follows:

- For t = 1, the spot and the futures markets are open. Spot traders supply ω_1 and demand $\mu_1 - mP_1$. The spot price is P_1, the futures price is F and m is the elasticity of the spot demand.

- For t = 2, the spot market is open and the futures contract are settled. Spot traders supply $\tilde{\omega}_2$ and demand $\tilde{\mu}_2 - mP_2$. The spot price is P_2. The futures contracts are then settled. I assume that there is a perfect convergence of the basis at the expiration of the futures contract. Thus, at time t = 2, the position on the futures market is settled at price P_2 that is prevailing on the spot market.

I assume that (μ_2, ω_2) is a vector of normal variables and $\text{cov}(\mu_2, \omega_2) = 0$, then μ_2 and ω_2 are independent. $\tilde{\xi}_2 = \tilde{\mu}_2 - \tilde{\omega}_2$ is the realized value of the net exogenous demand realized at period 2. For simplicity's sake, the used word for the rest of the chapter is net demand. The normality of variables allows the existence of a linear equilibrium with information asymmetry. This chapter's model follows a linear-normal setting.

The adopted methodology in this work distinguishes private and public information (Tang, 2014). Private information is content which is known only by a share of the population of operators. In this chapter's model, each group (speculators, storers and processors) is endowed with a signal which is common to each of its members. A signal which is known only by a specific group is thus considered as private. At time t = 1, operators receive a signal $(s_j)_{j\in\{I,P,S\}}$ common to the group which they belong. This signal is unbiased such as:

$$\forall j \in \{I, P, S\},\ s_j = \tilde{\xi}_2 + \varepsilon_j \quad \text{with } \varepsilon_j \sim N(0, \sigma_j^2) \tag{1.1}$$

I could assume groups receive information about the random spot supply or demand, but it does not change the outcome of the model. In a rational expectations equilibrium (REE) à la Grossman (1977), owning an asset brings a payoff in the last period. The main unknown factor is what is random. The REE relies on a linear-normal model Vives (2010). The latter implies the payoffs are linear-quadratic. The random parameters and the signals follow a normal distribution. Therefore, the conditional expectations are affine, so they are the sum of a linear combination of the informative variables (signals and prices) and a constant (the unconditional expectation). A linear combination of normal variables gives an other normal variable. Agents anticipate the random factor of the payoff, which follows a normal distribution. Whatever, the factor is a sum of normal variables or not, there is no difference because the outcome is still a unique normal variable which agents estimate.

The assumption of a common group signal enables separating the issues of liquidity and information. Indeed, a new agent does not bring further information necessarily. Operators can get their information from common sources like forecasts from institutions. Moreover, some components of the net demand may be impossible to uncover (Stein, 1987).
The following list makes some clarifications in order to understand the settings of the model:

- Production of the commodity is inelastic: the quantities ω_1 and $\tilde{\omega}_2$ that reach the spot market at times t = 1 and t = 2 are exogenous to the model. Operators know ω_1 and μ_1 , and share the same prior about $\tilde{\omega}_2$ and $\tilde{\mu}_2$. The operators making intertemporal decisions (storers, processors and speculators) update their decision according to their information set. The latter includes the signal received by the operator according to one's group and public information at time t = 1. This chapter's methodology defines public information as content known by the whole population of operators. Everyone on the market knows prices. The last ones are endogenous variables, which are the results of clearing equations. Prices are the outcome of the positions of the agents based on their information. Thus, operators can infer the private information of the other agents from prices. Therefore, we can write the information set ($(\mathcal{F}_j)_{j\in\{I,P,S\}}$) such as :

$$\forall\, j \in \{I, P, S\},\ \mathcal{F}_j = (s_j, F, P_1) \tag{1.2}$$

- A negative spot demand equals extra spot supply. If for instance $P_1 > \frac{\mu_1}{m}$, then the spot price at time t = 1 is so high that additional means of production become profitable, and the global economy provides additional quantities to the spot market. The number

μ_1 (demand when $P_1 = 0$) is the level at which the economy saturates that induces spot traders to demand quantities larger than μ_1 ,that is, the traders offer a negative price $P_1 < 0$ for the commodity. The same situation occurs at time t = 2.

- Excluding the discounting issues imply to set the risk-free interest rate at 0.

1.3 Main equations

This section describes the main equations of the model. Subsection 1.3.1 explains the utilities and profit functions of the industrial hedgers. From them, are derived optimal positions. Then, subsection 1.3.2 computes the market-clearing equations. All the equations are taken directly from Ekeland et al. (2019). This chapter's innovation adds information set to every group of traders.

1.3.1 Industrial hedging

Hedgers make two choices at t = 1. First, they choose the amount of commodities they will use for their economic activities. Second, they determine their positions on the futures market. Subsubsection 1.3.1.1 shows how processors hedge, then subsubsection 1.3.1.1 details the hedging of the storers and 1.3.1.3 derives the hedging pressures from the hedgers' positions computed previously.

1.3.1.1 Processor's hedging

The processor seeks to hedge the quantity of input y bought in the second period on the spot market at the price P_2. Z is a constant which depends on the output price.
The realized profit function at time t=2 is:

$$\pi_P = (y - \frac{\beta}{2}y^2)Z - yP_2 + f_P(P_2 - F) \tag{1.3}$$

β is the parameter of the quadratic function of production. f_P is the position of the processor on the futures market.The processor's utility is mean-variance. Its maximization program is thus:

$$\max_{y\in[0,\frac{1}{\beta}],f_P\in\mathbb{R}} U_P = E_1[\pi_P|\mathcal{F}_P] - \frac{\alpha_P}{2}\text{Var}_1[\pi_P|\mathcal{F}_P] \tag{1.4}$$

Such as $\mathcal{F}_P = (s_P, F, P_1)$. α_P and s_P respectively are the risk aversion and the signal of the processor. Therefore, the processor's optimal decisions (f_P^*, y^*) are:

$$y^* = \frac{Y^*}{\beta Z} \tag{1.5}$$

$$f_P^* = y^* + \frac{E_1[P_2|\mathcal{F}_P] - F}{\alpha_P \text{Var}_1[P_2|\mathcal{F}_P)} \tag{1.6}$$

Such as $Y^* = \max(Z - F, 0)$ which is the gross payoff from the arbitrage to hedge inputs. The futures market is also used by the processor to plan his or her production. If the price of the input F is below the margin per input Z, the processors will produce. The position on the futures market can be decomposed into two elements: a hedging component y^* (the processor goes long on futures contracts to protect himself against an increase in the spot price) and a speculative one:

$$\frac{E_1[P_2|\mathcal{F}_P] - F}{\alpha_P \text{Var}_1[P_2|\mathcal{F}_P)} \tag{1.7}$$

Processors use their position on the futures market to speculate. The speculative component is positive (resp. negative) if the expected spot price is higher (resp. lower) than the futures price. Therefore, the overall position of processors is different from the amount of inputs they need to hedge if the futures price is not equal to its expected payoff. The separation of the physical and the futures decisions is consistent with Danthine (1978).

1.3.1.2 Storer's hedging

Storers buy units of input x in the first period to sell them in the second period.
The storer gets the following realized profit at time t=2:

$$\pi_I = x(P_2 - P_1) + f_I(P_2 - F) - \frac{1}{2}Cx^2 \tag{1.8}$$

C is the parameter for the quadratic storage cost function.
The program of the storer is thus:

$$\max_{x \in \mathbb{R}^+, f_I \in \mathbb{R}} U_I = E_1[\pi_I|\mathcal{F}_I] - \frac{\alpha_I}{2}\text{Var}_1[\pi_I|\mathcal{F}_I] \tag{1.9}$$

Such as $\mathcal{F}_I = (s_I, F, P_1)$. α_I and s_I respectively are the risk aversion and the signal of the storer. I define also the optimal hedge position x^*:

$$x^* = \frac{X^*}{C} \tag{1.10}$$

Such as $X^* = \max(F - P_1, 0)$, which is the gross payoff of the contango arbitrage, excluding the storage cost. If the futures price is higher than the spot price in the first period, the storer will store an amount of the commodity to sell it at the futures price.
The optimal futures position of the storer is:

$$f_I^* = \underbrace{-x^*}_{\text{hedging}} + \underbrace{\frac{E_1[P_2|\mathcal{F}_I] - F}{\alpha_I \text{Var}_1[P_2|\mathcal{F}_I]}}_{\text{speculation}} \tag{1.11}$$

The separation between hedging and speculation is still verified. First, storers hedge 100 percent of their physical positions, and then they adjust this position according to their expectations.

1.3.1.3 Hedging pressure

The hedging decisions described above are independent of the private signal, which is consistent with Danthine (1978). The reason is that the futures price is certain. Therefore, the Danthine separation of hedging and speculation decisions implies the hedging issue is solved in a certain environment, while the speculative position is decided in an uncertain one. The storers compare the future price to the spot price in period 1. The processors do the same between the futures price and the forward price of their output. The interests of the two categories are the opposite. If the future price increases, the storers have a stronger incentive to increase their hedge while the processors would wish to decrease their one.

From now, synthetic weights of processing units (n_P) and storing units (n_I) are used when it is relevant. They are defined as such:

$$n_P := \frac{N_P}{\beta Z} \tag{1.12}$$

$$n_I := \frac{N_I}{C} \tag{1.13}$$

The hedging pressure (or the unbalance of hedging positions) is represented by

$$HP := n_I X^* - n_P Y^* \tag{1.14}$$

It is important to notice the hedging pressure is a weighted sum of the hedging positions. They are not adjusted by the speculative components of the futures positions of the hedgers. Therefore, the hedging pressure is public information because it relies on the prices which are known by everyone.

1.3.2 Clearing of the markets

All the agents have a mean-variance program. The received signal is the same for all the agents of the same group. For example, all the processors have the same signal. Likewise, storers and speculators have another signal which is identical for all the population in their group. Subsubsection 1.3.2.1 lists the optimal positions for the different groups on the futures markets. Subsubsection 1.3.2.2 shows the spot clearing conditions and subsubsection 1.3.2.3 the futures clearing condition. Then subsubsection 1.4.1.1 derives the system of the market clearing conditions.

1.3.2.1 The optimal positions on the futures markets

The traders are endowed with the information common to their group. The set of their information includes the price and the private signal common to all the group members. Speculators do not hedge, so their position is limited to a speculating component. According to the hedging positions described by (1.5) and (1.10), we get:

$$f_I = \frac{E_1[P_2 - F|\mathcal{F}_I]}{\alpha_I \mathrm{Var}_1[P_2|\mathcal{F}_I]} - \frac{X^*}{C} \tag{1.15}$$

$$f_P = \frac{E_1[P_2 - F|\mathcal{F}_P]}{\alpha_P \mathrm{Var}_1[P_2|\mathcal{F}_P]} + \frac{Y^*}{\beta Z} \tag{1.16}$$

$$f_S = \frac{E_1[P_2 - F|\mathcal{F}_S]}{\alpha_S \mathrm{Var}_1[P_2|\mathcal{F}_S]} \tag{1.17}$$

$\mathcal{F}_j$ and α_j for $j = I, P, S$ respectively stands for the information set which is unbiased and for the risk aversion. Speculators have a speculating position only and not a hedging position. The conditional moments of operators are included in the futures positions and not in the spot ones. Therefore, the information goes first through the futures price.

1.3.2.2 The clearing of the spot market

On the spot market, there is a physical constraint on the market-clearing condition. Only positive quantities are allowed. Thus, the supply has to be equal to the demand to clear the spot market. At the first period, the supply and the demand of the spot traders are known, respectively μ_1 and ω_1. Agents do not know in the first period the outcome of the random supply ($\tilde{\omega}_2$) and demand of the spots traders ($\tilde{\mu}_2$) in the second period. Storers buy a quantity $n_I X^*$ in the first period to sell it in the next period. The processors buy the quantity $n_P Y^*$ on the spot market in the second period that they hedged in the previous period. These settings enable to derive the market-clearing conditions for both periods:

$$\underbrace{\omega_1}_{\text{spot supply}} = \underbrace{n_I X^*}_{\text{storage in}} + \underbrace{\mu_1 - mP_1}_{\text{spot demand}} \tag{1.18}$$

$$\underbrace{\tilde{\omega}_2}_{\text{spot supply}} + \underbrace{n_I X^*}_{\text{storage out}} = \underbrace{n_P Y^*}_{\text{processors demand}} + \underbrace{\tilde{\mu}_2 - mP_2}_{\text{spot demand}} \tag{1.19}$$

The clearing equation of the spot market in the second period (1.19), in function of the hedging pressure defined in (1.14), is:

$$P_2 = \frac{\tilde{\xi}_2 - HP}{m} \tag{1.20}$$

Such as $\tilde{\xi}_2 = \tilde{\mu}_2 - \tilde{\omega}_2$ which is the random exogenous net demand. From equation 1.20, are deduced the conditional moments:

$$E_1[P_2|\mathcal{F}_j] = \frac{E_1[\xi_2|\mathcal{F}_j] - HP}{m} \tag{1.21}$$

$$\text{Var}_1[P_2|\mathcal{F}_j] = \frac{\text{Var}_1[\xi_2|\mathcal{F}_j]}{m^2} \tag{1.22}$$

The hedging pressure (HP) and the storage level ($n_I X^*$) are functions of the futures and spot prices (respectively F and P_1) according to the definition (1.14) and the clearing condition (1.18). Moreover, the spot price at maturity (P_2) varies negatively with the hedging pressure according to (1.20). This chapter highlights feedback from the futures price to the spot prices at both periods. If information varies, the futures positions are modified. Thus, the futures price varies, which changes the hedging pressure and the spot price at t = 1 and t = 2.

1.3.2.3 The clearing of the futures market

For the futures market, we get the following market-clearing condition:

$$\sum_{j=\{I,P,S\}} N_j f_j = 0 \tag{1.23}$$

According to the agents' positions given by (1.15),(1.16) and (1.17), the clearing equation (1.23) becomes:

$$N_I(\frac{E_1[P_2|\mathcal{F}_I]-F}{\alpha_I \mathrm{Var}_1[P_2|\mathcal{F}_I]}-\frac{X^*}{C})+N_P(\frac{E_1[P_2|\mathcal{F}_P]-F}{\alpha_P \mathrm{Var}_1[P_2|\mathcal{F}_P]}+\frac{Y^*}{\beta Z})+N_S\frac{E_1[P_2|\mathcal{F}_S]-F}{\alpha_S \mathrm{Var}_1[P_2|\mathcal{F}_S]}=0$$
$$\Leftrightarrow \quad \sum_{j=\{I,P,S\}} N_j\frac{E_1[P_2|\mathcal{F}_j]-F}{\alpha_j \mathrm{Var}_1[P_2|\mathcal{F}_j]}-HP=0$$

The development above gives the futures price:

$$F=\frac{1}{\Upsilon_P}(\sum_{j=\{I,P,S\}} N_j\psi_{j,p}E_1[P_2|\mathcal{F}_j]-\mathrm{HP}) \tag{1.24}$$

Such as:

$$\Upsilon_P := \sum_{j=\{I,P,S\}} N_j \Psi_{j,p} \tag{1.25}$$
$$\psi_{j,p} := (\alpha_j \mathrm{Var}_1[P_2|\mathcal{F}_j])^{-1},\ j=I,P,S \tag{1.26}$$

$\Psi_{j,P}$ is the inverse of the product of the risk aversion and the conditional variance of the price to the signal of the agent i. It is the risk-adjusted information advantage (Vives, 2010). Higher it is, higher is the speculative position, which is equal to the spread between the conditional expected spot price times the informational advantage. Υ_P is related to market depth because it impacts the sensitivity of the futures price to the hedging pressure (HP).
The injection the conditional expectations (1.21) and variances (1.22), of net demand in the equation of the futures price according to the moments of the spot price at maturity (1.24), generates the following:

$$F=\frac{1}{\Upsilon_\xi}\sum_{j=\{I,P,S\}} N_j\psi_{j,\xi}\frac{E_1[\tilde{\xi}_2|\mathcal{F}_j]}{m}-\frac{1}{m}\phi HP \tag{1.27}$$

Such as :

$$\Upsilon_\xi := \sum_{j=\{I,P,S\}} N_j \psi_{j,\xi} \tag{1.28}$$

$$\psi_{j,\xi} := (\alpha_j \mathrm{Var}_1[\xi_2|\mathcal{F}_j])^{-1},\ j = I, P, S \tag{1.29}$$

$$\phi := 1 + \frac{1}{m\Upsilon_\xi} \tag{1.30}$$

The sensitivity (ϕ) of the demand to the hedging pressure (Ekeland et al., 2019) is given by (1.30). When the hedging pressure (HP changes by one unit, the futures price moves by $\frac{\phi}{m}$. The inverse of the impact of the hedging pressure on the futures price ($\frac{m}{\phi}$) is the measure of market depth (Vives, 2010). The futures market is deep if a variation of the hedging pressure is absorbed with a limited impact on the moves of the futures price. Higher is Υ_ξ, lower is the sensitivity of the price to the hedging pressure. When Υ_ξ leans toward infinite, the sensitivity of the futures price to the hedging pressure declines toward one, and so the market depth tends to m.

1.4 Characterization of the equilibrium

Previous sections have defined a sufficient condition for the existence of a rational-expectation equilibrium. Now, this section defines the necessary conditions.

1.4.1 Solving the equilibrium

1.4.1.1 System to solve

The market-clearing equations (Ekeland et al., 2019) correspond to the equilibrium on the spot and the futures markets. On the spot, the supply is equal to the demand. The short positions are forbidden. The futures market, which is financial, meets the equilibrium when the sum of the positions is null. Therefore, the following system to solve is:

$$\begin{cases} P_1 = \frac{1}{m}(\xi_1 + n_I X^*) \\ P_2 = \frac{1}{m}(\tilde{\xi}_2 - HP) \\ F = \frac{\sum_{j=\{I,P,S\}} N_j \Psi_{j,\xi} E_1[\xi_2|F, s_j]}{m\Upsilon_\xi} - \frac{1}{m}\phi\, HP \end{cases} \tag{1.31}$$

Such as the following defined variables are:

$$\begin{cases} n_P := \frac{N_P}{\beta, Z} \\ n_I := \frac{N_I}{C} \\ X^* := \max(F - P_1, 0) \\ Y^* := \max(Z - F, 0) \\ HP := n_I X^* - n_P Y^* \end{cases} \tag{1.32}$$

1.4.1.2 A piecewise linear equilibrium

The market-clearing conditions (1.31) define the equilibrium as such :

Definition 1.4.1 (Equilibrium) *An equilibrium is a family of quantities and prices* (X^*, Y^*, P_1, F, P_2) *such that:*

1. *The nonnegativity constraint of quantities is fulfilled :* $(X^*, Y^*) \in \mathbb{R}_+^2$
2. *Prices are nonnegative:* $F \geq 0$, $P_1 \geq 0$ *and* $P_2 \geq 0$ *almost surely.*
3. *Each agent, of a group* $j = \{I, P, S\}$, *relies on one's information set which is composed of a private signal* ($s_j = \tilde{\xi}_2 + \epsilon_j$) *and public information which includes the futures price* F *and the spot price* P_1. *Therefore, we get the following information set :*

$$\forall j \in \{I, P, S\}, \mathcal{F}_j = (s_j, F, P_1) \tag{1.33}$$

4. *The following market-clearing conditions for the spot and futures markets in the first period is fulfilled :*

$$\begin{cases} mP_1 - n_I X^* = \xi_1 \\ mF + \phi\, HP = \frac{\sum_{j=\{I,P,S\}} N_j \Psi_{j,\xi} E_1[\xi_2 | \mathcal{F}_j]}{\Upsilon_\xi} \end{cases} \tag{1.34}$$

5. *The following condition for the spot market at maturity is fulfilled:*

$$P_2 = \frac{1}{m}(\tilde{\xi}_2 - n_I X^* + n_P Y^*) \tag{1.35}$$

There is an unique equilibrium for each sub-region. I get 4 regions (Ekeland et al., 2019):

- The region 1 where $F > P_1$ and $Z > F$ so both kind of industrialist are hedging.
- The region 2 where $F > P_1$ and $Z < F$ so storers are hedging only.
- The region 3 where $F < P_1$ and $Z < F$ so no one is hedging.
- The region 4 where $F < P_1$ and $Z > F$ so processors are hedging only.

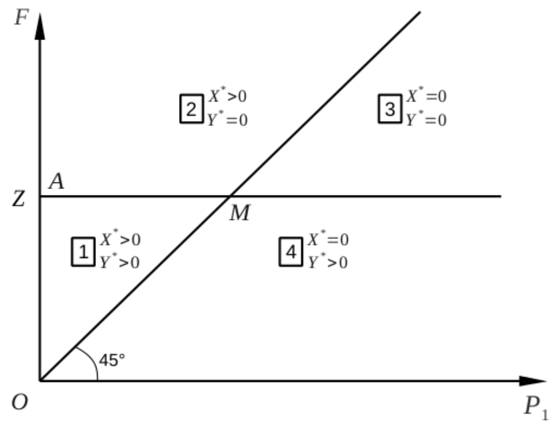

Figure 1: Physical and financial decisions in space (P_1 , F): the four regions defined by Ekeland et al. (2019)

I will show that this equilibrium is fully revealing through the futures price. It means that the futures price reveals all the private information. More precisely, the futures price is a sufficient statistics of all the private signals.

1.4.2 A fully-revealing equilibrium based on the futures price

1.4.2.1 The characteristics of a FRREE

A fully revealing rational expectations equilibrium (FRREE) means that the information from the private signals to make the best estimate of the payoff is revealed by the prices (Grossman, 1976). Mathematically, the prices are a sufficient statistics of signals. Therefore, knowing prices is equivalent to know all the signals. I will show that the futures price is a sufficient statistics alone. Thus, the futures price is an efficient estimator,which fulfills its function of price discovery.

Definition 1.4.2 (Fully-Revealing Rational Equilibrium) *With S as the set of the private signals such as $S = \{(s_I, s_P, s_S)\}$, P_2 as the spot price at maturity and $\mathcal{F}_M = (F, P_1)$ the* *market information set which includes the prices in the first period, a FRREE exists if the two following conditions hold (Bray, 1981):*

$$E_1[P_2|\mathcal{F}_M] = E_1[P_2|S] \tag{1.36}$$

$$Var_1[P_2|\mathcal{F}_M] = Var_1[P_2|S] \tag{1.37}$$

The private signals are normal variables, as explained in section 1.2, thus (1.36) implies (1.37). The conditions described by Bray (1981) have an economic meaning. They disregard their private signal to look at the information included in the prices only. A FRREE implies the same conditional moments because the agents get the same information. Therefore, the speculative positions vary according to the risk aversion only. In a FRREE, the ratio of two speculative positions is the ratio of the risk aversion.

Nonetheless, the market information set boils down to the futures price for two motives. First, the expectations are included in the speculative positions which are traded directly on the futures market. Second, the expectations are included in the spot price when the latter is a function of the futures price. The market meets this condition only in contango ($F > P_1$).

The subsubsection below shows that a FRREE through the futures price exists. The following one establishes its uniqueness.

1.4.2.2 Existence of a FRREE

The concept of an artificial economy was first coined by Grossman (1978) and then generalized by Bray (1981). In the artificial economy, the traders pool their priors before trading. It means the whole information in the economy is common knowledge. This situation is equivalent to a FRREE because a sufficient statistics is equivalent to own all the information. Therefore, if an equilibrium exists in an artificial economy, it means that the FRREE exists too. I assume an artificial economy with K groups and I the set for all the information. There is one theorem of existence demonstrated below. The name of the "Bray-Grossman theorem" has been chosen in tribute to the two authors quoted above.
First, this subsubsection begins with a lemma of separation between the speculative and the hedging positions, short or long. This lemma enables proving the existence of the FRREE with a hedging pressure. I call it the Danthine lemma in tribute of Danthine (1978) which first establishes a separation result for a long hedging position.

Lemma 1.4.1 (Danthine Separation) *I call a profit function* Danthine-separable *if the* *futures position, derived from the optimization of the expected utility, is a sum of the speculative and the hedging positions. A profit function such as* $\pi_j = f_j(P_2 - F) + h_j P_2 + H_j(h_j)$ *of agent j with a mean-variance utility, such as* $EU_j[\pi_j|\pi_j] = E_1[\pi_j|\mathcal{F}_j] - \frac{\alpha_j}{2} Var_1[\pi_j|\mathcal{F}_j]$*, is Danthine-Separable if* $H_j(h_j)$ *is continuously differentiable (class* C^1*) and does not depend on any conditional moment or random variable. The function* H_j *is the impact of the hedgers' economic activity on one's profit.* f_j *is a futures position and* h_j *is a hedging position.* P_2 *is the spot price at maturity and* F *is the futures price.*

Proof.
The program of the agent j is:

$$\max_{h_j \in \mathbb{D}_j, f_j \in \mathbb{R}} \mathrm{EU}_j[\pi_j|\mathcal{F}_j] = E_1[\pi_j|\mathcal{F}_j] - \frac{\alpha_j}{2}\mathrm{Var}_1[\pi_j|\mathcal{F}_j] \tag{1.38}$$

I get the following first-order conditions:

$$\frac{\mathrm{EU}_j[\pi_j|\mathcal{F}_j]}{\partial f_j} = 0 \tag{1.39}$$
$$\frac{\mathrm{EU}_j[\pi_j|\mathcal{F}_j]}{\partial h_j} = 0 \tag{1.40}$$
$$\tag{1.41}$$

These conditions give respectively:

$$f_j = \frac{E[P_2|\mathcal{F}_j] - F}{\alpha_j \mathrm{Var}[P_2|\mathcal{F}_j]} - h_j \tag{1.42}$$
$$H'(h_j) = \alpha_j \mathrm{Var}[P_2|\mathcal{F}_j](f_j + h_j) - E[P_2|\mathcal{F}_j] \tag{1.43}$$

Substituting the expression of f_j in (1.42) to (1.43) gives the following result:

$$H'(h_j) = F \tag{1.44}$$

H_j is a C^1 function, so there is a solution to the equation above. This solution does not depend on any moment or random variable. Therefore, we the result 1.44 shows a separation between speculation and hedging.
End of proof.

If the agent is naturally a short hedger, the hedging position is positive ($h_j \geq 0$) and $H_j(h_j)$ is a cost function. F is the price rewarding a long position. The long hedger increases her long hedge until the marginal cost is equal to the price. In this chapter's model, the storer has a storage level (x) associated to a cost function $C(x) = P_1 x + \frac{C}{2}x^2$, which is increasing and convex. If at the opposite, the agent is naturally a long hedger, the hedging position is negative ($h_j \leq 0$) and $H_j(h_j)$ is a revenue. Therefore, a long hedger increases her marginal revenue until it is equal to F, which acts as a constant marginal price. In the situation of a long hedger, it is equivalent to assume a profit function $\pi_j = f_j(P_2 - F) - h_j P_2 + H_j(h_j)$ with $h_j \geq 0$. I make this choice in our model for clarity's sake. A processor has a given quantity of inputs $y \geq 0$ with a gross profit function ($G(y) = y - \frac{\beta}{2}y^2$). It would have been equivalent to assume $y \leq 0$ with a gross profit function such as ($G(y) = -y - \frac{\beta}{2}y^2$).

The separation, between speculative and hedging positions, is possible. Therefore, it is possible to show the existence of a FRREE in a futures market where a hedging pressure exists. The latter needs to be linear in the futures price to get an equilibrium in the linear-normal setting.

Proposition 1.4.2 *In an efficient market, the relationship between the futures price and the hedging pressure is linear.*

First, let us consider the region 1 where $F > P_1$ and $Z > F$.

According to the spot price in the first period given by the market-clearing conditions (1.31), the spot price is a linear function of the futures price when the storers are active ($n_I > 0$):

$$P_1 = \frac{\mu_1 - \omega_1 + n_I F}{m + n_I} \tag{1.45}$$

The futures price is itself a function of the sufficient statistics. The spot price does not reveal more information than the futures price because it is a function of the sufficient statistics through the futures price. The spot price does not include any information when the storers are inactive ($n_I = 0$) because the spot price is not a function of the futures price. The information is conveyed from the futures market to the spot market in contango but is not when the market is backwardated. Nonetheless, both prices are simultaneous, so the transfer is instantaneous. If the market is in contango, there is price discovery on both markets while there is only information in the futures one in case of backwardation.

I consider the following linear hedging pressure of the futures price:

$$HP = -\gamma_0 + \gamma_1 F \tag{1.46}$$

According to the hedging pressure given by the market-clearing conditions (1.31) we get in the region 1:

$$\gamma_1 = \frac{mn_I}{m+n_I} + n_P \quad (1.47)$$

$$\gamma_0 = n_P Z + (\mu_1 - \omega_1)\frac{n_I}{m+n_I} \quad (1.48)$$

γ_1 and γ_0 vary according to the region where the market belongs:

- In the Region 2, $F > Z$ and $F > P_1$ which implies short hedging only ($n_I > 0$ and $n_P = 0$):

$$\gamma_1 = \frac{mn_I}{m+n_I} \quad (1.49)$$

$$\gamma_0 = (\mu_1 - \omega_1)\frac{n_I}{m+n_I} \quad (1.50)$$

  In this situation, the hedging pressure is strictly nonnegative because only the storers hedge by going short, and the processors do not hedge.

- In the Region 3, $F > Z$ and $F < P_1$ which implies no hedging: $\gamma_1 = \gamma_0 = 0$.

- In the Region 4, $F < Z$ and $F < P_1$ which implies long hedging only ($n_I = 0$ and $n_P > 0$):

$$\gamma_1 = n_p \quad (1.51)$$

$$\gamma_0 = n_P Z \quad (1.52)$$

  In this situation, the hedging pressure is strictly non positive because only the processors hedge by going long and the storers do not hedge.
  Now, it is possible to show the conditions of the existence of an equilibrium with hedging pressure.

Theorem 1.4.3 (Bray-Grossman) *A FRREE exists if the following conditions are met:*

1. *Agents have mean-variance utilities such as for each agent j has a utility function such as* $U_j(\pi_j) = E_1[\pi_j|\mathcal{F}_J] - \frac{\alpha_j}{2} Var_1(\pi_j|\mathcal{F}_j)$ *with* α_j *as a constant absolute risk aversion and* $\mathcal{F}_j$ *as information set of the agent j.*

2. π_j *is a profit function such as* $\pi_j = f_j(P_2 - F) + h_j P_2 + H_j(h_j)$ *is Danthine-Separable.*

3. *The sum of the hedging positions defined as the hedging pressure* $HP = \sum_j h_j$ *is linear such as* $HP = -\gamma_0 + \gamma_1 F$ *with* $(\gamma_0, \gamma_1) \in (\mathbb{R}^+)^2$. *A positive sign of the hedging pressure (HP) stands for a net short hedging demand on the futures market.*

Proof.

All the information is pooled. Therefore, all the traders get access to all the signals. The set of all the private signals is S. The mean-variance utility function and the Danthine-separable profit function implies the speculative position of the mean-variance trader of kind j is:

$$\frac{1}{\alpha_j} \frac{E_1[P_2|S] - F}{\mathrm{Var}_1[P_2|S]}$$

If there is a nominal weight N_j of the kind j of traders, their aggregate speculative position is:

$$\frac{N_j}{\alpha_j} \frac{E_1[P_2|S] - F}{\mathrm{Var}_1[P_2|S]}$$

The clearing condition of the futures market is a null sum of all the positions. There is two kinds of position: the speculative ones and the hedging ones. The sum of the latter is the hedging pressure defined such as $HP = -\gamma_0 + \gamma_1 F$. Higher is the futures price, shorter are the hedgers. Therefore, the market-clearing condition of an artificial economy gives:

$$\sum_j \frac{N_j}{\alpha_j} \frac{E_1[P_2|S] - F}{\mathrm{Var}_1[P_2|S]} - HP = 0$$
$$\Leftrightarrow \quad F = \frac{\sum_j \frac{N_j}{\alpha_j} \frac{E_1[P_2|S]}{\mathrm{Var}_1[P_2|S]} + \gamma_0}{\sum_j \frac{N_j}{\alpha_j \mathrm{Var}_1[P_2|S]} + \gamma_1}$$

F is a linear function of the sufficient statistic $E_1[P_2|S]$. All the other terms of the equations are constant. Thus, the equilibrium of the artificial economy is fully revealing.
End of proof.

Moreover, theorem 1.4.5 proves this FRREE is unique.

1.4.2.3 Uniqueness of the FRREE

The following lemma helps to prove the theorem of the uniqueness of the FRREE in this chapter's model. The whole demonstration is directly inspired by Bray (1981).

Lemma 1.4.4 (Bray equality) *When the variables are normal, we get the following equality :* $Cov(P_2 - E_1[P_2|F], E_1[P_2|\mathcal{F}_j]) = Var[E_1[P_2|\mathcal{F}_j] - E_1[P_2|S]]$.

The proof of this lemma is in equations 2.38 and 2.39 of Bray (1981).

According to the clearing equations (1.31) and the definitions (1.32), we can write a linear futures price in the expectation, such as $F = \theta_1 + \theta_2 \sum_{i=1}^{N} \lambda_j E_1[P_2|\mathcal{F}_j]$ with F>0, $(\theta_k)_{k\in\{1,2\}} \in \mathbb{R}$, $\lambda_j > 0$, and a linear hedging pressure (HP) in the futures price, such as $HP = \gamma_1 F - \gamma_0$ with $(\gamma_j)_{i=\{0,1\}} > 0$, which correspond to the following coefficients for the region 1 :

$$\begin{aligned}
\theta_1 &= \frac{\gamma_0}{\sum_j^N \lambda_j + \gamma_1} \\
\theta_2 &= (\sum_j^N \lambda_j + \gamma_1)^{-1} \\
\lambda_j &= N_j \psi_j \\
\gamma_0 &= \frac{n_P Z + n_I \xi_1}{m + n_I} \\
\gamma_1 &= \frac{m + n_P(m + n_I)}{m + n_I}
\end{aligned}$$

With $\psi_j = \frac{N_j}{\alpha_j \mathrm{Var}[E_1[P_2|F]}$ which is the risk-adjusted information advantage. $\psi_j > 0$ implies $\lambda_j > 0$. ELV is a set of four particular cases (the four regions). The other regions are characterized by one or all of both groups of hedgers who are inactive. Therefore, setting to zero one or both of the synthetic weight (n_I for the storers and n_P for the processors) enables getting the values for the other regions, as explained in the previous subsubsection. A theorem directly inspired from (Bray, 1981) shows the equilibrium is fully revealing in each region, hence the name of "*Bray theorem.*"

Theorem 1.4.5 (Bray) *In a futures market with N different signals where* $F = \theta_1 + \theta_2 \sum_{i=0}^{N} \lambda_j E_1[P_2|\mathcal{F}_j]$ *where F>0,* $(\theta_k)_{k\in\{1,2\}} \in \mathbb{R}$, $\lambda_0 \geq 0, \lambda_j > 0$, *F is a sufficient statistics so we get an unique FRREE.*

Proof.
S is the vector of all the signals. The projection characterization implies $\mathrm{Cov}(P_2 - E_1[P_2|F], F) = 0$ for normal variables (Bray, 1981). I assume we are in a futures market with N different sig-

nals where $F = \theta_1 + \theta_2 \sum_{j=1}^{N} \lambda_j E_1[P_2|\mathcal{F}_j]$ with F>0, $(\theta_k)_{k\in\{1,2\}} \in \mathbb{R}$, $\lambda_j > 0$. Therefore:

$$\begin{aligned} \text{Cov}(P_2 - E_1[P_2|F], F) &= 0 \\ \Rightarrow \sum_{j=1}^{N} \lambda_j \text{Cov}(P_2 - E_1[P_2|F], E_1[P_2|\mathcal{F}_j]) &= 0 \\ \Rightarrow \sum_{j=1}^{N} \lambda_j \text{Var}[E_1[P_2|\mathcal{F}_j] - E_1[P_2|S]) &= 0 \\ \Rightarrow \forall j \in [[1,N]], E_1[P_2|\mathcal{F}_j] = E_1[P_2|S]) & \end{aligned}$$

End of proof.

The two theorems prove the model's equilibrium is fully revealing. According to the definition 1.4.2 of the FRREE, the futures price according to the moments of the spot price at maturity (1.24) becomes:

$$F = E_1[P_2|F] - \frac{\text{Var}_1[P_2|F]}{\sum_{j=\{I,P,S\}} \frac{N_j}{\alpha_j}} HP \tag{1.53}$$

Thus, we get an unique risk premium, or futures price bias, for every agent in the market such as:

$$E_1[P_2|F] - F = \frac{\text{Var}_1[P_2|F]}{\sum_{j=\{I,P,S\}} \frac{N_j}{\alpha_j}} HP \tag{1.54}$$

1.5 Information makes asset pricing stochastic

First, subsection 1.5.1 studies the predictability of the spot price at maturity by the futures price (1.53). Then, subsection 1.5.2 shows the risk premium derived from the FRREE (1.54) implies a possible Hirshleifer effect.

1.5.1 The stake of predictability

A sufficient statistics of a variable is equivalent to know all the information about the outcome of it. Therefore, the sufficient statistic can be used as a unique predictor. Thus, informational efficiency implies predictability. More precisely, are showed below the conditions for the futures price to be a sufficient statistics. In this case, the futures price can be used as the unique predictor of the spot price at the maturity of the contract.

Subtracting the futures price F from the spot price in the second period P_2, given by the market-clearing conditions (1.31), gives the following equation:

$$P_2 - F = \frac{\tilde{\xi}_2 - E_1[\xi_2|F]}{m} + \frac{HP}{m^2\Upsilon_\xi} \tag{1.55}$$

So we get the following empirical prediction according to the linear hedging pressure (1.46):

$$P_2 = (1 + \frac{\gamma_1}{m^2\Upsilon_\xi})F - \frac{\gamma_0}{m^2\Upsilon_\xi} + \frac{\tilde{\xi}_2 - E_1[\xi_2|F]}{m} \tag{1.56}$$

Thus we get a coefficient of regression for F, a constant and a normally-distributed error term:

$$\beta = (1 + \frac{\gamma_1}{m^2\Upsilon_\xi}) \tag{1.57}$$

$$\alpha = -\frac{\gamma_0}{m^2\Upsilon_\xi} \tag{1.58}$$

$$u = \frac{\tilde{\xi}_2 - E_1[\xi_2|F]}{m} \tag{1.59}$$

From the projection characterization, COV($\xi_2 - E_1[\xi_2|F], F) = 0$, thus F and u are independent. Therefore, we get a linear regression such as :

$$P_2 = \alpha + \beta F + u \tag{1.60}$$

α (which is negative) and β (which is greater than 1) make the futures price F a biased predictor except in the region 3. Indeed, when there is no hedging pressure, there is no risk premium too. β is the coefficient of reaction to the information supplied by the futures price. α is a constant in the risk premium. It is important to notice that these coefficients depend on the regions determined by the sign of basis $(F - P_1)$ and the sign of the spread between the forward price of the output and the futures price of the input (Z-F). The information shocks can modify these signs.

The conditional risk premium is defined such as:

$$E_1[P_2|F] - F = \alpha + (\beta - 1)F \tag{1.61}$$

The conditional risk premium is the bias in the futures price. The efficient unbiased statistics is the futures price minus the conditional risk premium. If the model were not piecewise but perfectly linear, the conditional risk premium would vary around the unconditional risk premium defined such as:

$$E_0[P_2] - E_0[F] = E_0[\alpha] + E_0[(\beta - 1)F] \tag{1.62}$$

It could be tempting to estimate the conditional risk premium by estimating the unconditional risk premium first. The conditional risk premium would be computed just by replacing the average futures price by the actual futures price. However, it is not that simple.

The coefficients of the regression depend on γ_0 and γ_1 which are functions of the synthetic weights of the hedgers (n_j and n_P), the sensitivity of the physical demand to the spot price (m) and the forward price of the final good (Z). Therefore, the coefficients of the regression vary according to the region where the market belongs. Indeed, they depend on both of the basis ($F - P_1$) and the spread between the forward price of the output and the futures price of the input (Z-F). Information can change the relationship between the spot price at maturity and the futures price because the hedging pressure is piecewise linear. The risk is that the coefficients of the unconditional premium are different from the conditional one because the market has switched from one region to another.

The existence of several regions might generate instability in the values of the coefficients. These factors can be time-varying, so the regression could be challenging to make. A precise estimation of the risk premium can be hard to get. Nonetheless, it is still possible to test the autocorrelation of the error term. If the errors are correlated, the market cannot be efficient. Moosa and Al-Loughani (1994) do that. They test the existence of an unconditional risk premium and the autocorrelation of the residuals for the Ist Texas Intermediate (WTI) crude oil. They find both unbiasedness and autocorrelation of the residuals. Their result means the futures price is an inefficient biased forecast of the spot price at maturity.

1.5.2 Risk premium as the counterpart of the hedging pressure

The futures price bias, or risk premium, is a direct function of the hedging pressure (1.54). Their signs can change randomly. Without differential information, the equilibrium is deterministic. In this case, given exogenous parameters correspond to one equilibrium which will always belong to the same region. It is not valid anymore with informed agents because the prices in the first period become stochastic. Therefore, the risk premium varies randomly, and so does the hedging pressure. It means that for the same initial settings, the region of the equilibrium can change according to the value of the signals.

The risk premium depends positively on the variance of the spot price at maturity (or negatively of its precision), negatively of the nominal weights and positively of the risk aversion (or negatively of the risk tolerance). The risk premium is the cost of hedging, which is risk sharing. The equation (1.54) can be interpreted as a net inverse demand for risk (or the supply of risk-bearing). The hedging pressure is the amount of risk to share in this model's equilibrium. The coefficient $\frac{\text{Var}_1[P_2|F]}{\sum_{j\{I,P,S\}}\frac{n_j}{\alpha_j}}$ is the slope of this demand. The futures price bias is the expected income of a futures contract, and so its relationship to hedging pressure can be assimilated to an Engel curve. The latter is the demand of a good according to an income. A direct consequence of the Danthine (1978) separation between the futures and the physical decisions is that all agents speculate (as explained in section 1.3.1). Thus, every agent demands risk for speculation purposes. The demand for risk depends on the expected income of a futures contract. Higher is the absolute value of the expected payoff, higher is the absolute value of the demand of risk. The function of the risk premium according to the hedging pressure is a straight line. This result is consistent with the existence of a representative agent for this market[3]. Gorman (1953) shows a representative agent exists when the Engel curves are parallel straight lines for all the agents at the same price. Here, all the speculating agents have the same curve. The existence of a representative agent implies a negative effect on risk-sharing Schlee (2001). Thus, a Hirshleifer effect might occur in the model's equilibrium.

1.6 Policy implications

The G20 created the Agricultural Market Information System (AMIS) in 2011. One aim is to improve agricultural market information, analysis and short-term supply and demand forecasts at both national and international levels. It is why the AMIS provides a Market Monitor that it defines as such[4]:

> «The AMIS Market Monitor provides a synopsis of major developments in international commodity markets, focusing on wheat, maize, rice, and soybeans. It represents the collective assessment of the member organizations of AMIS concerning the international market situation and outlook. Published ten times a

[3] See appendix 1.C.1

[4] The definition is on their website.

year, the report aims at improving market transparency and detecting emerging problems that might warrant the attention of policy makers.»

In this chapter's model, the AMIS policy appears as an improvement of the price informativeness. At the equilibrium, the futures price is a linear function of the sufficient statistics of signals. Let us say that the AMIS introduces a new signal ($s_A = \tilde{\xi}_2 + \varepsilon_A$) which is public, meaning every operator includes this information in one's information set (Tang, 2014). If there is one more signal, the precision of the sufficient statistics will improve. If more signals about the net demand at maturity are introduced, errors are more likely to wash out. Thus, speculation becomes less risky, and traders accept a lower risk premium. This method is similar to subsection 5.2 in Goldstein and Yang (2017b) in which there is one public signal for all the agents. Goldstein and Yang (2017b) highlight the "Hirshleifer effect" in an exchange economy when the precision of the public signal improves. The public or private nature of the signal does not matter in a FRREE because all the information is revealed through prices. Therefore, the disclosure of information increases price informativeness automatically in this equilibrium[5].

The elasticity of the net hedging demand supply increases. The risk premium given by the equation (1.54) is rewritten to get the inverse net hedging supply:

$$RP = (\tau^1_{\xi_2|F}\, m^2 \sum_{j\in\{I,P,S\}} T_j)^{-1} HP \tag{1.63}$$

$T_j = N_j \alpha_j^{-1}$ is the product of the risk tolerance and the nominal weight of a group or weighted risk-tolerance. An additional signal increases the conditional precision of the net demand according to the futures price. Thus the absolute risk premium decreases, which can be represented graphically with a decreasing slope in the plan (HP, RP) as in figure 2. Inversely, the elasticity of the net hedging supply increases. This phenomenon has the same effect than an increase in the weighted risk-tolerance. All of them decrease the cost of hedging and so the risk premium, which is the net payoff of speculators. The last ones lose because of the benefits of speculation decrease.

[5] In a partially-revealing rational expectations equilibrium, the disclosure of public information does not always improve the price informativeness because private information can be crowded out (Tang, 2014). Moreover, this crowding-out effect can even hurt economic operators when disclosure is about variables which are important for their economic decisions (Goldstein & Yang, 2018).

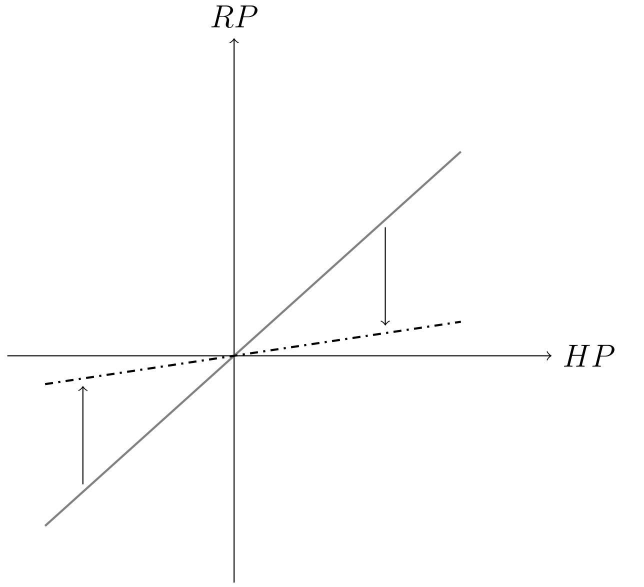

Figure 2: The thick gray line is the initial net inverse hedging supply. The black dashed line is the net inverse hedging supply with increased elasticity. The black arrows show that for a given hedging pressure, the risk premium decreases.

It is interesting to notice that the release of a public signal has the same effects than an increase in the weight of the speculators. Public forecasts released by AMIS generate the same consequences than financialization. The latter increases competition among speculators so it decreases the risk premium, which is the net payoff of speculation. Ekeland et al. (2019) show a decreasing risk premium implies an increasing absolute value of the hedging pressure because hedging becomes less costly for the dominating side of the hedgers. The introduction of a public signal improves the precision of the sufficient statistics. Investing becomes less risky, which gives an incentive to speculate more. Thus, the competition rises among speculators which decreases the risk premium and increases the absolute hedging pressure as well.

Indirect utilities are respectively for the speculators, the storers and the processors according to the utilities given by (1.4) and (1.9):

$$U_B = f_B(E_1[P_2|F] - F) - \frac{1}{2}\alpha_B f_B^2 \mathrm{Var}_1[P_2|F] \quad (1.64)$$

$$U_I = (x + f_I)E_1[P_2|F] - f_I F - xP_1 - \frac{C}{2}x^2 - \frac{1}{2}\alpha_I (x + f_I)^2 \mathrm{Var}_1[P_2|F] \quad (1.65)$$

$$U_P = (-y + f_P)E_1[P_2|F] - f_P F + (y - \frac{\beta}{2}y^2)Z - \frac{1}{2}\alpha_P(-y + f_P)^2 \mathrm{Var}_1[P_2|F] \quad (1.66)$$

The rewritten utility functions according to the positions given by (1.17), (1.15) and (1.16) are:

$$U_B = \frac{(E_1[P_2|F]-F)^2}{2m^2\alpha_B\sum_{j\in\{I,P,S\}}T_j}\tau^1_{\xi_2|F} \quad (1.67)$$

$$U_I = \frac{(E_1[P_2|F]-F)^2}{2m^2\alpha_I\sum_{j\in\{I,P,S\}}T_j}\tau^1_{\xi_2|F}+\frac{1}{2}(F-P_1)^2 \quad (1.68)$$

$$U_P = \frac{(E_1[P_2|F]-F)^2}{2m^2\alpha_P\sum_{j\in\{I,P,S\}}T_j}\tau^1_{\xi_2|F}+\frac{1}{2}(Z-F)^2 \quad (1.69)$$

Every utility function has a speculating component because of both speculators and hedgers speculate. Hedgers have a hedging component in addition to the speculating one. The increase in the precision of the signal ($\tau^1_{\xi_2|F}$) has three effects. First, the risk-adjusted information advantage increases, which raises the speculating component. Thus, the volume of the speculating positions rises. Second, the risk premium decreases, which is an adverse effect of the first effect. Therefore, the volume of risk to share increases. The dominating hedgers see the hedging component of their utility increases while it decreases for the ones of the dominated side. Therefore, the effects are both ambiguous for hedgers and speculators. In the appendix 1.C.2, we show $\frac{dU_B}{d\tau^1_{\xi_2|F}}>0$ implies $\frac{\frac{dHP}{HP}}{\frac{d\tau^1_{\xi_2|F}}{\tau^1_{\xi_2|F}}}>\frac{1}{2}$. This threshold is the consequence of the quadratic nature of the utility function.

A FRREE is equivalent to an equilibrium where every agent is endowed with the sufficient statistics $\tilde{s}_n$ as a signal. Therefore, $\tilde{s}_n$ sum up information . More this statistics explains the variation of the net demand, more the futures price is informative. The explained variation is the square of the correlation between the statistics and the net demand (ρ). Moreover, $\rho^2=\beta_s$ defined in (1.74). β_S is a measure of price informativeness (Vives, 2010). If $\beta_S=0$, the signals are not informative at all, and the price is not informative. At the opposite, if $\beta_S=1$, the signals forecast the net demand perfectly and the price is fully informative. Introducing an additional signal implies a more precise sufficient statistics which improves informativeness automatically. Thus, the outcome of better informativeness enables to study the effect of the AMIS policy.

The variation of the utility of speculators may be non monotonous as in the figure 3a. When the proportion of storers is higher as in the figure 3b, the utility is strictly decreasing. Numerical values are chosen to fit region 1.

When the informativeness is low, the introduction of better price informativeness may generate an improvement of welfare by increasing the speculating component in the utilities

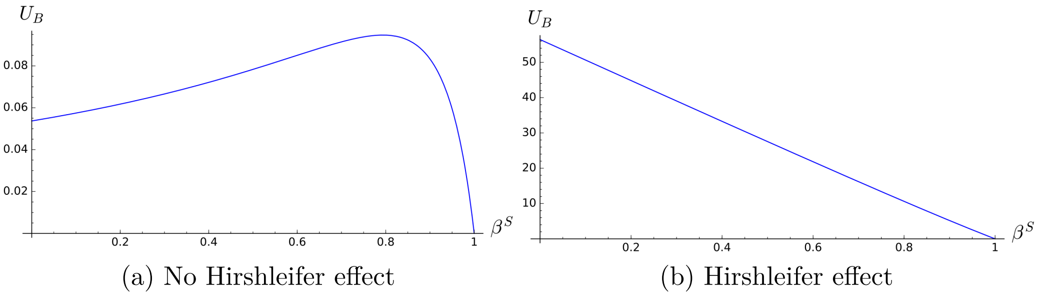

Figure 3: Utility of the speculators according to the precision. The values in the figure on the left are: $n_j = 1$, $n_P = 1$, $\alpha_j = 2$, $\alpha_P = 2$, m = 0.5, $\alpha_S = 2$, $N_S = 1$, $\xi_1 = 70$, $E[\xi_2|F] = 80$, Z = 170. On the right, the only difference is $n_I = 2$ to implement the Hirshleifer effect.

in some cases. If there is no Hirshleifer effect, the utility of the dominating hedging side is increasing convex while the dominated side's one is concave decreasing. When there is no Hirshleifer effect, dominating hedgers always benefit from more informativeness about the net demand in the next period. The gains from hedging offset their loss for a decreasing payoff of speculation. At the opposite, the Hirshleifer effect makes all the utilities decreasing. In the parameters of the simulation, the processors dominate hedging. Thus, their utility is increasing convex in figure 4a[6].

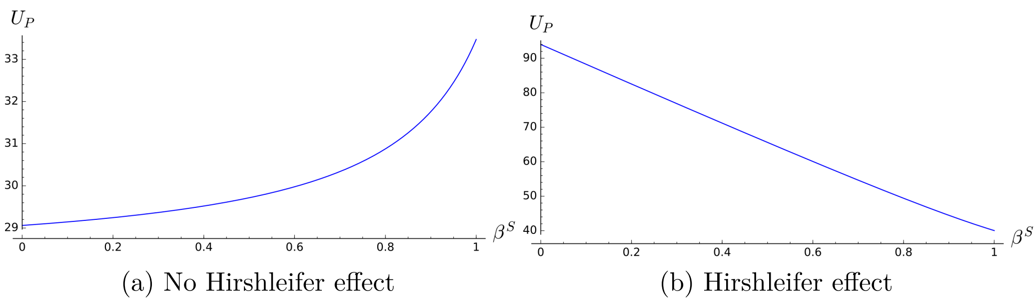

Figure 4: Utility of the processors according to the precision. The values in the figure on the left are: $n_I = 1$, $n_P = 1$, $\alpha_j = 2$, $\alpha_P = 2$, m = 0.5, $\alpha_S = 2$, $N_S = 1$, $\xi_1 = 70$, $E[\xi_2|F] = 80$, Z = 170. On the right, the only difference is $n_I = 2$ to implement the Hirshleifer effect.

Doubling the weight of the dominated side of hedgers generates the Hirshleifer effect. In this case, the risk premium is already very elastic to the hedging pressure. Thus, the gains from hedging are meager while there are still significant losses from the decreasing payoff of speculation. Therefore, the utility of the dominating hedgers diminishes as well.

[6]Section 1.C.3 shows that there is a symmetry for hedgers. When there is no Hirshleifer effect, the dominating side always gets a increasing convex utility or a concave decreasing utility if there is a Hirshleifer effect. It works both for long and short hedging.

1.7 Conclusion

To conclude, this chapter presents a two-period model adding private information in a theoretical frame unifying hedging pressure and storage theories. This chapter's model enables to study how prices aggregate the different pieces of information spread among market operators. This model's outcome is the futures price is a biased but efficient predictor of the spot price in the next period. Thus, the market is strongly efficient because the futures price always reveal all the information.

The futures price bias, which is the conditional risk premium, varies directly through the futures price and indirectly when the equilibrium regime changes. The coefficients of the regression relationship vary with the basis and the spread between the output price and the futures price. Therefore, estimating the coefficients of the unconditional risk premium, or expected risk premium, to compute the risk premium can be misleading. Moreover, in practice, the spread with the output price is not always known. Therefore, the estimation of the conditional risk premium is harder.

New signals increase the precision of the futures price. Thus, the lower risk gives an incentive to speculate more, which increases the competition among speculators. The risk premium is driven down, and the absolute hedging pressure increases as financialization does. Better price informativeness creates two opposite effects. First, better information decreases risk, which generates a negative impact on risk sharing. Second, More precise information helps hedgers to make decisions which increase the risk sharing. A «Hirshleifer effect» might occur if the negative impact on risk sharing dominates such as the well being of every operator is hurt. Therefore, hedgers and speculators can be both opponents of policies like the market monitor of the AMIS when their lower benefits of speculation make their utility decrease.

An interesting extension would be to introduce noise generated by the equity portfolio of speculators. This setting would generate a Partially Revealing Rational Expectation Equilibrium (PRREE). This property would enable studying more realistically the effect of additional signals.

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Appendix

1.A Properties of the Quasi-equilibrium and the equilibrium

Note that $n_I = \frac{n_I}{C}$, $N_p = \frac{N_P}{\beta Z}$ and $\phi = 1 + \frac{\mathrm{Var}_1[P_2|F]}{m \sum_{j=\{I,P,S\}} \frac{n_I}{\alpha_j}}$ The region is determined by $(\bar{\xi_1}, E_0[\xi_2])$, and the final expressions of equilibrium prices are as follows. A remark for all subsequent calculations. Starting from Region 1, setting $n_P = 0$ gives expressions for Region 2; setting $n_j = 0$ gives expressions for Region 4. Setting both weights to 0 gives region 3.

1.A.1 Quasi-equilibrium

1.A.1.1 Drawing the boundaries

This subsubsection describes the modified theorem 1 of Ekeland et al. (2019) and examines the images by φ of Regions 1 to 4. In Figure 1, the point O is the origin in $\mathbb{R}^2_+$, by A the point (0, Z), and by M the point (Z, Z). In Region 1 (triangle OAM):

$$\varphi(P_1, F) = \begin{pmatrix} mP_1 - n_j(F - P_1) \\ \frac{mF + \phi\,[n_I(F-P_1) - n_P(Z-F)] - \beta_S \tilde{s}_n}{1-\beta_S} \end{pmatrix}$$

This map is composed by the system (1.75). The images $\varphi(A), \varphi(M)$ and $\varphi(0)$ are easily computed:

$$\begin{aligned} \varphi(0) &= (0, -\beta_S \tilde{s}_n - \phi\, n_P Z), \\ \varphi(A) &= (-Z n_I, -\beta_S \tilde{s}_n + Z(m + n_I \phi)), \\ \varphi(M) &= (mZ, -\beta_S \tilde{s}_n + mZ) \end{aligned}$$

From this, one can find the images of all four regions. The image of Region 1 is the triangle $\varphi(0)\varphi(A)\varphi(M)$. The image of Region 2 is bounded by the segment $\varphi(A)\varphi(M)$ and by two infinite half-lines: one of which is the image of $\{P_1 = 0, F \geq Z\}$, the other being the image of $\{P_1 = F, F \geq Z\}$. In Region 2, the system is:

$$\varphi(P_1, F) = \begin{pmatrix} mP_1 - n_I(F - P_1) \\ mF + \phi\, n_I(F - P_1) - \beta_S \tilde{s}_n \end{pmatrix}$$

The first half-line emanates from the continuation of the segment $\varphi(M)\varphi(A)$. The second half-line emanates from $\varphi(0)\varphi(M)$ and is carried by the vector $(1, 1 - \frac{\beta_S \tilde{s}_n}{mZ})$. The image of Region 4 is bounded by the segment $\varphi(M)$ and by two infinite half-lines, one of which is the image of F $= 0$, the other being the image of $\{P_1 \geq F, F = Z\}$. In Region 4, the system is:

$$\varphi(P_1, F) = \begin{pmatrix} mP_1 \\ mF - \phi\, n_I(Z - F) - \beta_S \tilde{s}_n \end{pmatrix}$$

So the first half-line emanates from $\varphi(0)$ and is horizontal. The second emanates from $\varphi(M)$ and is horizontal. The image of Region 3 is entirely contained in $\mathbb{R}^2_+$ where it is the remainder of the three images described above.

1.A.1.2 The solution for the prices

1.A.1.2.1 Region 1.

$$\begin{aligned} P_1 &= \frac{m(m + (n_I + n_P)\phi)\frac{\xi_1}{m} + mn_I\frac{E[\xi_2|F]}{m} + n_I n_P \phi\, Z}{m(m + (n_I + n_P)\phi) + m(m + n_I) + n_I n_P \phi} \\ F &= \frac{mn_I\phi\frac{\xi_1}{m} + m(m + n_I)\frac{E[\xi_2|F]}{m} + (m + n_I)n_P\phi\, Z}{mn_I\phi + m(m + n_I) + (m + n_I)n_P\phi} \\ P_2 &= \frac{\tilde{\xi}_2}{m} + \frac{mn_I\phi\frac{\xi_1}{m} - ((m + n_I)n_P + mn_I)\frac{E[\xi_2|F]}{m} + (m + n_I)n_P\phi\, Z}{mn_I\phi + m(m + n_I) + (m + n_I)n_P\phi} \end{aligned}$$

The basis:

$$F - P_1 = \frac{-m(m + n_P\phi)\frac{\xi_1}{m} + m^2\frac{E[\xi_2|F]}{m} + mZ}{mn_I\phi + m(m + n_I) + (m + n_I)n_P\phi}$$

So we can deduce the following sensitivity of the basis to the conditional expected net demand at maturity ($E[\xi_2|F]$):

$$\frac{\partial(F - P_1)}{\partial\, E[\xi_2|F]} = \frac{m}{mn_I\phi + m(m + n_I) + (m + n_I)n_P\phi} > 0$$

The basis is always increasing with $E[\xi_2|F]$. Moreover ξ_1 does not depend of the latter because:

$$mP_1 - n_I(F - P_1) = \frac{m(m + (n_I + n_P)\phi - n_I(m + n_P\phi))\frac{\xi_1}{m} + n_I(n_P\phi - m)Z}{m(m + (n_I + n_P)\phi) + m(m + n_I) + n_I n_P\phi}$$

For region 2, $n_P = 0$. For region 3, $n_P = n_I = 0$. For region 4, $n_P = 0$. These variation do not modify the sign of the derivative of the basis and that the net demand at period 1 does not depend of its expected conditional value at period 2.

At the second period, we get the following condition for a positive differencial of the clearing equation of the second period:

$$m\frac{dF}{dS}+\phi\frac{d\text{HP}}{dS}>\beta_S(1-\beta_S)$$

This condition is always fulfilled for $\beta_S \neq 0$. By definition, $\beta_S \in]0,1[$.

1.A.2 Distribution that supports the equilibrium

Ekeland et al. (2019) determined a distribution that supports the equilibrium. For any region, the condition is the following because the equilibrium is fully revealing:

$$E_1[P_2|F]>0$$

The conditions are similar to Ekeland et al. (2019):

$$\frac{E_1[\xi_2|F]}{m} > \frac{n_I\frac{\xi_1}{m}+(m+n_I)n_PZ}{m(m+(\phi-1)n_P)+n_I(m\phi+(\phi-1)n_P)} \quad \text{in region 1} \tag{1.70}$$

$$\frac{E_1[\xi_2|F]}{m} > -\frac{n_I}{m+n_I\phi}\frac{\xi_1}{m} \quad \text{in region 2} \tag{1.71}$$

$$\frac{E_1[\xi_2|F]}{m} > 0 \quad \text{in region 3} \tag{1.72}$$

$$\frac{E_1[\xi_2|F]}{m} > \frac{n_PZ}{m\phi+(\phi-1)n_P} \quad \text{in region 4} \tag{1.73}$$

1.B Information shakes the borders

Let us define the realized value $\tilde{s}_n$ of the sufficient statistics of the signals. Therefore, the FRREE implies :

$$E_1[\xi_2|F]=E_0[\xi_2]+\beta_S(\tilde{s}_n-E_0[\xi_2]) \tag{1.74}$$

Such as $\beta_S=\frac{\text{COV}(s_n,\xi_2)}{\text{Var}(s_n)}$.

The solution for the first period (1.34) given in definition 1.4.1 of the equilibrium, using (1.74), is such as:

$$\begin{cases} mP_1-n_IX^*=\xi_1 \\ \frac{mF+\phi HP-\beta_S\tilde{s}_n}{1-\beta_S}=E_0[\xi_2] \end{cases} \tag{1.75}$$

Information makes the expectation of the net demand varies randomly, which impacts the hedging pressure (HP). Thus, the futures prices (F) and the spot price at period 1 (P_1) varies randomly. The futures price (F) increases with the conditional expectation of net demand at maturity ($E[\xi_2|F]$). If there is a conditional expectation of a net demand lower than the unconditional one, it means traders anticipate a negative demand shock at maturity on the spot market. A negative net demand shock means a lower spot price and thus a lower payoff. Traders will go shorter on the futures market. The reasoning is reverse with a higher conditional expectation meaning a positive demand shock.
The direct effect of the statistics ($\tilde{s}_n$) is nonpositive for the unconditional expected demand. For a given unconditional expected value of the net spot demand at maturity ($E_0[\xi_2]$), the futures price decreases because the speculative component of traders is shorter. The mechanism is reverse if a positive net demand shock is expected at the opposite. The hedging pressure (HP), which is decreasing of the futures price, will rise until both sides of the market-clearing equations (1.75) hold. Moreover, when the sufficient statistics for the net demand at maturity increases, the futures price increases more than the spot price. Thus, the basis ($F - P_1$) increases with the conditional expectation of net demand at maturity ($E[\xi_2|F]$). Nonetheless, the l.h.s term of the clearing equation of the first period does not depend on this expectation. Therefore, the total demand on the spot market in the first period never depends on the expectations of the net demand in the second period. While the l.h.s of the second period is increasing with the sufficient statistics. [7]. The system (1.75) in the unconditional space ($\xi_1, E_0[\xi_2]$) is:

[7] The quasi-equilibrium is more detailed in appendix 1.A.1

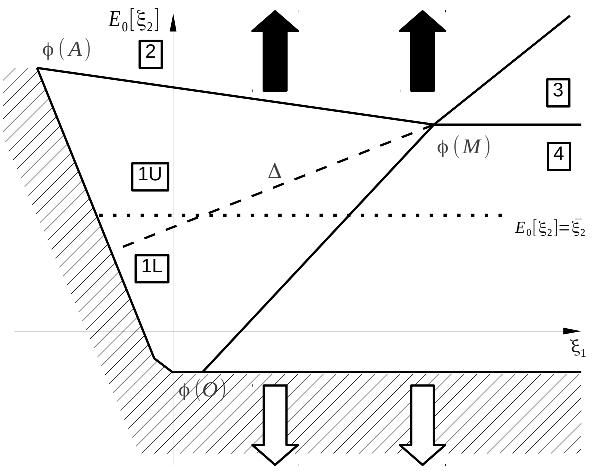


Figure 5: In the space $(\xi_1, E_0[\xi_2])$, The borders between the regions will be stochastic as well. They will be shifted upward if $d\tilde{s}_n < 0$ (black arrows) meaning a negative net demand shock or downward if $d\tilde{s}_n > 0$ (white arrows) which is a positive net demand shock.

It is possible to drow a line (Δ) in the plan (F, P_1) which separates the region 1 between two subregions. The first region is divided into two sub-regions, the region 1U where the hedging pressure is positive and the region 1L where the hedging pressure is negative. Ceteris paribus for a given futures price, if the conditional expectation of net demand increases, the unconditional expectation which meets the equilibrium will be higher. The same reasoning is reverse when the conditional expectation decreases.

1.C Hedging and Hirshleifer effect

First, subsection 1.C.1 and 1.C.2 present the conditions for the Hirshleifer effect. Second, subsection 1.C.3 compares two cases, one where the storer dominate hedging like in the main article and the other one where the storers dominate.

1.C.1 Representative agent

The profit function of the representative agent R is:

$$\pi_R = f_R(P_2 - F) + N_I x(P_2 - P_1) - N_I \frac{1}{2} C x^2 + N_P(y - \frac{\beta}{2} y^2) Z - N_P y P_2 \tag{1.76}$$

With:

$$\max_{x_R \in \mathbb{R}^+, y_R \in [0, \frac{1}{\beta}], f_R \in \mathbb{R}} U_R = E_1[\pi_R | F] - \frac{\alpha_R}{2} \text{Var}_1[\pi_R | F] \tag{1.77}$$

I get:

$$f_R = \frac{E_1[P_2|F] - F}{\alpha_R \text{Var}_1[P_2|F]} - x_R + y_R \quad (1.78)$$

$$x_R = N_I \frac{F - P_1}{C} \quad (1.79)$$

$$y_R = N_P \frac{Z - F}{\beta Z} \quad (1.80)$$

The clearing condition on the futures market becomes $f_R = 0$ so we get:

$$E_1[P_2|F] - F = \alpha_R \text{Var}_1[P_2|F]\text{HP} \quad (1.81)$$

With $\text{HP} = N_I x - N_P y$. α_R is the risk aversion of the market. According to the equation of the risk premium (1.54), we get:

$$\alpha_R = \frac{1}{\sum_{j=\{I,P,S\}} \frac{N_j}{\alpha_j}} \quad (1.82)$$

The market risk aversion is the inverse of the arithmetic mean of the risk tolerances ($\sum_{j=\{I,P,S\}} \frac{N_j}{\alpha_j}$), which is related to the harmonic average of the risk aversion. This result is consistent with Lintner (1969).

1.C.2 Elasticity of the hedging pressure to the conditional net demand precision

The following equation for the utility of speculators is:

$$(2m^2 \alpha_B (\sum_{j=\{I,P,S\}} T_j)^2 \tau^1_{\xi_2|F})^{-1} \text{HP}^2 \quad (1.83)$$

The derivative by the precision gives:

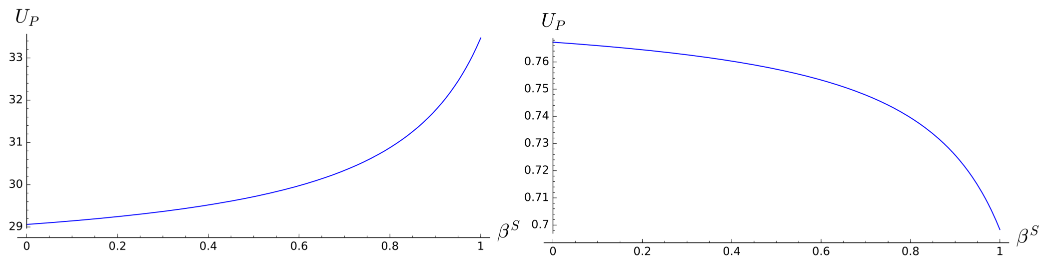
$$\frac{dU_B}{d\tau^1_{\xi_2|F}} = (2m^2 \alpha_B (\sum_{j=\{I,P,S\}} T_j)^2)^{-1} \frac{HP}{\tau^2_{\xi_2|F}} (-HP + 2\tau^1_{\xi_2|F} \frac{dHP}{d\tau^1_{\xi_2|F}}) \quad (1.84)$$

The variation of the precision modifies prices through the sensitivity of the demand to the expected hedging pressure (1.30). When the precision increases, the risk premium decreases, and so does the sensitivity. Ekeland et al. (2019) show the absolute value of the hedging pressure increase when the precision rises. Therefore, $\frac{dHP}{d\tau^1_{\xi_2|F}}$ and HP have the same sign.

Thus, $\frac{dU_B}{d\tau^1_{\xi_2|F}} > 0$ implies $\frac{\frac{dHP}{HP}}{\frac{d\tau^1_{\xi_2|F}}{\tau^1_{\xi_2|F}}} > \frac{1}{2}$.

1.C.3 Dominating hedging

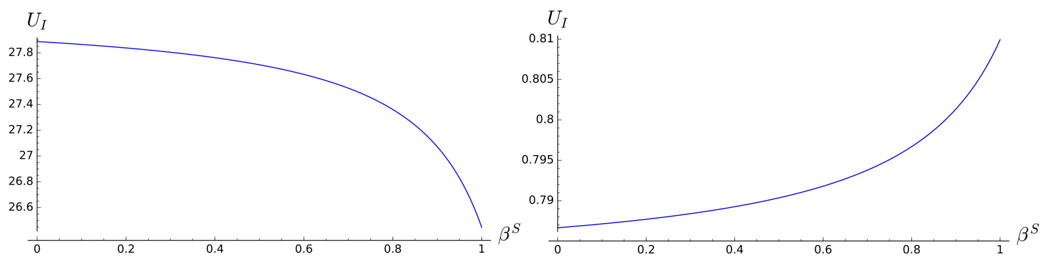
On the left side, the processors dominate, and on the right one, it is the storers. The output forward price and the conditional expected demand are lower in this example when the storers dominate hedging.



(a) Processors dominate hedging (b) Storers dominate hedging

Figure 6: Utility of the processors according to the precision. The values in the figure on the left are: $n_I = 1$, $n_P = 1$, $\alpha_j = 2$, $\alpha_P = 2$, m = 0.5, $\alpha_S = 2$, $N_S = 1$, $\xi_1 = 70$, $E[\xi_2|F] = 80$, Z = 170. On the right, the only difference is $Z = 145$ to implement the domination of storers.

Both situations are symmetric.



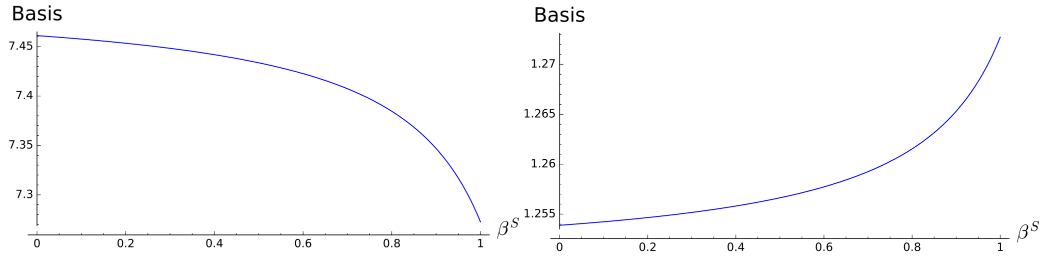
(a) Processors dominate hedging (b) Storers dominate hedging

Figure 7: Utility of the storers according to the precision. The values in the figure on the left are: $n_I = 1$, $n_P = 1$, $\alpha_j = 2$, $\alpha_P = 2$, m = 0.5, $\alpha_S = 2$, $N_S = 1$, $\xi_1 = 70$, $E[\xi_2|F] = 80$, Z = 170. On the right, the only difference is $Z = 145$ to implement the domination of storers.

The spread of arbitrage used by hedgers increases for the dominating ones, but it decreases for the dominated ones. Storers hedge according to the basis to make a contango arbitrage.

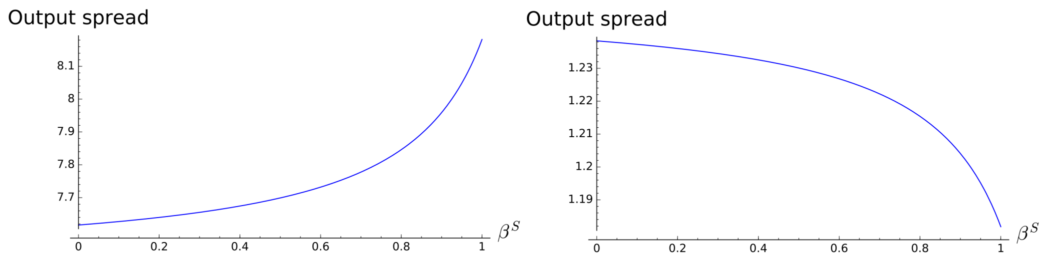
Processors make their arbitrage between the scaled forward price of the output and the futures price of the input. The difference between these two prices is the "output spread."

When there is a Hirshleifer effect, the dynamics of the spreads remain the same but all the utilities are decreasing straight slopes.



(a) Processors dominate hedging (b) Storers dominate hedging

Figure 8: Basis according to the precision. The values in the figure on the left are: $n_I = 1$, $n_P = 1$, $\alpha_j = 2$, $\alpha_P = 2$, m = 0.5, $\alpha_S = 2$, $N_S = 1$, $\xi_1 = 70$, $E[\xi_2|F] = 80$, Z = 170. On the right, the only difference is $Z = 145$ to implement the domination of storers.



(a) Processors dominate hedging (b) Storers dominate hedging

Figure 9: Output spread according to the precision. The values in the figure on the left are: $n_I = 1$, $n_P = 1$, $\alpha_j = 2$, $\alpha_P = 2$, m = 0.5, $\alpha_S = 2$, $N_S = 1$, $\xi_1 = 70$, $E[\xi_2|F] = 80$, Z = 170. On the right, the only difference is $Z = 145$ to implement the domination of storers.

Chapter 2

Technical trading on the US natural gas futures market: the dry wood waiting the spark ?

Contents

2.1 Introduction

Tokic (2011) highlights 90% of Commodity Trading Advisers (CTA) registered in IASG.com only use technical/quantitative analysis in their trading approaches. CTAs provide individualized advice for customers who want to take positions on commodity futures or options. They can be hired by a Commodity Pool Operator (CPO) to make investment decisions. Both are regulated by the National Futures Association (NFA) and the Commodity Futures Trading Commission (CFTC). Natural gas is concerned by this issue where money managers like CTA are about half of the open interest according to CFTC data. Thus, a significant share of traders on the US natural gas market tends towards trend following. Such a proportion raises the issue of self-fulfilling trends which might be generated by financial shocks or manipulations (like Amaranth in 2006). This issue is particularly hot in the US, where natural gas is Roughly 30% of the energy mix.

This chapter focuses on the consequences of trend-following strategies on the US natural gas pricing. First, This study contributes to the literature about futures risk premium by evaluating the impact of trend-chasing trading and rational speculation at a weekly frequency. Technical analysis is a broad set of tools that aims to measure market sentiment. This framework assumes that market movements are not random, but they follow patterns and trends. Technical traders have to determine the direction of the current trend and determining if dynamic will keep on. Therefore, strategies based upon technical analysis are said "*trend-following.*". The names of "trend-chasing" behavior, "momentum trader" or "positive feedback trading" are also common in literature. This kind of strategy generates a "*Tinkerbell effect.*" Their effects exist because traders believe it. If traders buy when the price is rising, the price will be kept on increasing and vice-versa. Trend-following strategies contribute to volatility and might generate bubble patterns. De Long, Shleifer, Summers, and Waldmann (1990) show that the price of stocks can vary irrespective of the fundamental value of the asset. The self-fulfilling prophecy is activated so "*rational destabilizing speculation*" can occur. Tokic (2011) suggested a generalization for futures markets. Rational speculators taking large positions generate a huge variation of prices. If trend-followers are active on the market, they exacerbate the trend, which increases volatility. Moreover, contrarians are forced to give up because of too expensive margin calls. Thus, they undo their short positions, which is called "*short covering.*" This phenomenon is a kind of "forced trend-following trades." A bubble emerges and then bursts. Second, This study estimates the feedback of the futures price to spot price with instrumental variables, which enables to test for informational frictions.

Trend-followers can impact the futures pricing, but do they influence the spot market indirectly? The traditional answer tells financial activities on the futures market cannot generate a bubble on the spot market. If the futures price increases, the basis increases as well, so storage becomes more profitable. Storers become long on the spot market and short on the futures market. Therefore, the storage level rises. Moreover, the price elasticity of the demand is not zero. Spot demand decreases. The storage level delays demand in the spot market. This decline of the spot price is why the basis increases, and so does the storage level. Therefore, a bubble would generate continuously increasing inventories. Such a dynamic is not sustainable (Hamilton, 2009). Fattouh, Kilian, and Mahadeva (2013) tell that inventory data show no evidence of speculative pressure, and the 2008 spike is likely the result of the rising demand.

Nonetheless, Cheng and Xiong (2014a) say the surging global demand fails to explain the 2008 price spike. The authors add commodity prices are barometers of the economy, which generates informational frictions. High commodity prices can reveal a robust global demand. Sockin and Xiong (2015) show that under some conditions, this informational effect of commodity prices can offset the cost effect, which makes demand decreasing with the price. Therefore, the price elasticity of demand can be zero and even more surprising, demand can increase with price because of the informational effect. The direct consequence is a bubble, generated by a financial shock, can arise both on futures and spot price in this situation.

What is the influence of trend-following strategies on the US natural gas pricing? This study aims to test if there is evidence consistent with the influence of trend-followers on futures and spot prices of the US natural gas market.

First, the literature review exposes issues about the topic of this chapter and motivations to this study. The second section presents the data. Third, regressions are run for constant maturities of one month, two months, and three months. Results show that futures prices depend on the value the week before. Moreover, there is little evidence of the impact of hedging pressure, which is the net difference between the short positions and the long positions of hedgers. While the coefficient of the variation of the hedging pressure is significantly positive. These results hold before and after the 2008-spike. Thus, results are consistent with the existence an impact of trend-followers and with commercial traders acting as contrarians. there is no found evidence of any informational effect. The relationship between the US natural gas futures and spot prices is unstable between 2009 and 2015. Last, results are consistent with the idea speculation exacerbate trends on the futures market and spread to the spot market.

2.2 Literature and motivations

2.2.1 Literature review

This chapter follows the approach of the risk premium, which evaluates the different underlying forces contributing to the US natural gas pricing. Moreover, this study looks at the feedback of the futures price to the spot price of the US natural gas market. A first intuitive way to look at the pricing is to study fundamentals. Abundant literature exists about the risk premium, which is the payoff of speculators to bear the overall risk of hedgers, which is the hedging pressure. This hedging pressure theory has four implications (G. Gorton & Rouwenhorst, 2004):

1. The expected payoff of a futures position is the risk premium. The realized payoff is the risk premium plus any unexpected deviation of the future spot price from the expected future spot price
2. A long position in futures is expected to earn positive (excess) returns as long as the futures price is set below the expected future spot price.
3. If the futures price is set below the expected future spot price, the futures prices will tend to rise over time, providing a return to investors in futures contracts.
4. Expected trends in spot prices are not a source of return to an investor in futures contracts.

In this theoretical framework, speculators take the opposite side of hedgers. Speculators offset the net demand implied by the hedging pressure. Thus, the market clears. Therefore, speculators bring liquidity according to this theoretical frame. Indeed, if the hedging pressure is net short, the futures price goes down and will be below the spot price. Speculators have long positions to clear the market. At the opposite, if the hedging pressure is long on futures, speculators are short. Bessembinder (1992) finds that net short hedging pressure is positively related to higher futures returns. This result is consistent with speculators providing risk-sharing services as the counterpart of hedging pressure. De Roon, Nijman, and Veld (2000) confirms this result which is still significant even after they control for "*price pressure,*" which is a temporary liquidity effect of the short hedging demand pushing prices temporarily downward and vice-versa if hedgers are net long.

Nonetheless, G. B. Gorton, Hayashi, and Rouwenhorst (2013) find no evidence that the positions of participants predict risk premiums on commodity futures. They find the contemporaneous hedging pressure is positively related to futures returns, but there is no significant influence of ex-ante hedging pressure on futures returns. Commercials positions become shorter while noncommercials go longer when the futures price increase. Thus, noncommercials behave like momentum traders.

Fishe and Smith (2018); G. B. Gorton et al. (2013); Kang, Rouwenhorst, and Tang (2017); Rouwenhorst and Tang (2012) find that non-commercial traders are trend followers and commercial traders are contrarian. The implication is very important because trend-followers ask for risk sharing as well, so they need counterparts. Therefore, two kinds of risk premiums exist on the market, one for hedgers and another one for trend-followers (Kang et al., 2017). This fact completely changes the nature of interactions on the market because commercial traders can be the counterpart of a risk-sharing demand coming from speculators who want to bet on futures trends. Roles reverse. This paper belongs to this set of literature by confirming these findings. In this chapter, This paper sets up a method to estimate these two kinds of risk premium by modifying the regression of Schwarz (2012) to capture trend-chasing strategies at a weekly frequency. The spot price at maturity is included to capture rational speculation as well, like in Moosa and Al-Loughani (1995).

Literature has always been a very critic of trend-following strategies. The latter is very common among the Commodity Trading Advisor (CTA). The CTA using technical strategies have been accused of impeding diversification (Billingsley & Chance, 1996; Elton, Gruber, & Rentzler, 1987). They are a "market failure" literally (Bhardwaj, Gorton, & Rouwenhorst, 2014). Their performance is not significantly higher than the treasury bills. Their performance is not significantly higher than the treasury bills. , and they do not exhibit any excess return (which is called "*alpha*").

Nonetheless, trend-following strategies and momentum strategies can bring significant profit (Chaves & Viswanathan, 2016; Szakmary, Shen, & Sharma, 2010). Han, Hu, and Yang (2016) show that moving average timing strategy may generate a higher payoff than buy-and-hold. Yin and Yang (2016) who show that moving-average and momentum indicators outperform macroeconomic ones to predict oil futures returns. Moreover, they bring significant economic gains with both higher Sharpe ratio and Certainty Equivalent Return.

Cifarelli and Paladino (2010) show evidence of trend-following trading on crude oil spot prices from 6 October 1992 to 24 June 2008. They estimate a behavioral ICAPM with a CCC

GARCH-M model for the oil spot returns. They find a significant positive coefficient for the lagged spot returns, which is consistent with positive feedback trading. Moreover, they also find a positive sensitivity of spot returns to lagged futures returns. Trend-followers make the price increasing with its past values, which might generate bubbles (De Long et al., 1990). This dynamic is self-fulfilling so that the price can rise far above the fundamentals. Joëts (2015) backs this point with a Heterogeneous Agent Model (HAM) applied to the natural gas market. In times of uncertainty, agents are more trend-following. During extreme price decreases, the chartist agents averse to uncertainty dominate the natural gas market completely. In this context, irrational fluctuations can drive out fundamental-based trading. It can lead to a "*cascading behavior*" with a self-fulfilling trend. During normal times, there is only a slight majority of uncertain chartists on the market. Fundamentalists compose the rest.

Tokic (2011) extends De Long et al. (1990) to the 2008 crude oil spike. Institutional traders un-purposely destabilize the efficient crude oil pricing by going long after a rise generated by noise traders. They generate an upward trend which triggers positive feedback trading from managed futures funds. Then, hedgers offset their short positions because margin calls become too expensive. Thus, the crude oil price keeps on rising. The trend goes on until investors sell for profit, which bursts the bubble[1]. Tokic's theory is different from the highly controversial Master Hypothesis (Masters, 2008), which states that institutional investors caused the 2008 spike[2]. In Tokic's framework, institutional investors are not the origin of the spike. They strengthen the impulse given by bullish noise traders[3]. By going long, CIT offset downward fundamental forces. This dynamic generates a trend which is followed by technical traders. Tokic (2011) finds that commercial producers of crude oil aggressively reduced their short hedge positions in 2008 by analyzing the Commitment of Traders (CoT) provided by the CFTC. This result is consistent with short covering among commercial traders during the 2008 spike.

A convective "risk flow" (Cheng, Kirilenko, & Xiong, 2015) might cause a reversal. When financial investors are distressed, they are tempted to undo their positions. Cheng et al.

[1] Tokic (2012) qualified later Tokic (2011) in light of a DCOT report analysis. Money managers played well the trend, and there seems to be short covering among commercials and nonreportable positions. Nonetheless, the trend is less clear among swap dealers. The aggregation of heterogeneous agents in groups explains why swap dealers are a noisy proxy for CIT because they also take positions for physical operators (Cheng & Xiong, 2014a).

[2] This hypothesis is backed by Singleton (2014), who finds CIT positions predict oil futures returns. Nonetheless, the replication of his work has been a failure (Hamilton & Wu, 2015).

[3] Noise trading can be caused by hedging from economic activities. Therefore, the "rational destabilization" described by Tokic (2011) let the room open for a bullish impulse coming from fundamentals such as the global demand for example.

(2015) find that institutional investors' positions are more sensitive to the variations of the VIX. When the VIX increases, their positions decrease. The futures price decreases, which gives an incentive to hedgers to go longer. Therefore, speculators transfer risk to hedgers. In this paper, I find the US natural gas futures prices depend positively of their value the week before. This result means price trends can be self-fulfilling in the US natural gas markets.

Furthermore, speculation distorts futures prices upward if there are informational frictions (Cheng & Xiong, 2014a). A rising level of inventories according to the increasing price means that traders know the difference between a speculation-induced rise and a fundamentals-induced one. It is not necessarily true. Commodity prices can be interpreted as barometers of the economy. A demand shift upward might mean a healthy economy because companies buy more inputs to face a higher output demand. This signal about the global economy to traders is known as the informational effect. Sockin and Xiong (2015) show that this informational effect can offset the cost effect (the decreasing demand according to the price). Thus, the demand would be increasing with the price, which is counter-intuitive. The direct consequence is that the price would rise without inventories doing so as well. Nonetheless, I do not find evidence of an informational effect.

Even without any informational effect, speculation exacerbates trends. Adams and Glück (2015); Adams and Kartsakli (2017); Henderson, Pearson, and Wang (2015); Juvenal and Petrella (2015); Tang and Xiong (2012) highlight the role of financial vehicles such as Commodity Index Traders (CIT), ETFs or Commodity-Linked Notes (CLN) in the increase of commodity prices between 2004 and 2008. According to these authors, the long positions of CIT generate comovements and upward price pressure on indexed commodities, which spread to their spot markets. Basak and Pavlova (2016) provide a theoretical explanation for this phenomenon. Trend-following strategies are based on the trends of a single market, but they generate similar dynamics. The accumulating long positions of technical traders can reinforce a bullish trend on commodity prices in a self-fulfilling dynamics. In the context of an excellent economic conjuncture, speculation exacerbates the price increase and hurt demand, even if global demand is the main factor driving commodity prices upward (Kaufmann & Ullman, 2009). This explanation is consistent with Juvenal and Petrella (2015) who find that speculation was a force driving down crude oil prices in the crash of 2008. My work does not address the influence of CIT but is complementary to this topic. The issue with technical trading is similar about two points, trend exacerbation and feedback from the futures market to the spot market. I find evidence consistent with the influence of technical traders and feedback from the futures price to the spot price in the US natural gas market. These findings are in accordance with the idea speculation has real effects on economic activity, shared by the papers quoted here.

In this paper, I estimate the influence of the past prices on the US natural gas futures market and the sensitivity of the spot price to the futures price. I check if my results are consistent with a significant influence of trend-following strategies and informational frictions on the US natural gas market.

2.2.2 Motivations

Money managers represent about 40% of the market total open interest in average from 2006 to 2015[4]. By adding the swap dealers, financial operators positions become roughly 70% of

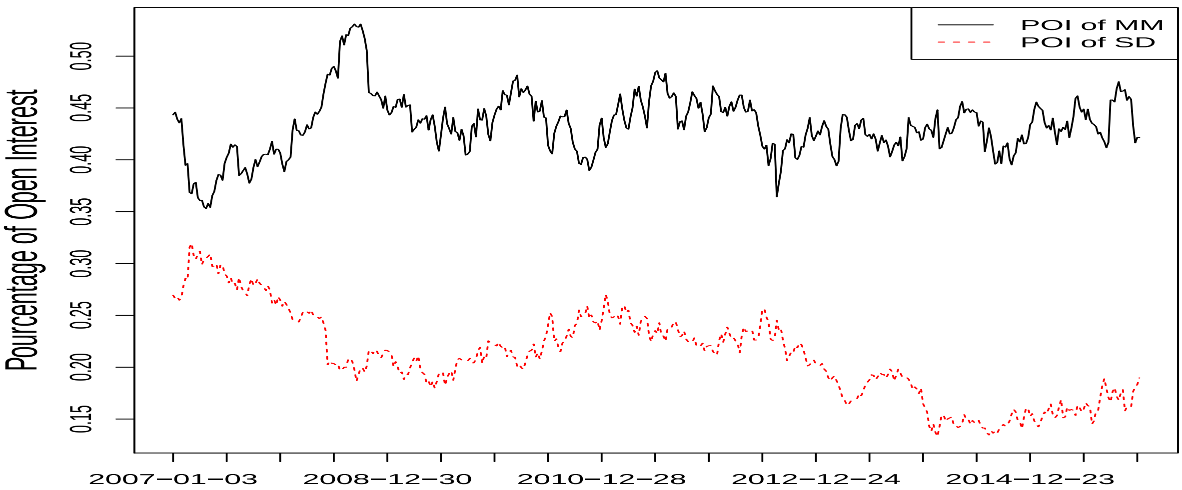


Figure 1: Percentage of open interest of the money managers (black line) and the swap dealers (red dashed line) in the US natural gas futures market.

the open interest through years. Trend-following strategies are prevalent among CTAs, which weight nearly half of the open interest.

This study focuses on trend-following strategies which are a kind of momentum. A first approach is to use the PnL of a futures contract the week before as a signal to take a long or a short position (De Long et al., 1990). The PnL of a long position for a given day is the difference between the price this day and the price at a chosen previous day. A positive PnL is a sign to take a long position, while a negative PnL is a sign for a short position. De Long et al. (1990) calls this strategy "*positive feedback trading.*"Let us consider $F_{t-\Delta t,T}$, the futures

[4]The percentage of open interest (POI) is equal to the sum of the long, short and twofold spread positions divided by the market total open interest which is the sum of all the positions on the market (Chen & Chang, 2015). Computations are made from the DCOT report of CFTC.

price at maturity T at time $t - \Delta t$, and $F_{t-\alpha\Delta t,T}$, the lagged futures price for maturity T at time $t - \alpha\Delta t$. α is an integer. The trend-follower compares $F_{t-\Delta t,T}$ and $F_{T,t-\alpha\Delta t}$. If the price at time $t - \Delta t$ is greater than the one at time $t - \alpha\Delta t$, the position will be long. Otherwise, it will be short. Δt is an interval of time that can be chosen arbitrarily. α is an exogenous integer. In this study's approach, Δt represents one week. Therefore, $t - \Delta t$ is the week before at time t and $t - \alpha\Delta t$ is an arbitrarily chosen prior week. If Δt is a pace of one week and $\alpha = 2$, $t - \alpha\Delta t$ is the week before the last week. The name for this variation of profit is "*weekly PnL*." Thus, this strategy looks at the PnL of a futures contract in a past period going from the week before to an earlier day arbitrarily chosen. The aggregate position of trend-followers (Q_C) is as such :

$$Q_t^C = N_C(F_{t-\Delta t,T} - F_{t-\alpha\Delta t,T}) \tag{2.1}$$

N_c is the sensitivity of the technical traders' total position to the weekly PnL.

Trend-following strategies are not always voluntary. They can be the outcome of short covering when traders are forced to undo their positions because of unaffordable margin calls. It can be compared to the stop-loss orders on the stock markets. Closing contrarian positions strengthen the trend. Nonetheless, the short covering does not aim to follow a trend during a given period, unlike technical traders do. Short covering depends on the nearest past price. Thus, the alternative hypothesis is that trend-following strategies depend on the last price ($F_{t-\Delta t,T}$), as described by (Koutmos, 1997). The aggregate position of trend-followers (Q_C) is as such :

$$Q_t^C = N_C F_{t-\Delta t,T} \tag{2.2}$$

Commodity prices are barometers of the economy. They convey information. A higher commodity price might be the consequence of higher demand. Therefore, demand could increase because agents anticipate a stronger economy. This informational effect can be high enough to offset the cost effect. This study considers two different cases about the value of price elasticity:

1. The classical case of hedging pressure theory when there is no influence of informational effect: the spot demand is decreasing with the price strictly. The informational effect does not offset the cost effect. If there is a financial shock rising the futures price, the spread between the futures price and the spot price (called the *basis*) increases. The effect is different whether the forward curve is in contango or backwardation. When the

futures price is increasing with maturity (contango), the storage level increases, which is a positive demand shock on the spot market. Therefore, the spot demand decreases because of the higher spot price. This last effect mitigates the rise of the spot price. The storage level replaces the spot demand. Thus, the sensitivity of the futures price to the spot price is lesser than one. There is an under-feedback from the futures price to the spot price. For any shock affecting the futures price directly, the spot price will vary less than the futures price. The basis grows. The level of inventories rises. This dynamic generates a positive supply shock at maturity. The release of inventories, at the expiration of the futures contracts, drives the spot price down.

When the futures price is decreasing with maturity (backwardation), the basis remains still negative. Storage is not increasing, but the rising futures price makes hedging costly for long hedgers. The latter reduce their hedging positions, which will translate in a negative demand shock at maturity. The spot price is driven down at maturity as well. Nonetheless, inventories did not vary.

2. The informational effect offsets the cost effect: the spot demand is increasing with the price. The informational effect offsets the cost effect. If there is a financial shock rising the futures price, the temporary higher demand of the storers will push the spot price upward. Therefore, the spot demand increases because of the higher spot price, which deters storage activity. The spot price rises even further. Thus, there is an over-feedback from the futures price to the spot price. For any shock affecting the futures price directly, the spot price will vary more than the futures price. The basis diminishes. The inventory level decreases. It is the situation described by Sockin and Xiong (2015).

The second case is the only one where a bubble is sustainable because the storage level does not increase. This explanation is the missing link to Tokic (2011). I define the bubble theorized by Tokic (2011) and the necessary condition to it, which is the informational effect described by Sockin and Xiong (2015) as such :

Definition 2.2.1 (Tokic bubble) *When there is an upward trend, trend-following traders exacerbate this rise. Short hedgers and other contrarian speculators are forced to cancel their positions. This last step, known as "short covering," is a forced trend-following strategy. Therefore, a bubble emerges and grows more and more.*

Definition 2.2.2 (Sockin-Xiong Condition) *The situation where the informational effect offsets the cost effect with an over-feedback or perfect feedback. Therefore, the sensitivity of* *the spot price to the futures price is magnified, becoming greater than one.*

Thus, we make the following proposition:

Proposition 2.2.1 *A "Tokic bubble" can emerge if only the "Sockin-Xiong condition" is fulfilled.*

2.3 Empirical Investigation

This section exhibits some facts about the studied spot market, the Henry Hub in Louisiana, and the derivatives market in the New York Mercantile Exchange (NYMEX).

2.3.1 Data

The dataset includes daily data from 2000-02-01 to 2015-07-28 except for the hedging pressure, which is weekly. Table 1 describes the time series.

The figure 2 shows highly volatile gas prices with a very high correlation between the spot price and the constant-maturity futures prices. The 2005 spike is the consequence of hurricane Katrina which breaks the supply of provisions at Henry hub which is in Louisiana. There are spikes in 2008, 2010 and the last one in 2014 just before the crude oil price crashes and remains low.

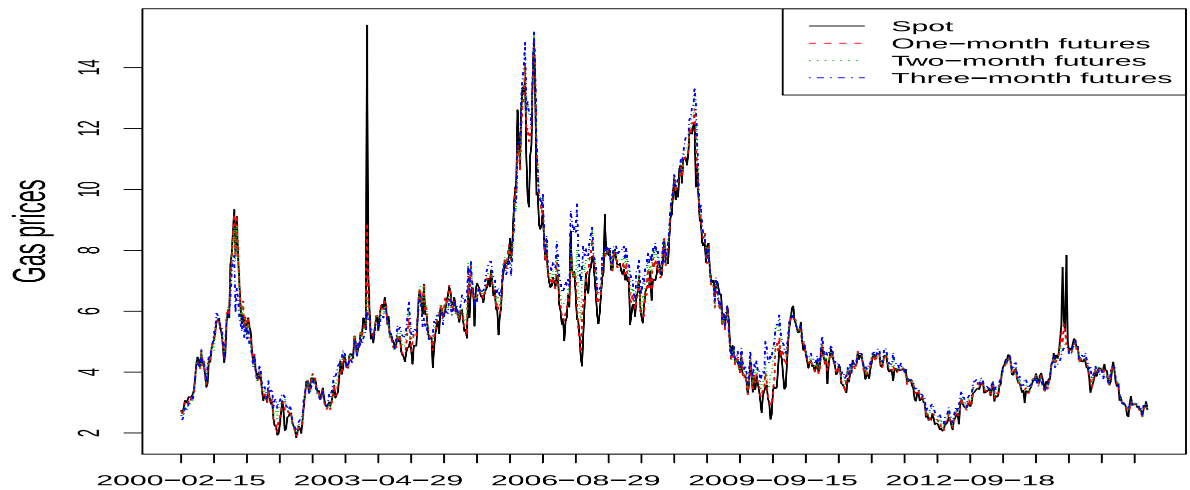


Figure 2: Evolution of the spot and three first maturities with weekly variations during the time frame of the dataset.

For the same period, other sources are:

Name	content	unit of measure	source
P_t	Price of the natural gas on the physical market. It is based on the delivery at the Henry Hub in Louisiana. Official daily closing prices at 2:30 p.m	Dollar and cents per MMBtu.	EIA (through datastream)
$F_{t,T}$	Natural gas constant-maturity futures price. It is based on the NYMEX natural gas futures contract. The used roll method is the nearest future with a switchover the following last trading day. The series starts at the nearest contract month, which forms the first values for the continuous series until the contract reaches its expiry date. At this point, data from the next contract month is used. No adjustment for price differentials is made. The constant maturity used are one, two and three months.	Dollar and cents per MMBtu.	datastream
P_T	The spot price of the day of the expiration of the futures contract. For each quotation day of the futures contract, the later spot price at maturity is the reference.	Dollar and cents per MMBtu	Computed through the spot price time series with an R script.
Q_t	The physical traded volume of natural gas on the Henry Hub.	Thousands of MMBtu	Provided free of charge by Platts
HP_t	The Hedging Pressure (HP) is the difference between the long and short positions of the commercial traders. This time series is weekly.	Number of contracts	The Commitment of the Traders (COT) by the CFTC
$B_{t,T}$	One-month WTI futures price	Dollar per barrel	Datastream
HDD_T	Weekly Heating Degree Days (HDD) population-weighted for the US	Number of degrees that a day's average temperature is below 65 degrees Fahrenheit	American Gas Association

Table 1: Description of the data

- The Commitment of the traders (CoT) by the CFTC. The only data which is weekly.
- Traded volume in thousands of MMBtu on the Henry Hub Natural Gas market provided free of charge by Platts.

The CoT is a breakdown by categories of the open interest of the natural gas futures market. There are four categories:

- Producer/Merchant/Processor/User: They are commercial hedgers who have physical activity.
- Swap Dealers: They trade swaps on natural gas that they hedge on the futures market.
- Managed Money: This category includes Commodity Trading Advisors (CTA), Commodity Pool Operator (CPO), and unregistered funds identified by CFTC. They trade futures contracts on behalf of clients.
- Other Reportables: The rest of the traders who are not in the categories above.

A trader's classification can change over time.

The definition of the hedging pressure variable (HP_t) in a futures market is the difference between the number of short and the number of long positions by commercial traders :

$$HP_t = \text{short positions of commercial traders}_t - \text{long positions of commercial traders}_t \quad (2.3)$$

If the sign of hedging pressure is positive, the short hedging demand nominates. Otherwise, a negative hedging pressure means a net long hedging demand on the market. Two essential points about hedging pressure have to be made. First, hedgers speculate and trade far more than their hedging needs (Cheng & Xiong, 2014b). Second, hedging pressure can be the counterpart of the trend-followers demand for risk sharing (Kang et al., 2017).
The derivatives markets depend on their underlying, the Henry Hub. The influence of the latter, in the traded physical volumes, in the US has been declining because of structural changes in the US natural gas production. Henry Hub is one gas hub among more than 100 ones on the North American continent. The production of natural gas in Louisiana has declined in particular from the Southern part of the state and the outer continental shelf. The flows of shale gas from the North of the state did not offset the supply drop. Physical liquidity decreased (Leach & Schlesinger, 2015). A great part of the US shale gas production

Table 2: Summary of the weekly data

HP is the hedging pressure, which is a net sum of the number of contracts traded. $\Delta \mathrm{HP}_t$ is the weekly variation of hedging pressure. $F_{t,T}$ is the price per MMBtu for a constant-maturity natural gas futures with $T = \{1, 2, 3\}$ (one month, two months and three months). P_t is the spot price at the maturity of the natural gas futures contract. Q_t is the weekly physical volume traded on Henry Hub in thousands of MMBtu.

Statistic	N	Mean	St. Dev.	Min	Max
HP_t	765	19,159.120	26,792.440	−76,790.370	104,793.700
$\Delta\,\mathrm{HP}_t$	764	−16.077	6,718.234	−23,230.230	27,658.030
$F_{t,1}$	765	5.181	2.217	1.906	14.976
$F_{t,2}$	765	5.285	2.252	1.988	15.126
$F_{t,3}$	765	5.376	2.288	2.116	15.176
P_t	765	5.130	2.213	1.845	15.390
Q_t	765	1,430.387	1,845.306	39.241	10,083.840

is far of the Henry Hub in particular in the Appalachians and Dakota. The produced gas of these locations went to other hubs.

In average, hedging pressure is positive. The first quarter is positive as well, so short hedging from commercial traders dominates most of the time. This fact is consistent with the interpretation of Keynes et al. (1930), who explains that producers are more willing to hedge their risks rather than consumers. There are broad ranges of variations for natural gas. The highest price for both one-month futures and the spot is four times higher than the smallest one. It can be explained partly by seasonality. There is the same issue for the variations of the physical traded volume. Figure 3 shows the year 2010. There is a spike in January when the temperatures are the coldest. Then the price slowly decreases until spring comes in March. The term structure is backwardated. Storage is scarcer, and expectations about the spot price for the next month are downward. The period between May and September is more uncertain because traders are making their expectations about the next winter. In October, the term structure becomes in contango. It is an incentive to increase the storage level. Expectations are upward for the next month, which is November, announcing winter is coming. Then, prices are increasing at the end of the year, which is the beginning of the winter.

Time series are deseasonalized with an exponential moving average. This method captures nonlinear variations of the cycles. [5] The stationarity of time series needs to be verified. If all the variables are stationary, the residual will be it as well. Thus, significance tests hold.

[5] The exponential moving average is more accurate than dummy variables or simple moving averages, which captures linear parts of the seasonality only.

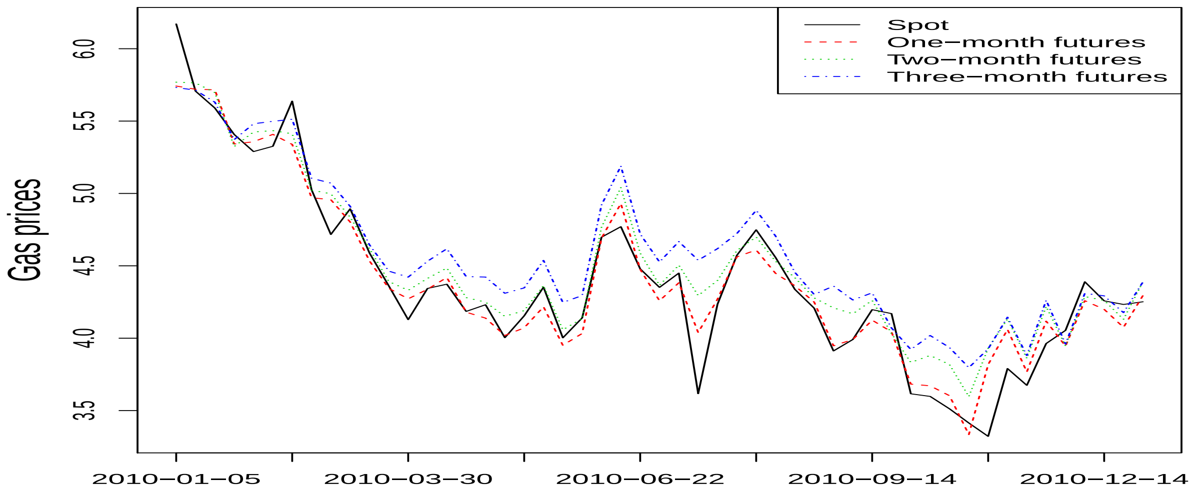


Figure 3: Snapshot of the spot and three first maturities with weekly variations during the year 2010.

However, if variables are nonstationary, residuals might be non stationary either. Therefore, they would not be white noise. The tests would be invalid and could indicate significant reliable results while the regression is spurious. we check if the variables are cointegrated. Non stationary variables are cointegrated when the residuals of the regression are stationary.

2.3.2 Setting the empirical tests

Two aims guide this chapter. The first part looks at the sensitivity of the spot price to the futures price to check if there is a sign of an informational effect. Second, the sensitivity of the futures price to past values is estimated. In each equation, other variables are put as control.

The regression for the futures price is directly inspired by Schwarz (2012) who focuses on returns, however. The cointegration relationship established in subsection 2.3.3 enables to estimate non-differentiated time series in levels. The explanative variables include a second lag of the explained variable and the spot price at maturity. The latter variable comes from Moosa and Al-Loughani (1995). The aim is to measure the weight of rational speculation, which takes positions according to the expected spot price at maturity. The latter is assumed to be unbiased.

I test the following system :

$$P_t = a_{10} + a_{11} F_{T,t} + a_{12} Q_t + n_t \tag{2.4}$$

$$F_{T,t} = a_{20} + a_{23} \tilde{P}_T + a_{24} F_{t-\Delta t,T} + a_{25} F_{t-\alpha\Delta t,T} + a_{26} \mathrm{HP}_t + a_{27} \Delta\, \mathrm{HP}_t + v_t \tag{2.5}$$

The study look in particular at these specific values:

- The sensitivity of the spot price to the futures price (a_{11}). If it is greater than one, there is an informational effect offsetting the cost effect with an over-feedback. Therefore, the Sockin-Xiong condition would be fulfilled (see definition 2.2.2). The empirical condition for a informational effect is the equation (2.14).

- The sensitivity of the futures price to its value last week (a_{24}) and the week before (a_{25} with $\alpha = 2$). Δt is a variation of one week. A positive coefficient is consistent with the existence of trend-following strategies and short covering. This study tests two alternative hypotheses for the trend-following positions. The first is based on the difference between the futures price last week and the price the week before, or weekly PnL (De Long et al., 1990) as described by equation (2.1). a_{24} and a_{25} must be positive. The other one is based solely on the price last week (Koutmos, 1997). a_{24} must be positive only as in the empirical condition (2.11).

- The sensitivity to the hedging pressure (a_{26}). The hedging pressure is the difference between the short and the long position of commercials. According to the risk premium theory, the hedging pressure becomes shorter when the futures price decreases, and vice versa when hedgers get longer (Bessembinder, 1992). The expected profit of speculation has to be positive. Therefore, if hedgers are net short, the expected profit of a futures position has to be positive for speculators to go long as counterparts of hedgers. The expectation from assumptions is a negative value of the coefficient a_{26}.

- The price pressure (a_{27}). If hedging is driving trade, an increase in short hedging drives the futures price downward. This liquidity effect is temporary. In this situation, the value of the coefficient a_{27} should be negative. Afterward, this temporary effect would reverse (De Roon et al., 2000). Otherwise, if the coefficient is positive, the hedging pressure is not driving prices. Thus, hedgers are contrarian and provide risk-sharing to speculators who are trend-following (Kang et al., 2017).

Therefore, if the hedging pressure theory is verified, the system meets the following constraints:

$$a_{11} \leq 1 \tag{2.6}$$

$$a_{24} = 0 \tag{2.7}$$

$$a_{25} = 0 \tag{2.8}$$

$$a_{26} > 0 \tag{2.9}$$

$$a_{27} < 0 \tag{2.10}$$

At the opposite, if technical traders have an impact and drive the risk demand as described by Kang et al. (2017), the coefficient for the variation of hedging pressure and past returns are positive. Therefore, the following conditions are met :

$$a_{24} \in \,]0,1[\tag{2.11}$$

$$a_{25} \in [0,1[\tag{2.12}$$

$$a_{27} > 0 \tag{2.13}$$

Such a situation means commercials act as contrarian and prices depend positively on their past values. Therefore, such a result implies there is positive feedback trading among non-commercial operators.

The presence of information frictions, as defined by Sockin and Xiong (2015), implies :

$$a_{11} \geq 1 \tag{2.14}$$

If the sensitivity of the spot to the futures price is greater than one, the demand is increasing with the spot price. An increasing futures price raises the spot price even more. Thus, both prices can rise at the same time with a constant or a decreasing storage level. This analysis is possible because of the cointegration of regression variables and the instruments.

2.3.3 Cointegration

This study applies the Philipps-Ouliaris cointegration test on the linear equations for the futures (2.5) and the spot prices (2.4). This first step is "*cointegration regression.*" Then, the next step is to test if the residuals are stationary. So the second step is checking for a unit root in the residuals with a Phillips-Peron test. The produced statistics has the advantage to be robust against residuals' autocorrelation. The statistics are presented in table 3.

Computing the difference between the price of last week with the price the week before

Table 3: Cointegration tests for time series in levels. *** Significant at the 1% level. All futures maturities are tested, one-month, two-month and three-month ($T = \{1, 2, 3\}$).

Equation	Philipps-Ouliaris statistics 2000-2008	PO stat 2009-2015	Critical val
(2.4) Spot equation (T=1)	401.8489***	351.8967***	46.4097
(2.4) Spot equation (T=2)	385.9248***	219.6988***	46.4097
(2.4) Spot equation (T=3)	303.1218***	152.889***	46.4097
(2.5) Futures equation (T=1)	363.2453***	336.5441***	63.2149
(2.5) Futures equation (T=2)	291.1958***	320.3459***	63.2149
(2.5) Futures equation (T=3)	331.8646***	294.4527***	63.2149

($\Delta t = 2$) enables checking if the trend followers look at the weekly PnL of a futures contract..

2.3.4 The instruments of the GMM regression

The spot price and the futures price are endogenous in the spot clearing equation (2.4). Moreover, endogeneity arises in equation (2.5) because the lagged values. Instrument variables enable to establish causality. Moreover, autocorrelation and heteroskedasticity in the error terms are common issues in financial time series. The continuous updated efficient (CUE) Generalize Methods of Moments (GMM) deals with both issues. The variance matrix of the moments is estimated with the Newey-West estimator (Newey & West, 1987) to be heteroskedasticity and auto-correlation consistent (HAC). ts superiority motivates the choice of the CUE GMM over other GMM estimators in finite samples (Hansen, Heaton, & Yaron, 1996). The aim is to avoid false rejections on the study's sample, which is finite.

The J-stat verifies the validity of the instruments (Hansen, 1982). The null hypothesis is that the conditions on moments hold, which means the model is well-specified. If the test does not reject the null hypothesis, the chosen instruments are consistent with the exclusion restriction. A large J-stat shows the model is mis-specified but does not tell what is wrong in the exclusion restriction. Moreover, J-stat is the output of an overidentifying restriction test. If the model is strictly identified, the J-stat is zero by nature, so the test does not work. The number of instruments has to be higher than the number of explaining variables.

Literature establishes the causal flow from WTI crude oil to US natural gas prices (Brown & Yucel, 2008; Jadidzadeh & Serletis, 2017; Ji, Zhang, & Geng, 2018)[6]. The measured causal-

[6]Nonetheless, I found one article with dissent conclusions (Batten, Ciner, & Lucey, 2017).

ity from natural gas to crude oil prices is marginal according to the same authors. Nonetheless, the apex of the shale gas revolution happened during the second period of the study's investigation, between 2009 and 2015 (Joskow, 2015). This innovation generated instability in the natural gas - crude oil relationship. Historically, technological and economic changes shift the cointegration relationship between crude oil and natural gas in the US (Ramberg & Parsons, 2012). These shifts, which are called "*decoupling,*" can be temporary or definitive. Literature finds results consistent with a decoupling, but let unknown if this is temporary or not (Caporin & Fontini, 2017; Geng, Ji, & Fan, 2016).

There is cointegration between crude oil and natural gas prices in levels between 2000 and 2008 but not between 2009 and 2015[7]. Nonetheless, the relationship is more stable between the natural gas futures prices and the logarithm of the crude oil price, as shown in 4. The only

Table 4: Cointegration tests for the natural gas futures price and the crude oil futures log price at each maturity.

All futures maturities are tested, one-month, two-month and three-month ($T = \{1, 2, 3\}$). $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Maturity (T)	Philipps-Ouliaris statistics 2000-2008	PO stat 2009-2015
1	34.3513**	26.4766**
2	31.109**	23.5753*
3	28.7603**	20.2531

cointegration regression which fails is the third-maturity in the second period. The critical value for significance at the 10% level is 20.3933 (compared to a PO stat of 20.2531). The shift in the Philipps-Ouliaris statistics is the same for every maturity (a difference of roughly 8). I assume there is a cointegration for the rest of the study.

The maturity is the same for WTI and Natural Gas futures. The regression of the futures price is just over-identified with a degree of freedom equal to one. This over-identification enables running the J-test to check if the moment conditions are valid. The instruments I add to the explanatory variables are the one-week and two-week lagged values of the WTI log price plus the deseasonalized Heating Degree Days[8]. The set of instruments of the spot price equation (2.4) encompasses the ones of the futures price equation and the physical daily traded volume. The physical daily traded volume is a control in the spot equation to take into account the fundamental dynamics of the physical market.

[7] See the appendix 1.B.1.

[8] The deseasonalization enables me to capture the temperature variation specific to a given week.

2.3.5 Results

2.3.5.1 Evidence of trend-following and informational effect

First, table 5 shows the results for the futures price.

Table 5: Results for the futures equation

$$F_{t,T} = a_{20} + a_{23}\tilde{P}_T + a_{24}F_{t-\Delta t,T} + a_{25}F_{t-2\Delta t,T} + a_{26}\text{HP}_t + a_{27}\Delta\text{HP}_t + v_t$$
Set of instruments : $(\tilde{P}_T, B_{t-\Delta t,T}, B_{t-2\Delta t,T}, \text{HP}_t, \Delta\text{HP}_t, \text{HDD}_T)$

	Dependent variable:					
	$F_{t,1}$	$F_{t,1}$	$F_{t,2}$	$F_{t,2}$	$F_{t,3}$	$F_{t,3}$
	2000-2008	2009-2015	2000-2008	2009-2015	2000-2008	2009-2015
P_1	0.248875600*** (0.071882960)	0.343436200** (0.140640500)				
P_2			0.085594980*** (0.027506010)	0.076047390 (0.051818850)		
P_3					0.043128180** (0.019136830)	0.026141000 (0.035728130)
HP_t	0.000000291 (0.000001283)	0.000005061 (0.000000408)	0.000001840* (0.000001031)	0.000000127 (0.000000453)	0.000001974** (0.000000842)	0.000000315 (0.000000476)
$\Delta\,\text{HP}_t$	0.000017370*** (0.000002530)	0.000005061 (0.000003707)	0.000018723*** (0.000002754)	0.000013076*** (0.000002927)	0.000018928*** (0.000002750)	0.000015672*** (0.000002546)
$F_{t-\Delta t,1}$	0.635031900*** (0.139968300)	1.086026000*** (0.337237100)				
$F_{t-2\Delta t,1}$	0.119643200 (0.142045500)	−0.469318000 (0.295538200)				
$F_{t-\Delta t,2}$			0.697244700*** (0.153949900)	0.999819400*** (0.226895700)		
$F_{t-2\Delta t,2}$			0.218905100 (0.149100600)	−0.081011460 (0.230803800)		
$F_{t-\Delta t,3}$					0.819474300*** (0.134930100)	0.940065800*** (0.198577700)
$F_{t-2\Delta t,3}$					0.140725800 (0.131501800)	0.035057750 (0.195104000)
Constant	−0.001518689 (0.047187840)	0.192223000 (0.122115600)	−0.014603470 (0.061674080)	0.021134010 (0.110089900)	−0.037400580 (0.060520730)	−0.016516380 (0.098966780)
Observations	431	333	431	333	431	333
J-stat	0.062271	0.11078	0.012916	0.18616	0.24383	1.1271

Note: *p<0.1; **p<0.05; ***p<0.01

The J-test does not reject the moment conditions with a p-value lesser than 10% for any regression of table 5.

The coefficient of the hedging pressure is not significant most of the time. Moreover, signs are positive, which is not consistent with the hedging pressure theory.

In the first period, the coefficient for the spot price at maturity decreases with maturity. Between 2009 and 2015, the coefficient is significantly positive for the first regression only. Unbiased expectations would lead to a coefficient equal to one for the spot price at maturity. Well, this assumption is at the core of hedging pressure theory.

There is a positive coefficient of autoregression for the one-day lagged futures price at every constant maturity used. This result is consistent with the existence of trend-followers with positions depending on the price the week before (Koutmos, 1997) and short covering (Tokic, 2011). Nonetheless, there is no significant coefficient for a market-timing between the one-day lagged futures price and the two-day lagged futures price. The coefficients for the lagged values are similar for both periods, before and after 2008.

Furthermore, the sensitivity of the futures price to the variation of hedging pressure is significantly positive for any maturity whatever the period. This result is consistent with commercials acting as contrarian traders providing risk-sharing services to noncommercial traders, and in particular money managers (Fishe & Smith, 2018; G. B. Gorton et al., 2013; Kang et al., 2017; Rouwenhorst & Tang, 2012).

These study's results are consistent with Joëts (2015), which finds evidence of the natural gas market dominated by chartist agents.

2.3.5.2 An unstable relationship between the futures and the spot prices: the divorce at stake

Moment conditions are rejected for every maturity in the second period with p-values lesser than 10%, as shown in table 6. While the consistency of regressions holds for the first period. 2008 has been a pivotal year. A structural break in the sensitivity of the spot price to the futures price is highlighted. The relationship between the spot and the futures prices becomes highly unstable.

The values of sensitivities rising above one are consistent with the emergence of informational effect in 2008 (Sockin & Xiong, 2015). Nonetheless, the rejection of the validity of moment conditions between 2009 and 2015 impedes from concluding. The period between 2009 and 2015 corresponds to the apex of the shale revolution. The changing structures of the US natural gas market impact the futures-spot relationship. There are two consequences (Ramberg & Parsons, 2012). First, this technological innovation generates high volatility in the changing US natural gas market. Second, the relationship between natural gas and crude oil prices becomes unstable. Therefore, the WTI price weakens sharply as an instrument for the US natural gas price. This increasing weakness could explain the sensitivity of the spot to futures price would be highly time-varying, which makes estimation difficult for a time frame of several years.

Between 2000 and 2008, the value of the sensitivity of the spot price to the futures price is decreasing with maturity. These paper's findings are consistent with Cifarelli and Paladino (2010), which finds a significant influence from futures positive feedback trading to spot prices on the crude oil market. Indeed, if thereare positive feedback futures trading and feedback from the futures price to the spot price, thus positive feedback futures trading affects the spot price.

Table 6: Results for the spot equation:

$$P_t = a_{10} + a_{11}F_{t,T} + a_{12}Q_t + n_t$$
Set of instruments : $(\tilde{P}_T, B_{t-\Delta t,T}, B_{t-2\Delta t,T}, \mathrm{HP}_t, \Delta\mathrm{HP}_t, \mathrm{HDD}_T, Q_t)$

	Dependent variable:					
	P_t	P_t	P_t	P_t	P_t	P_t
	2000-2008	2009-2015	2000-2008	2009-2015	2000-2008	2009-2015
Constant	0.016377190	−0.270700100***	0.276821700*	−0.621895600**	0.738718600**	0.344811200
	(0.096384820)	(0.080539750)	(0.162303000)	(0.245815400)	(0.292262600)	(0.353424500)
$F_{t,1}$	0.980529100***	1.089433000***				
	(0.013623870)	(0.024137430)				
$F_{t,2}$			0.923522200***	1.184791000***		
			(0.021512370)	(0.074344570)		
$F_{t,3}$					0.818842300***	0.875024800***
					(0.039142010)	(0.105995900)
Q_t	0.000004735	−0.000127706***	−0.000010366	−0.000251823***	0.000174770**	−0.000091668
	(0.000007744)	(0.000038236)	(0.000016102)	(0.000081237)	(0.000083947)	(0.000127806)
Observations	431	333	431	333	431	333
J-stat	2.31957	12.25624**	5.92238	8.309805*	6.02887	9.82097*
Note:						*p<0.1; **p<0.05; ***p<0.01

2.3.5.3 No evidence for the hedging pressure theory

The test for the hedging pressure theory is to set the value of the coefficient of the spot price at maturity to unity ($a_{23} = 1$). Moment conditions are not rejected for the second period. The corresponding regressions exhibit negative signs for the coefficients of the hedging pressure, which are significant for the second-month and third-month maturities. Moreover, the absolute value is increasing with maturity. At first glance, this result is consistent with the hedging pressure theory (Bessembinder, 1992; De Roon et al., 2000) and hedging decisions affecting mid and long term futures prices. Higher is hedging pressure higher is the risk premium. The commitment of traders include the positions across all the maturities available. Nonetheless, the estimated value is low. For example, the value of the coefficient a_{26} (which is the sensitivity of the third-month futures price to hedging pressure) is -0.000015751. In average, hedging pressure was about 12,758.190 contracts from 2000 to 2008. Thus, the average effect of hedging pressure on the two-month futures price was roughly \$0.2. Compared to the average futures price, which was \$6.21, so the hedging pressure effect is minuscule. This digit is consistent with a small risk premium for hedging. The hedging pressure theory predicts that financialization diminishes the risk premium (Ekeland, Lautier, & Villeneuve, 2019). An increasing weight of speculators increases the supply of risk-sharing and lowers the elasticity of risk-premium to hedging pressure.

Nonetheless, the constant is significantly positive in the second period for every maturity. Thus, risk premia in the US natural gas market exhibit an "*alpha,*" which is an abnormal rate of return. Thus, a long futures position would have a return over the reward for the assumed risk, embodied by the hedging pressure. The hedging pressure theory does not predict any constant excess return that adds to the risk premium generated by the volume of hedging pressure. Therefore, the regression results of the second period are not consistent with the hedging pressure theory. The latter is neither valid for both periods of this study's sample.

2.3.5.4 Little evidence for an informational effect

In the first period, except for the first-month maturity, the moment conditions are rejected for every constrained regression. The first-month also called nearby, or front-month futures is very close to the spot price. Thus, the shortest maturity is often used as a proxy for the spot price. Thus, getting a valid constrained regression for the first-month maturity is not very surprising. Moreover, the unconstrained regression show sensitivities significantly lesser than one for the second-month maturity and the third-month maturity. In the second period, unconstrained regressions are all rejected. Nonetheless, moment conditions of the constrained regression are valid for the second-month maturity and third-month maturity. However, the latter maturity gets a p-value close of 10% (0.10757). It is impossible to conclude about an informational effect that offsets the cost effect as described by Sockin and Xiong (2015).

Between 2000 and 2008, The values of sensitivities of the spot to the futures price are consistent with the storage theory. In contango, a financial shock, increasing futures prices, makes the basis rising as well. Thus, the storage level rises. That was not the case in 2008

Table 7: Results for the constrained futures equation

$$F_{t,T} = a_{20} + a_{23}\tilde{P}_T + a_{24}F_{t-\Delta t,T} + a_{25}F_{t-2\Delta t,T} + a_{26}\mathrm{HP}_t + a_{27}\Delta\mathrm{HP}_t + v_t$$

This regression is run with the following constraint $a_{23} = 1$. The aim is to test the validity of the predictions of the hedging-pressure theory. The latter statesthat the futures price is equal to the sum of the expected spot price at maturity plus a risk premium depending on the hedging pressure.

	Dependent variable:					
	$F_{t,1}$	$F_{t,1}$	$F_{t,2}$	$F_{t,2}$	$F_{t,3}$	$F_{t,3}$
	2000-2008	2009-2015	2000-2008	2009-2015	2000-2008	2009-2015
HP_t	0.000005238	−0.000001907	0.000006168	−0.000005957***	0.000006601	−0.000015751***
	(0.000003734)	(0.000001166)	(0.000005858)	(0.000002260)	(0.000006585)	(0.000004327)
$\Delta\,\mathrm{HP}_t$	−0.000001496	−0.000007401	−0.000020079*	−0.000006676	0.000000815	0.000008824
	(0.000005242)	(0.000005806)	(0.000010851)	(0.000009424)	(0.000012070)	(0.000009147)
$F_{t-\Delta t,1}$	−0.064941210	0.459948700				
	(0.317676200)	(0.540638300)				
$F_{t-2\Delta t,1}$	0.032802350	−0.595842300				
	(0.296797400)	(0.567110300)				
$F_{t-\Delta t,2}$			−1.668684000***	1.262848000		
			(0.601365300)	(0.848872800)		
$F_{t-2\Delta t,2}$			1.589731000***	−1.565779000*		
			(0.565174500)	(0.854103900)		
$F_{t-\Delta t,3}$					−2.163333000***	0.558359700
					(0.709428900)	(0.735416000)
$F_{t-2\Delta t,3}$					2.206324000***	−0.997910400
					(0.667663100)	(0.751462000)
Constant	0.343952000	0.671624500**	0.430412300	1.563118000**	−0.067531580	2.264698000**
	(0.282497100)	(0.297211800)	(0.481420500)	(0.641358300)	(0.569241500)	(1.120596000)
Observations	431	333	431	333	431	333
J-stat	9.8143697*	2.60339	20.571***	3.51309	16.608***	3.82003
Note:						*p<0.1; **p<0.05; ***p<0.01

(Fattouh et al., 2013; Hamilton, 2009). Nonetheless, this is consistent with speculation driving down the spot price at maturity in backwardation because the hedging demand is hurt by the increasing hedging cost when the futures price goes up. The term structure of the natural gas market was backwardated in 2008 and 2014. Prices spiked then crashed to be in a term structure in contango[9]. This explanation is consistent with Juvenal and Petrella (2015), which finds speculation was a force driving down crude oil prices in 2008. The self-fulfilling dynamics of speculation is consistent as well with Kaufmann and Ullman (2009). The latter finds speculation exacerbates the increase of the crude-oil price and hurt demand.

Table 8: Results for the constrained spot equation:

$$P_t = a_{10} + a_{11}F_{t,T} + a_{12}Q_t + n_t$$

This regression is run with the following constraint $a_{11} = 1$. The aim is to test the existence of an informational effect. The latter makes the commodity demand increasing with the spot price, which makes the sensitivity of the spot price to the futures price greater or equal to one.

	Dependent variable:					
	P_t	P_t	P_t	P_t	P_t	P_t
Maturity (T)	1	1	2	2	3	3
	2000-2008	2009-2015	2000-2008	2009-2015	2000-2008	2009-2015
Q_t	0.000011634**	−0.000069946	0.000025288**	−0.000163780**	−0.000005361	−0.000219193***
	(0.000005862)	(0.000042630)	(0.000012416)	(0.000067444)	(0.000021236)	(0.000076774)
Constant	−0.102878000***	−0.001607501	−0.252260600***	−0.025337480	−0.066457410	−0.054481410
	(0.028859370)	(0.024221660)	(0.065913990)	(0.037703210)	(0.107453700)	(0.051237680)
Observations	432	333	432	333	432	333
J-stat	6.34967	10.877474**	14.6517222**	2.76388	16.1266950***	10.43285
Note:						*p<0.1; **p<0.05; ***p<0.01

2.4 Conclusion

This study estimates the influence of trend-followers on the Nymex, the US gas natural futures markets, and the feedback from the latter on Henry Hub, the physical market, from February 2000 to July 2015. The dataset splits into two subperiods. The first one is from 2000 to 2008, including the period before and during the spike. The second one is after the spike from 2009 to 2015. Results are consistent with the existence of an impact of the trend-following strategies on the US natural gas futures and spot markets.

The estimation of the parameters of the futures equations shows a dominating role of

[9]This phenomenon is not incompatible with "convective risk flows," which makes futures prices crashes (Cheng et al., 2015). Both dynamics can work simultaneously.

trend-following speculation for weekly variations on the Henry Hub and Nymex from February 2000 to July 2015. Moreover, the price pressure of commercials is positive when they get short, meaning they are contrarian. This result is consistent with the trend-followers affecting the US natural Gas futures market.

The feedback effect from the futures market to the spot market is confirmed. 2008 has been a pivotal year. The period 2000-2008 exhibits a sensitivity of the spot price to the futures price lesser but close to one. After 2008, there is not a stable relationship anymore between the spot and the futures prices.

These study's findings are consistent with speculation exacerbating trends on the futures market and generating feedback to the spot market. This situation can lead the US natural gas prices to spike and crash as in 2008 or in 2014.

Further studies are needed to investigate the existence of an informational effect, in particular around 2008. Moreover, it would be interesting to look at methodologies able to capture the time-varying aspect of the sensitivity of the spot price to the futures price.

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Appendix

1.A Summary for the data of the two periods

There the summaries for the data at both periods:

Table 1.A1: Summary for the period 2000-2008

Statistic	N	Mean	St. Dev.	Min	Max
HP_t	432	12,702.830	22,516.440	−76,790.370	59,321.840
Δ HP$_t$	431	−155.587	7,663.354	−22,127.470	27,658.030
$F_{t,1}$	432	6.215	2.407	1.906	14.976
$F_{t,2}$	432	6.335	2.452	1.988	15.126
$F_{t,3}$	432	6.432	2.503	2.116	15.176
P_t	432	6.141	2.402	1.845	15.390
Q_t	432	2,107.259	2,217.094	230.059	10,083.840

Table 1.A2: Summary for the period 2009-2015

Statistic	N	Mean	St. Dev.	Min	Max
HP_t	333	27,534.850	29,480.680	−42,113.220	104,793.700
Δ HP$_t$	333	164.490	5,254.344	−23,230.230	21,496.850
$F_{t,1}$	333	3.839	0.769	2.073	6.095
$F_{t,2}$	333	3.923	0.759	2.160	6.187
$F_{t,3}$	333	4.007	0.760	2.286	6.227
P_t	333	3.819	0.853	2.061	7.840
Q_t	333	552.284	291.790	39.241	1,505.260

1.B Robustness

1.B.1 Regressions with WTI in levels as an instrument

The WTI and HH prices are not cointegrated between 2009 and 2015. Nonetheless, the results of the regressions are not very different. HDD at maturity is not used as an instrument here. The third-day lagged of the WTI is used instead.

As table 1.A3 shows, the WTI and HH prices are not cointegrated in the second period for every maturity. For the second-month and third-month maturities, the cointegration at the first period is only at the 10% significance level.

Table 1.A3: Cointegration tests for the natural gas futures and crude oil futures price at each maturity.

All futures maturities are tested, one-month, two-month and three-month ($T = \{1, 2, 3\}$).
*p<0.1; **p<0.05; ***p<0.01

Maturity (T)	Philipps-Ouliaris statistics 2000-2008	PO stat 2009-2015
1	26.1063**	13.049
2	24.2314*	11.4001
3	24.1711*	9.7025

Table 1.A4: Results for the futures equation with WTI in levels as instruments

$$F_{t,T} = a_{20} + a_{23}\tilde{P}_T + a_{24}F_{t-\Delta t,T} + a_{25}F_{t-2\Delta t,T} + a_{26}\text{HP}_t + a_{27}\Delta\text{HP}_t + v_t$$

	Dependent variable:					
	$F_{t,1}$ 2000-2008	$F_{t,1}$ 2009-2015	$F_{t,2}$ 2000-2008	$F_{t,2}$ 2009-2015	$F_{t,3}$ 2000-2008	$F_{t,3}$ 2009-2015
P_1	0.231350100*** (0.072262480)	0.114605400 (0.112890600)				
P_2			0.076308490** (0.030563140)	0.077873440 (0.050492020)		
P_3					0.041168160* (0.021253800)	0.051006410 (0.038271760)
HP_t	0.000000157 (0.000001186)	0.000000032 (0.000000460)	0.000001356 (0.000000956)	0.000000151 (0.000000451)	0.000001649** (0.000000827)	0.000000159 (0.000000434)
$\Delta\,\text{HP}_t$	0.000017359*** (0.000002708)	0.000010321** (0.000004173)	0.000018422*** (0.000002790)	0.000013368*** (0.000003090)	0.000018610*** (0.000002828)	0.000015148*** (0.000002494)
$F_{t-\Delta t,1}$	0.722781300*** (0.135995800)	1.152548000*** (0.301120500)				
$F_{t-2\Delta t,1}$	0.050586080 (0.133742600)	−0.264049700 (0.334054000)				
$F_{t-\Delta t,2}$			0.840796300*** (0.144387800)	0.928014700*** (0.245709600)		
$F_{t-2\Delta t,2}$			0.085558080 (0.142852900)	−0.011119770 (0.256981400)		
$F_{t-\Delta t,3}$					0.902717100*** (0.143765900)	0.908036000*** (0.201688700)
$F_{t-2\Delta t,3}$					0.059043500 (0.142233300)	0.028180260 (0.202964600)
Constant	−0.007370134 (0.056194710)	−0.011012860 (0.131172200)	−0.017579320 (0.072057850)	0.020230650 (0.115336900)	−0.027370180 (0.067676520)	0.050909030 (0.122268200)
Observations	431	333	431	333	431	333
J-stat	0.25457	3.294857*	0.47871	0.19961	0.0089548	0.047677
Note:						*p<0.1; **p<0.05; ***p<0.01

Differences between tables 1.A4 and 5 are quite small. Signs, figures and significance are relatively similar. The difference is that the regression for the first-month maturity between 2009 and 2015 is not valid when WTI prices in levels are used as instruments. The absence of cointegration can explain this fact.

Table 1.A5: Results for the spot equation with WTI as instrument in levels:

$$P_t = a_{10} + a_{11}F_{t,T} + a_{12}Q_t + n_t$$

	Dependent variable:					
	P_t	P_t	P_t	P_t	P_t	P_t
	2000-2008	2009-2015	2000-2008	2009-2015	2000-2008	2009-2015
Constant	0.004166174	−0.331882900***	0.232725000	−0.555870500**	1.001725000***	−1.209216000***
	(0.092696560)	(0.094664670)	(0.192572700)	(0.238254100)	(0.325281000)	(0.466905800)
$F_{t,1}$	0.983064200***	1.109731000***				
	(0.012744460)	(0.028639790)				
$F_{t,2}$			0.928728700***	1.163947000***		
			(0.024103800)	(0.072692530)		
$F_{t,3}$					0.800025300***	1.336707000***
					(0.042078430)	(0.129868200)
Q_t	0.000005018	−0.000115554***	−0.000003686	−0.000242807***	0.000023170	−0.000339304***
	(0.000008051)	(0.000039321)	(0.000018358)	(0.000077127)	(0.000044234)	(0.000121218)
Observations	431	333	431	333	431	333
J-stat	3.32367	14.794643**	8.38014	8.124911*	5.58556	11.132341**
Note:						*p<0.1; **p<0.05; ***p<0.01

In both tables 1.A5 and 6, the regressions of the first period are valid only. The valid regressions exhibit very similar results.

Tables 1.A6 and 5 have third-month maturity as a common valid regression. In both cases, there is a positive constant. This result is not consistent with the hedging pressure theory.

In table 1.A7, the first-month maturity in the first period is the only valid regression. The sensitivity of the spot to the front-month should be close to one because the expiry is soon.

1.B.2 Regressions with values in log

To get a benchmark with the literature, this study also runs the regression with the logarithms of the variables. The hedging pressure is computed in percentage. It is crucial to notice coefficients do not have the same meaning in levels and log. In the former, coefficients show the sensitivity, which is about the absolute variation. While the coefficients of regression with log values represent elasticities, which are about the variation in percentage.

The cointegration relationship of log prices remains solid for both periods at every maturity.

Table 1.A6: Results for the constrained futures equation with WTI in levels as instruments :

$$F_{t,T} = a_{20} + a_{23}\tilde{P}_T + a_{24}F_{t-\Delta t,T} + a_{25}F_{t-2\Delta t,T} + a_{26}\text{HP}_t + a_{27}\Delta\text{HP}_t + v_t$$

This regression is run with the following constraint $a_{23} = 1$. The aim is to test the validity of the predictions of the hedging-pressure theory. The latter states that the futures price is equal to the sum of the expected spot price at maturity plus a risk premium depending on the hedging pressure.

	Dependent variable:					
	$F_{t,1}$	$F_{t,1}$	$F_{t,2}$	$F_{t,2}$	$F_{t,3}$	$F_{t,3}$
	2000-2008	2009-2015	2000-2008	2009-2015	2000-2008	2009-2015
HP_t	0.000001034	-0.000002217^{**}	0.000143199^{***}	-0.000005005^{**}	0.000020450^{*}	-0.000006029
	(0.000003547)	(0.000001038)	(0.000055453)	(0.000002145)	(0.000010662)	(0.000004027)
$\Delta\,\text{HP}_t$	0.000000626	-0.000015045	-0.000099197^{***}	-0.000010923	-0.000005984	-0.000002248
	(0.000004671)	(0.000010530)	(0.000034917)	(0.000010032)	(0.000015396)	(0.000008763)
$F_{t-\Delta t,1}$	-0.386149200^{*}	1.395461000				
	(0.216255200)	(1.030927000)				
$F_{t-2\Delta t,1}$	0.315752200	-1.570768000				
	(0.201238700)	(1.086741000)				
$F_{t-\Delta t,2}$			-0.988417800	1.551871000^{*}		
			(0.678276300)	(0.843426400)		
$F_{t-2\Delta t,2}$			0.219015300	-1.852089000^{**}		
			(0.315078200)	(0.849670900)		
$F_{t-\Delta t,3}$					-1.936363000^{***}	0.633825600
					(0.594801900)	(0.584588600)
$F_{t-2\Delta t,3}$					1.791951000^{***}	-1.083711000^{**}
					(0.456688700)	(0.452035400)
Constant	0.495332000^{*}	0.835582500^{**}	0.083654090	1.536103000^{**}	0.288381200	2.380084000^{**}
	(0.286897700)	(0.353410500)	(3.311516000)	(0.644729100)	(1.145030000)	(1.193721000)
Observations	431	333	431	333	431	333
J-stat	4.800697^{*}	5.699277^{*}	10.5511008^{***}	5.845754^{*}	23.669^{***}	4.32371
Note:						*p<0.1; **p<0.05; ***p<0.01

Table 1.A7: Results for the constrained spot equation with WTI levels as instruments :

$$P_t = a_{10} + a_{11}F_{t,T} + a_{12}Q_t + n_t$$

	Dependent variable:					
	P_t	P_t	P_t	P_t	P_t	P_t
Maturity (T)	1	1	2	2	3	3
	2000-2008	2009-2015	2000-2008	2009-2015	2000-2008	2009-2015
Q_t	0.000012821^{**}	-0.000068022	0.000030217^{**}	-0.000107824^{*}	0.000007592	-0.000184038^{**}
	(0.000005959)	(0.000044808)	(0.000013242)	(0.000058012)	(0.000022939)	(0.000074692)
Constant	-0.115186000^{***}	-0.014562730	-0.283151100^{***}	-0.013483960	-0.143713900	-0.029168050
	(0.030250480)	(0.026095410)	(0.070005280)	(0.034424530)	(0.107657500)	(0.056072570)
Observations	432	333	432	333	432	333
J-stat	4.01729	14.0773392^{***}	10.863719^{**}	9.521648^{**}	14.3608470^{***}	9.023048^{*}
Note:						*p<0.1; **p<0.05; ***p<0.01

Table 1.A8: Cointegration tests for the natural gas futures and crude oil futures log price at each maturity.

All futures maturities are tested, one-month, two-month and three-month ($T = \{1, 2, 3\}$).
*p<0.1; **p<0.05; ***p<0.01

Maturity (T)	Philipps-Ouliaris statistics 2000-2008	PO stat 2009-2015
1	349.7297***	268.1313***
2	181.2705***	106.9571***
3	41.4272***	26.9029**

Here, the study does not use the HDD at maturity as an instrument, but the third-day lagged value of the WTI crude oil log price instead.

The regression for the first-month maturity does not meet valid moment conditions in table 1.A9. There are differences in table 5. First, the signs of hedging pressure are consistent with hedging pressure theory but are only significant for the third-month maturity. The impact could explain this result at the mid and long term of hedging operations. Second, there is no positive feedback from the lagged values, except for the two-day lagged price for the second-month maturity. The third-month maturity exhibits positive sign price pressure of commercial and positive feedback from the one-day lagged price. This result is consistent with the existence of positive feedback trading. Third, constant is always significantly positive meaning there are abnormal weekly returns.

Valid regressions are the same between tables 1.A10 and 6. Log prices do not help to know if there was an informational effect between 2009 and 2015. The WTI-HH relationship is unstable in log values as well. For the first period, there is not a big difference in the values of coefficients between levels and logs. They are relatively similar.

Table 1.A9: Results for the futures equation with variables in log

$$F_{t,T} = a_{20} + a_{23}\tilde{P}_T + a_{24}F_{t-\Delta t,T} + a_{25}F_{t-2\Delta t,T} + a_{26}\text{HP}_t + a_{27}\Delta\text{HP}_t + v_t$$

	Dependent variable:					
	$F_{t,1}$	$F_{t,1}$	$F_{t,2}$	$F_{t,2}$	$F_{t,3}$	$F_{t,3}$
	2000-2008	2009-2015	2000-2008	2009-2015	2000-2008	2009-2015
P_1	0.965533600***	0.849471200***				
	(0.037432100)	(0.091954510)				
P_2			0.370698700	0.147264900		
			(0.320628200)	(0.386364900)		
P_3					−0.022344020	0.100124100
					(0.156980200)	(0.083326600)
HP_t	−0.183968300	−0.025242960	−0.292475700	−0.385595900	−0.287782300	−0.119654900**
	(0.157412600)	(0.101332500)	(0.459434600)	(0.237945000)	(0.329292800)	(0.058672100)
$\Delta\,\text{HP}_t$	0.307752200	0.033143760	2.252091000	1.040701000	1.363196000**	0.748158100**
	(0.416267500)	(0.662224500)	(3.084065000)	(1.219402000)	(0.591496000)	(0.344766400)
$F_{t-\Delta t,1}$	−3.384981000	−9.824145000				
	(3.018285000)	(8.430050000)				
$F_{t-2\Delta t,1}$	0.305290800	1.259364000				
	(0.802349800)	(5.069364000)				
$F_{t-\Delta t,2}$			−1.903011000	0.705065000		
			(1.539679000)	(0.659808500)		
$F_{t-\Delta t,2}$			2.720031000**	0.158759500		
			(1.298634000)	(0.934027000)		
$F_{t-\Delta t,3}$					1.381756000***	1.402700000***
					(0.499373500)	(0.520537600)
$F_{t-2\Delta t,3}$					0.295900100	−0.353722700
					(0.406554500)	(0.592917600)
Constant	0.087554230	0.219205400*	0.631119800**	0.925384500***	0.893319500***	0.926735000***
	(0.061303280)	(0.113103400)	(0.255364400)	(0.330468900)	(0.121762500)	(0.055579600)
Observations	431	333	431	333	431	333
J-stat	3.626265**	0.14839	2.25430	1.87471	0.83025	0.54490
Note:						*p<0.1; **p<0.05; ***p<0.01

Table 1.A10: Results for the spot equation with WTI as instrument in levels:

$$P_t = a_{10} + a_{11}F_{t,T} + a_{12}Q_t + n_t$$

	Dependent variable:					
	P_t	P_t	P_t	P_t	P_t	P_t
	2000-2008	2009-2015	2000-2008	2009-2015	2000-2008	2009-2015
Constant	−0.009201361	−0.048840970	0.085546580	−0.051014470	0.247197200*	0.063199090
	(0.045712680)	(0.034131120)	(0.093418930)	(0.063986640)	(0.144217800)	(0.083770820)
$F_{t,1}$	0.985724000***	1.096003000***				
	(0.015550810)	(0.018037960)				
$F_{t,2}$			0.938103500***	1.162795000***		
			(0.027635890)	(0.044706850)		
$F_{t,3}$					0.843363000***	0.958509100***
					(0.048005070)	(0.097071860)
Q_t	0.002618696	−0.012909550***	−0.001105552	−0.029426100***	−0.000553895	−0.005415224
	(0.003628801)	(0.004720968)	(0.007665346)	(0.006610958)	(0.013250660)	(0.012752790)
Observations	431	333	431	333	431	333
J-stat	4.9794	10.767822**	2.85721	8.369389**	4.04080	13.932804**
Note:						*p<0.1; **p<0.05; ***p<0.01

x

Chapter 3

Rational destabilization in Commodity Markets

Contents

3.1 Introduction

> "The trend is your friend, except at the end, when it bends."
>
> – Ed Seykota

Among the 289 Commodity Trading Advisers (CTA)[1] programs registered in `IASG.com`, 238 declare themselves as systematic traders, defined as traders using "a method of trading which follows a mechanical set of rules, normally using computers models, producing entry and exit orders to form trading decisions." This technical definition merges actors looking at past prices as information. Then, technical traders, momentum traders, chartists, and trend followers can be considered as systematic traders.

This article tackles with a specific mechanical set of rules, which buys when prices rise and sells when prices fall, labeled as positive feedback strategies by De Long, Shleifer, Summers, and Waldmann (1990). Positive feedback traders generate a "*Tinkerbell effect.*" By expecting that the price will go up, agents buy today to sell tomorrow, making the price go up today. This phenomenon is a self-fulfilling prophecy that any impulsion can trigger. De Long et al. (1990) show that anticipatory trades in a stock market impulse a trend exacerbated by positive feedback traders. This dynamic creates a bubble that destabilizes the market.

In the way of this work, Tokic (2011), demonstrated the potential of price destabilization of institutional investors by "imposing the limits to arbitrage to oil producers and oil consumers, particularly during the periods of financial crisis," on futures commodity markets. This paper proposes a model of a spot and a futures commodity market that offers new perspectives on analyzing the impact of technical traders on both prices' volatility and market efficiency. Among some results, this work can contribute to the explanation of the 2008 commodity price spike as well as the 2014 energy price crash. We contribute to the literature by creating the first model that shows how technical traders on the futures market can impact the spot market for a given commodity indirectly.

We define price stabilization by a lower price variability. If price variability decreases when a variable x increases, the variable x has a stabilizing effect on the price. For the opposite outcome on the price, the variable x is said to have a destabilizing effect. We consider both destabilizations of the futures and spot prices by the weight of technical traders among

[1]CTAs provide individualized advice for customers who want to take positions on commodity futures or options. They can be hired by a Commodity Pool Operator (CPO) to make investment decisions. Both are regulated by the National Futures Association (NFA) and the Commodity Futures Trading Commission (CFTC).

operators on the futures market.

The model of this paper is an extension of the two periods model introduced by Ekeland, Lautier, and Villeneuve (2019), with its main advantages. This framework unifies in a simple way the storage theory and the hedging pressure theory. Both futures and spot prices are endogenous in a dynamic self-fulfilling rational expectations equilibrium (REE). We introduce an intermediate period where technical traders enter the market according to the first-period price. We study the influence of technical traders on commodity markets and their potential capability to generate rational destabilization. We show technical traders destabilize the spot market by making other investors adopt a positive feedback trading strategy through an inter-temporal hedging strategy which is paradoxically a risk management strategy (we will refer to this strategy as the Merton Breeden Component). In the settings of the paper's model, economic agents who are rational speculators by anticipating the entrance of technical traders at time $t = 2$, are going to buy on the spot market to manage their profits' risk and hedge their stock before technical traders enter the market at time $t = 1$ increasing both the spot price and the futures price. Technical traders who react to past futures price go longer on the futures market (they do not act on the spot market). Additionally, the spot price at the last period $t = 3$ crashes because storers offer all their stocks, inflated by their behavior in the first period ($t = 1$). Rational speculators pulled the trigger then spot price destabilization occurs. The anticipated entrance of technical traders also has an ambiguous effect on the futures market. These results question the impact of the increasing size of assets managed by systematic traders[2].

The (finite-horizon) dynamic self-fulfilling REE framework of this paper also deals with equilibrium multiplicity. The latest "*(...) arises because of the circularity involved by the dynamic rational expectations loop: the price function depends upon the expectation of the price function*" (Biais, Bossaerts, & Spatt, 2010). Spiegel (1998) explains that agents need price series which match their belief systems. If several price series are consistent with the equilibrium definition, we get multiple equilibria. This result is well-known of the overlapping-generation literature (Biais et al., 2010; Ganguli & Yang, 2009; Spiegel, 1998; Watanabe, 2008). As demonstrated by Lucas (1978), a general equilibrium generates asset prices that are functions of the expected product of the payoff and a discount factor. In a dynamic setting, the payoff of the next asset in the next period includes the price in the next period. The payoff

[2]The assets under management (AUM) of systematic traders grew from \$22.9 billion in 1999 to \$316.4 billion in 2013. At the first semester of 2019, the volume of AUM is \$303 billion. Source: BarclayHedge

of a futures contract before each maturity is its price only.[3] Then, if there is no basis risk, the final payoff is the spot price at maturity. When futures positions are revised within the cash market holding period, the dynamic described by Lucas (1978) also appears. There is a relationship between the futures price in the first period and the expected one in the second period. While like in the one-period case, the futures price in the first period depends on the expected payoff at maturity. We get the rational expectations loop exhibited by overlapping-generation models. Within our model positions for a given futures contract are overlapped because they can be initiated at different periods, but they expire at the same time, maturity.

The paper's model even exhibits a second rational expectations loop. The underlying and so its expectations are endogenous in the paper's settings. The two loops described above impact the futures price so physical operations through hedging decisions. Therefore, the spot and the futures market intertwin through two rational expectations loop. Financial activity on the futures market impacts the spot price and so economic activity.

3.2 Literature review

Tokic (2011) extends De Long et al. (1990) to the 2008 crude oil spike. Institutional traders un-purposely destabilize the efficient crude oil pricing by going long after a rise generated by noise traders. They generate an upward trend which triggers positive feedback trading from managed futures funds. Then, hedgers offset their short positions because margin calls become too expensive. Thus, the crude oil price keeps on rising. The trend goes on until investors sell for profit, which bursts the bubble[4]. Tokic's theory is different from the highly controversial Master Hypothesis (Masters, 2008) that states that institutional investors caused the 2008 spike[5]. In Tokic's framework, institutional investors are not the origin of the spike. They strengthen the impulse given by bullish noise traders[6]. By going long, CIT offset downward fundamental forces. This dynamic generates a trend which is followed by technical traders. Tokic (2011) finds that commercial producers of crude oil aggressively reduced their short

[3]Unlike shares, there is no dividend on futures contracts.

[4]Tokic (2012) qualified later Tokic (2011) in light of a DCOT report analysis. Money managers played well the trend, and there seems to be short covering among commercials and nonreportable positions. Nonetheless, the trend is less clear among swap dealers. The aggregation of heterogeneous agents in groups explains swap dealers are a noisy proxy for CIT because they also take positions for physical operators (Cheng & Xiong, 2014a).

[5]This hypothesis is backed by Singleton (2014) which finds CIT positions predict oil futures returns. Nonetheless, the replication of his work has been a failure (Hamilton & Wu, 2015).

[6]Noise trading can be caused by hedging from economic activities. Therefore, the "rational destabilization" described by Tokic (2011) let the room open for a bullish impulse coming from fundamentals such as the global demand for example.

hedge positions in 2008 by analyzing the Commitment of Traders (CoT) provided by the CFTC. This result is consistent with short covering among commercial traders during the 2008 spike.

A "convective risk flow" (Cheng, Kirilenko, & Xiong, 2015) might cause this reversal. When financial investors are distressed, they are tempted to undo their positions. Cheng et al. (2015) find that institutional investors' positions are more sensitive to the variations of the VIX. When the VIX increases, their positions decrease. The futures price decreases, which gives an incentive to hedgers to go longer. Therefore, risk has been transferred from speculators to hedgers. This paper finds another explanation for the crash of the spot price. The risk management of technical traders by rational speculator agents give the incentive to hedgers to go shorter at first. This phenomenon generates a negative net demand shock at maturity that crashes the spot price at maturity.

Adams and Glück (2015); Adams and Kartsakli (2017); Henderson, Pearson, and Wang (2015); Juvenal and Petrella (2015); Tang and Xiong (2012) highlight the role of financial vehicles such as Commodity Index Traders (CIT), ETFs or Commodity-Linked Notes (CLN) in the increase of commodity prices between 2004 and 2008. According to these authors, the long positions of CIT generate comovements and upward price pressure on indexed commodities, which spread to their spot markets. Basak and Pavlova (2016) provide a theoretical explanation of this phenomenon. They show how the market structure (presence of index) conduct institutional investors (defined as investors integrating the index value to their utility) drive futures price upward, pushing the forward curve toward contango. This dynamic increases the storage level. Technical traders strategies are based on the trends of a single market, but they generate a similar phenomenon. The accumulating long positions of technical traders can reinforce a bullish trend on commodity prices in a self-fulfilling dynamic. In the context of a an excellent economic conjuncture, speculation exacerbates the price increase and hurt demand, even if global demand is the main factor driving commodity prices upward (Kaufmann & Ullman, 2009). This explanation is consistent with Juvenal and Petrella (2015) who find that speculation was a force driving down crude oil prices in the crash of 2008. Our work does not address the influence of CIT but is complementary to this topic. The issue with technical trading is similar about two points, trend exacerbation and feedback from the futures market to the spot market. This paper's model shows how these two dynamics impact economic activity on the physical market.

This issue is similar to the destabilizing effect of money-managed funds which exist since the 80s. In 1984, computed guided technical trading systems were a hot issue debated in the Hill (Bradford & Galbraith, 1984). The debate was about their potential for "herding" (executing similar orders at the same time) and trend-following strategies. Both are potentially destabilizing because they generate self-fulfilling trends (Lukac, Brorsen, & Irwin, 1988). Boyd, Büyükşahin, Haigh, and Harris (2016); Brorsen and Irwin (1987); Irwin and Yoshimaru (1999) do not find evidence for commodity pool operators increasing futures volatility. We show technical traders have ambiguous effects on futures volatility. They even can both stabilize the futures market while destabilizing the spot market.

Fishe and Smith (2018) find that futures prices follow a random walk so money managers do not generate deviation to fundamentals, even if money managers tend to be technical traders. Nonetheless, this argument does not hold when there is a loop between the price and the expected payoff of an asset because fundamentals are moving with the security price. For equity, Hirshleifer, Subrahmanyam, and Titman (2006) show the presence of irrational investors affect stock prices and companies' investments when there is feedback from stock prices to cash flows. These traders, who have baseless beliefs, might even generate profit which can be higher than the one of rational traders. Thus, they deduce "animal spirits" can have lasting financial and real effects. Irrational traders generate fluctuations to fundamentals even when markets are informationally efficient with prices following a random walk. Goldstein, Ozdenoren, and Yuan (2013) show the feedback from stock price to real investment generates trading frenzies. Speculators coordinate themselves to trade in the same direction, pushing the price and the firm's value upward. We show the financial feedback modifies fundamentals in the commodity markets as well. The word "fundamentals" is even misleading with feedback from financial markets to real assets.

Literature has always been a very critic of Commodity Trading Advisers (CTA) who are adept of technical trading and momentum strategies. The CTA using technical trading strategies have been accused of impeding diversification (Billingsley & Chance, 1996; Elton, Gruber, & Rentzler, 1987). They are called a "market failure" literally (Bhardwaj, Gorton, & Rouwenhorst, 2014). Their performance is not significantly higher than the treasury bills. Fees eat all their performance. They do not exhibit any excess return (which is called "alpha").

Nonetheless, technical trading strategies and momentum strategies can bring significant profit (Chaves & Viswanathan, 2016; Szakmary, Shen, & Sharma, 2010). Han, Hu, and Yang (2016) show that moving average timing strategy may generate a higher payoff than buy-and-hold. Yin and Yang (2016) who show that moving-average and momentum indicators outperform macroeconomic ones to predict oil futures returns. Moreover, they bring significant economic gains with both higher Sharpe ratio and Certainty Equivalent Return.

Fishe and Smith (2018); G. B. Gorton, Hayashi, and Rouwenhorst (2013); Kang, Rouwenhorst, and Tang (2017); Rouwenhorst and Tang (2012) find that non-commercial traders are technical traders and commercial traders are contrarian. The implication is very important because technical traders ask for risk sharing as well, so they need counterparts. Therefore, two kinds of risk premiums exist on the market, one for hedgers and another one for technical traders (Kang et al., 2017). This fact completely changes the nature of interactions on the market because commercial traders can be the counterpart of a risk-sharing demand coming from speculators who want to bet on futures trends. Roles reverse. Our paper provides a theoretical explanation of this phenomenon consistent with the existence of two sources of risk premium.

In asset pricing theory, speculators hedge against changing investment opportunities. Merton (1973) presents an inter-temporal model for the capital market with an arbitrary number of investors who maximize the expected utility of lifetime consumption and who can trade continuously in time. Unlike the one-period model (CAPM), current demands are affected by the possibility of uncertain changes in future investment opportunities. In this situation, speculators hedge against this risk generated by changing investment opportunities (Anderson & Danthine, 1983a; Breeden, 1979, 1984; Merton, 1971, 1973). Contrary to the CAPM, expected returns on risky assets differ from the risk-less rate even without systematic market risk. This additional intertemporal hedging component of speculation is often called the "Merton-Breeden component" in literature. In our model, the impact of technical traders on intertemporal speculation hedging is the leverage of rational destabilization. We show the risk management of technical traders modify the risk premium and so hedging decisions. Therefore, technical traders impact the spot price at maturity.

We wonder about the influence of the risk management of technical traders by rational agents over the spot market. We show that studies considering the overall impact of noncommercial positions (Bohl & Stephan, 2013; Kim, 2015) in the futures market on the spot price base themselves on a flawed homogeneous vision of speculation. An increase of trend-chasing traders destabilizes the spot price while an increasing weight of rational speculators has a stabilizing effect.

The kind of destabilization that we model differs from Hart and Kreps (1986). They early showed that speculators destabilize commodity prices and even assets in general by expecting price variation. Their model assimilates speculation on the spot market to storage. While in our model, speculation is on the futures market only. Moreover, we show spot destabilization can happen without any variation of the storage level when the forward curve is backwardated.

Previously, destabilization of the spot price by speculation on the futures market did not take its origins in positive feedback trading. The effect on the market tolerance (or speculative intensity), which is the pricing of risk on the futures market by rational mean-variance traders, has been considered on the conditional (Driskill, McCafferty, & Sheffrin, 1991) or ex-ante (Ekeland et al., 2019) price variances. We differ from these approaches by an ex-post evaluation of the variation of both prices. The introduction of a futures market has been considered as well to be compared to a non-futures scenario Ekeland et al. (2019); Newbery (1987). Like Stein (1987), we consider the choice is not between speculation or no speculation. Nonetheless, unlike him, we do not say the debate is between more and less speculation but between what kind of speculation. We show that risk management by rational operators of technical traders increases the spot price variability and happens even without storage because long hedging diminishes. At the opposite, we show that the increasing weight of rational operators stabilizes the spot price. This result is consistent with an increasing market tolerance dampening spot demand shocks in the absence of shocks in production (Newbery, 1987), storage demand (Kawai, 1983) or inventory cost (Driskill et al., 1991).

We unify hedging pressure theory, futures pricing and rational destabilization literature in a three periods model. We show how the risk management of the impact of technical trading by rational speculators increases spot price variability and futures price volatility.

3.3 Main settings

The theoretical framework is a three periods model. There is an initial period ($t = 1$), an intermediate one ($t = 2$) and a final one ($t = 3$). There are two markets: one spot market and an associated futures market with only one maturity with respective prices P_t and F_t at time t. All effective random values will be denoted with the symbol $\tilde{.}$ At the period $t \in \{1, 3\}$, spot traders generate an exogenous random supply ω_t. Their demand depends positively on an exogenous random variable (η_t) and negatively on the spot price (P_t). The spot market is under a constraint of positive inventories. In the futures markets, a contract can be opened at the initial ($t = 1$) or the intermediate ($t = 2$) period. The futures market is the only one open at the intermediate period. This justifies this assumption in two different ways. The first one, following Working (1953), is that futures contracts "*(...) serve primarily to facilitate hedging and speculation by promoting exceptional convenience and economy of the transactions*". Hence, having more frequent futures market clearing does not seem to be a restrictive hypothesis. Furthermore, futures positions are revised within the cash market holding period, as in Anderson and Danthine (1983a). The implications of the latest are crucial if there is feedback from the futures market to the spot market: revising futures positions impact the final payoff at maturity of the spot market. They are settled in the final one. When traders sell (buy) futures contracts, their position is short (long), and the number of futures contracts they hold is negative (positive). There is no basis risk, so at time 3, $P_3 = F_3$. Three kinds of operators make inter-temporal decisions. The two first ones are physical operators. They hedge their activity on the spot market with futures contracts. The last kind is the speculators. They only trade in the futures market. Two groups are myopic. They act for one period only: the exogenous spot traders at each period and the technical traders who are active at the intermediate period on the futures market only. Therefore, we extend Ekeland et al. (2019) in two ways: we add a period, with the futures market open, and by introducing technical traders. This extension is quite similar to Anderson and Danthine (1983b) where hedgers, endowed with a non-stochastic technology, choose their physical positions to hedge in the first period and a second period with the possibility to change futures positions. Thus, physical operators are similar to Ekeland et al. (2019):

- Hedgers of future sales. The name for these hedgers is storers or inventory holders (I). They have a storage capacity that they can use to buy the commodity on the spot market at $t = 1$ only to release it at $t = 3$. Thus, they have a long position on the physical market that they can hedge on the futures market;

- Hedgers of future purchases. The name of these hedgers is processors (P), or industrial users. They use the commodity to produce other goods that they sell to final consumers. They cannot store, and their production process is rigid: they commit at $t = 1$ to buy their input on the spot market at $t = 3$. Thus, they have an implicit commitment to buy on the spot market that they can hedge on the futures market. For the sake of simplicity, this paper assumes that the production process is instantaneous so that they also deliver their final product at $t = 3$.

There are two kinds of speculators:

- Rational peculators (S) use the commodity price's risk as a source of profit through their positions in the futures market. They do not trade on the spot market. Nor do they handle other financial assets. Like the hedgers, they are inter-temporal operators, and their expectations are rational;

- Trend Followers (C) take positions at $t = 2$ according to the futures price in $t = 1$. Trend-following strategy can be voluntary like for the chartist traders or involuntary. This last situation is known as "*short covering.*" When the price rises, short traders have to pay margin calls. When it is too expensive for them, they settle their position. It is equivalent to a stop-loss strategy in the stock market (Koutmos, 1997).

At time $t = 2$, investment opportunities change (Breeden, 1984; Merton, 1971, 1973). Active operators on the futures market take into account the relationship between the payoff of the positions taken in the first period and of the ones taken in the second period, to select their positions. All realized values are common knowledge for all kinds of agents. Let $\tilde{\mu}$ be additional news about the harvest at time $t = 3$ which is revealed at time $t = 2$ (before $t = 2$ it is unknown and denoted by μ). There are two effects of this quantity news on investment opportunities. First, this additional harvest information has a negative impact on the spot price at maturity (P_3). Second, $\text{Cov}_1[\mu, \xi_3] = 0$, with $\tilde{\xi}_t$ being equal to the exogenous net demand for the commodity at time t (see below). $\tilde{\mu}$ is an independent news shock that brings information on the exogenous net demand at maturity. This feature links spot prices between them through every period.

3.4 The optimal positions

The program of any rational agent i at each period t is:

$$\max_{d_t^i} EU_t^i(\pi_i) = E_t[\pi_i] - \frac{\alpha_i}{2}\text{Var}_t[\pi_i], \forall\, i \in \{I, P, S\} \tag{3.1}$$

With $d_t^i = \begin{pmatrix} f_t^i \\ s_t^i \end{pmatrix}$. f_t^i is the position on the futures market at time t of agent i and s_t^i is the position on the spot market at time t of agent i (we will denote them s^i when no ambiguity). $f_t^i > 0$ is a long position and vice-versa for a short position. In the rest of this work, $E_t(x)$, $\text{Var}_t(x)$ and $\text{Cov}_t(x_1, x_2)$ respectively denote the mean of variable x, the variance of variable x, and the covariance of variables x_1 and x_2 conditional to time $t \in \{1, 2, 3\}$.

3.4.1 Rational speculation

The speculators do not have any position to hedge. The profit of a speculator is expressed using the following profit function:

$$\pi_S = (P_3 - F_1)f_1^S + (P_3 - F_2)f_2^S \tag{3.2}$$

Speculators maximize their expected utility (3.1) with the given profit equation (3.2). The position of speculators is limited only to a speculative component which breaks down into two parts at period $t = 1$:

$$f_1^S = \frac{E_1[P_3 - F_1]}{\alpha_S \operatorname{Var}_1[P_3 - F_1]} - \frac{\operatorname{Cov}_1[P_3 - F_1, (P_3 - F_2)f_2^S]}{\operatorname{Var}_1[P_3 - F_1]} \tag{3.3}$$

The first term on the r.h.s is the long-term component of the speculator's position which is the ratio of the expected payoff $E_1[P_3 - F_1]$ on the risk of the payoff weighted by the speculators' risk aversion $\alpha_S \operatorname{Var}_1[P_3 - F_1]$. The second term is hedging of changing investment opportunities (Breeden, 1979, 1984; Merton, 1971, 1973). This result is the same as Anderson and Danthine (1983b). This hedging component is the regression coefficient of the PNL of the positions taken in the second period by the payoff of a long position taken the first period $(P_3 - F_1)$. Indeed, we can write the following regression:

$$(P_3 - F_2)f_2^S = \gamma_S + \beta_S(P_3 - F_1) + \varepsilon \tag{3.4}$$

With $\beta_S = \frac{\operatorname{Cov}_1[P_3 - F_1, (P_3 - F_2)f_2^S]}{\operatorname{Var}_1[P_3 - F_1]}$. The term for hedging of changing investment opportunities is β_S which measures how the payoffs of initial and intermediate periods vary together. For example, if the covariance is positive, β_S is positive[7]. speculators go shorter in the first period to reduce their exposure to risk. In the literature, β_S is called a "*Merton-Breeden hedging component.*" If the covariance is negative, reducing the overall risk implies for speculators to go longer. At time $t = 2$, the position is:

$$f_2^S = \frac{E_2[P_3 - F_2]}{\alpha_S \operatorname{Var}_2[P_3 - F_2]} - f_1^S \tag{3.5}$$

If the PNL are uncorrelated among time, both positions are independent and are just simple mean-reverting positions. Speculators close their positions taken at time 1 to take new posi-

[7]The R-squared from this regression estimates the proportion of endowment variance, which is eliminated by setting the hedge position equal to the pure hedge

tions at time 2. Futures accounts mark to market at each period[8]. We rewrite the profit of speculators, given by equation (3.2), as a unique function of f_1^S as follow:

$$\pi_S = (F_2 - F_1)f_1^S + (P_3 - F_2)\frac{E_2[P_3 - F_2]}{\alpha_S \mathrm{Var}_2[P_3 - F_2]} \tag{3.6}$$

Speculators settle profit and losses at each period. In the second period, speculators close their first-period positions and take a mean-variance position for the next period, which is the maturity of the futures contract.

We get the expression of f_1^S by injecting the futures positions of the second period (3.5) in the one of the first period (3.3):

$$f_1^S = \frac{E_1[P_3 - F_1] - \mathrm{Cov}_1\left[P_3 - F_1, (P_3 - F_2)\frac{E_2[P_3-F_2]}{\mathrm{Var}_2(P_3-F_2)}\right]}{\alpha_S(\mathrm{Var}_1[P_3 - F_1] - \mathrm{Cov}_1[P_3 - F_1, P_3 - F_2])} \tag{3.7}$$

As $\mathrm{Cov}_1[P_3 - F_1, P_3 - F_2] = \mathrm{Var}_1[P_3] - \mathrm{Cov}_1[P_3, F_2]$, we have $\mathrm{Var}_1[P_3] - \mathrm{Cov}_1[P_3 - F_1, P_3 - F_2] = \mathrm{Cov}_1[P_3, F_2]$. Hence, we simplify (3.7), such that:

$$f_1^S = \frac{E_1[P_3] - F_1 - \mathrm{Cov}_1\left[P_3, (P_3 - F_2)\frac{E_2[P_3]-F_2}{\mathrm{Var}_2[P_3]}\right]}{\alpha_S \mathrm{Cov}_1[P_3, F_2]} \tag{3.8}$$

The more the futures price in the second period (F_2) is positively correlated with the spot price at maturity (P_3), the smaller is the first term of the futures position.

3.4.2 Physical hedging positions

There are two kinds of hedgers, long and short ones. Like Danthine (1978), each hedgers' position is the sum of a hedging component and a speculation component. Speculation and hedging decisions are separable. The optimization in the second period is strictly similar to Ekeland et al. (2019). The hedging decision in the first period differ according to the risk expected at the intermediate period.

The speculation component (SC_i) for each hedger i at time $t = 1$ is:

$$\left.\begin{aligned} \mathrm{SC}_i &= \tfrac{E_1[P_3-F_1]}{\alpha_i \mathrm{Var}_1[P_3-F_1]} - \beta_i \\ \beta_i &= \tfrac{\mathrm{Cov}_1\left[P_3-F_1,(P_3-F_2)f_2^i\right]}{\mathrm{Var}_1[P_3-F_1]} \end{aligned}\right\} \forall\, i \in \{I, P, S\} \tag{3.9}$$

[8]Unlike Anderson and Danthine (1983b), the marked-to-market futures positions are a result in our paper and not a requirement.

3.4.2.1 Physical hedging position of the storers

Storers (I) are the short hedgers. They have storage capacity and can use this capacity to buy the commodity at $t = 1$ only to release it at $t = 3$ (since the spot market is not open at time $t = 2$). They trade on the spot market at $t = 1$. This paper thus separates the roles of processors and storers, although, in reality, processors can also hold inventory. Storers also operate on the futures market. They can hold any nonnegative inventory. The cost of storage between $t = 1$ and $t = 3$ is assumed to be quadratic and embodied by the parameters C. Thus, their profit is:

$$\pi_I = (P_3 - F_1)f_1^I + (P_3 - P_1)s^I + (P_3 - F_2)f_2^I - \frac{C}{2}(s^I)^2 \tag{3.10}$$

Therefore, the maximization of the expected utility of the profit above (introducing (3.10) into (3.1)), gives the following optimal positions at period $t = 1$:

$$f_1^I = SC_I - s^I \tag{3.11}$$

$$s^I = \frac{1}{C}\max(F_1 - P_1, 0) \tag{3.12}$$

The speculation position and the hedging position are separated. In the second period, the optimal position of the storers is:

$$f_2^I = \frac{E_2[P_3 - F_2]}{\alpha_I \operatorname{Var}_2[P_3 - F_2]} - \mathrm{SC}_I \tag{3.13}$$

Storers mark to market their speculative positions at time $t = 1$ but they roll the hedge of their storage activity. Since from (3.11), we get $SC_I = f_1^I + s^I$. Thus, the position at the intermediate period (3.13) becomes :

$$f_2^I = \underbrace{\frac{E_2[P_3 - F_2]}{\alpha_I \operatorname{Var}_2[P_3 - F_2]} - s^I}_{\text{speculation + hedging}} - \underbrace{f_1^I}_{\text{Closed position}} \tag{3.14}$$

3.4.2.2 Physical hedging position of the processors

Processors are industrial users. They use the commodity to produce other goods that they sell to consumers. They decide at $t = 1$ or $t = 2$ how much to produce at $t = 3$ for two reasons. First, there is the inertia of their production process. Second, they sell all of their production forward. They cannot store the commodity, so they have to buy all of their input on the spot market at $t = 3$. They also trade on the futures market. Therefore their profit is such that:

$$\pi_P = (P_3 - F_1) f_1^P + (P_3 - F_2) f_2^P + \left(s^P - \frac{\theta}{2} (s^P)^2 \right) Z - s^P P_3 \tag{3.15}$$

Z is the price of the output, which is common knowledge, and θ is the parameter embodying the constant marginal production cost of the output using s^P quantities of input. Therefore, introducing (3.15) into (3.1), we get the optimal positions at period $t = 1$:

$$f_1^P = \mathrm{SC}_P + s^P \tag{3.16}$$

$$s^P = \frac{1}{\theta Z} \max (F_1 - Z, 0) \tag{3.17}$$

The reasoning is the same than for the storers. They hedge more if the risk rises. The optimal solution at the intermediate period is:

$$f_2^P = \frac{E_2[P_3 - F_2]}{\alpha_P \, \mathrm{Var}_2[P_3 - F_2]} - \mathrm{SC}_P \tag{3.18}$$

Here, the position of processors at time $t = 2$ is an adjustment of the net position taken at time $t = 1$ (from (3.16), we get $SC_P = f_1^P - s^P$).

3.5 The spot market

There are two different categories of agents on the market:

(i) The demand from exogenous spot traders is $(\eta_t - m \, P_t)$ and supply (ω_t) at time t. Parameters η_t and ω_t are random at $t = 2$ and $t = 3$, and m represents the elasticity of demand (or production) respect to spot price constant on all periods;

(ii) The hedgers divided into two kinds. The storers are doing contango arbitrage, and the processors are arbitraging according to the spread between the scaled price of the output (Z) and the futures price at time t (F_t).

3.5.1 The hedging pressure

The storers buy at time $t = 1$ to sell at maturity $t = 3$. If $t = 1$, storers demand if there is a contango:

$$n_I [F_1 - P_1]^+, \text{ where } [x]^+ = \max (0, x) \tag{3.19}$$

n_I is the synthetic weight of storers at time t. We get $n_I = \frac{N_I}{C}$ (as in Ekeland et al. (2019)). At the last period (which is the third one), storers offer the same. The supply at maturity depends on the spread at the initial period. It is consistent with Ederington, Fernando, Holland, Lee, and Linn (2017) who document "*that inventories respond to not only contemporaneous but also lagged futures spreads, due to arbitrageurs contracting ahead.*"

At time $t = 3$, processors ask:

$$n_P[Z - F_1]^+ \tag{3.20}$$

$n_P = \frac{N_P}{\theta Z}$ is the synthetic weight of processors (as in Ekeland et al. (2019)). All these spot positions are the hedging component of the hedgers' positions. The hedging pressure is the net difference between short and long positions of hedgers (Ekeland et al., 2019). The hedging pressure at time $t = 1$, denoted by HP is defined such as:

$$\text{HP} = n_I[F_1 - P_1]^+ - n_P[Z - F_1]^+ \tag{3.21}$$

The hedging pressure is the net amount of commodity hedged on the market (Ekeland et al., 2019). The value of this measure is the difference between the hedged supply and demand at maturity.

3.5.2 Spot clearing

The condition for clearing is $D_t = S_t$. For $t = 1$, we get:

$$D_1 = \tilde{\eta}_1 - m\,P_1 + n_I[F_1 - P_1]^+ \tag{3.22}$$

$$S_1 = \tilde{\omega}_1 \tag{3.23}$$

At maturity ($t = 3$), we get:

$$D_3 = \tilde{\eta}_3 + n_P[Z - F_1]^+ - m\,P_3 \tag{3.24}$$

$$S_3 = \tilde{\omega}_3 + n_I[F_1 - P_1]^+ + \tilde{\mu} \tag{3.25}$$

3.6 The Futures market

3.6.1 The Intertemporal Speculative Pressure

The Intertemporal Speculative Pressure (ISP) is:

$$\text{ISP} = \text{Cov}_1 \left[P_3 - F_1, (P_3 - F_2) \frac{E_2[P_3 - F_2]}{\text{Var}_2[P_3]} \right] \tag{3.26}$$

The ISP is the adjustment of the mean-variance component of the speculation positions according to the impact of changing investment opportunities. This term is the one through which we find positive feedback of the futures market on the spot market. Technical traders decrease the covariance between the two payoffs.

3.6.2 Trend-following strategies

We introduce technical traders. We model them according to the traditional positive feedback trading theory. Their positions depend on past prices. The latest is legitimate by the existence of stop-loss strategies but also by margin calls. The higher the price is on the futures market at time $t = 1$, the longer is the position of the technical traders entering the market at time $t = 2$. They generate a positive auto-correlation on prices. The position at the intermediate period of the technical traders is modeled similarly to Koutmos (1997), and according to the synthetic weight of technical traders n_C such that:

$$n_C f_t^C = \begin{cases} 0 & \text{for } t = 1 \\ n_C F_1 & \text{for } t = 2 \end{cases} \tag{3.27}$$

3.7 The Equilibrium: Conditions and resolution

3.7.1 Clearing Conditions

The clearing conditions are:

$$D_1 = S_1 \tag{3.28}$$

$$D_3 = S_3 \tag{3.29}$$

$$(\frac{N_I}{\alpha_I} + \frac{N_P}{\alpha_P} + \frac{N_S}{\alpha_S})\frac{E_1[P_3] - F_1 - \text{ISP}}{\text{Cov}_1[P_3, F_2]} - \text{HP} = 0 \quad (3.30)$$

$$(\frac{N_I}{\alpha_I} + \frac{N_P}{\alpha_P} + \frac{N_S}{\alpha_S})\frac{E_2[P_3] - F_2}{\text{Var}_2[P_3]} + n_C\, F_1 - (\frac{N_I}{\alpha_I} + \frac{N_P}{\alpha_P} + \frac{N_S}{\alpha_S})\frac{E_1[P_3] - F_1 - \text{ISP}}{\text{Cov}_1[P_3, F_2]} = 0 \quad (3.31)$$

Let Υ_t be an indicator of market depth at time t such that $\Upsilon_1 = \frac{\frac{N_I}{\alpha_I}+\frac{N_P}{\alpha_P}+\frac{N_S}{\alpha_S}}{\text{Cov}_1[P_3,F_2]}$, and $\Upsilon_2 = \frac{\frac{N_I}{\alpha_I}+\frac{N_P}{\alpha_P}+\frac{N_S}{\alpha_S}}{\text{Var}_2[P_3]}$. The higher Υ_t is, the lower the contribution of hedging pressure (spot and intertemporal) to the risk premium *ceteris paribus* is. Let $\tilde{\xi}_t$ be the exogenous net demand for the commodity at time t, such that $\tilde{\xi}_t = \tilde{\eta}_t - \tilde{\omega}_t$. The first clearing condition We get the following systems for each period using the clearing conditions (3.28), (3.29), (3.30) and (3.31):

- First period:

$$m\, P_1 - n_I[F_1 - P_1]^+ = \tilde{\xi}_1 \quad (3.32)$$

$$E_1[P_3] - F_1 = \frac{\text{HP}}{\Upsilon_1} + \text{ISP} \quad (3.33)$$

- Second period:

$$E_2[P_3] - F_2 = -\frac{n_C\, F_1}{\Upsilon_2} + (E_1[P_3] - F_1 - \text{ISP})\frac{\text{Var}_2[P_3]}{\text{Cov}_1[P_3, F_2]} \quad (3.34)$$

- Third period:

$$\text{HP} + \tilde{\mu} = \tilde{\xi}_3 - m\, P_3 \quad (3.35)$$

  The settlement price of the futures contract is the spot price, so $F_3 = P_3$. There is no basis risk in this model.

Equations (3.33) and (3.34) give the risk premium at each period. The risk premium is the inverse supply of risk-bearing (or liquidity). The r.h.s shows the two components of the demand for risk transfer for both equations at the initial and the intermediate periods. The hedged positions (HP and $\tilde{\mu}$) and an inter-temporal speculative component. The risk-adjustment implied by rational speculation generates the Merton-Breeden component (ISP) in the first period. If the hedging pressure and the Merton-Breeden component share the same sign, speculators offer risk sharing with a discounted risk premium. At the opposite, if the Merton-Breeden component has an opposite sign of the hedging pressure, speculators add a premium to risk bearing.

An agent with a higher risk tolerance gets a bigger impact on the market. Therefore, the risk aversion and the market impact of the agent are proportionally inversely related. If the market depth in the first period increases because the nominal weight of a group of operators is rising, the market risk aversion tends toward the risk aversion of the most weighted group. The sensitivity of the risk premium to the hedging pressure is strictly decreasing when the market depth increases when the weight of the speculators (N_S) is rising. It is consistent with Ekeland et al. (2019). In a market with a heavyweight of rational speculators, the impact of hedging pressure and technical traders is shallow. If the market is risk neutral ($\Upsilon_t \to \infty$), the impact is even null because futures prices are unbiased.
If we combine (3.33) and (3.34), we get the following expression of the risk premium in the second period :

$$E_2[P_3] - F_2 = \frac{\overbrace{\text{HP}}^{\text{Hedging Pressure at } t=1} \quad \overbrace{-n_C\, F_1}^{\text{Technical traders position at } t=2}}{\Upsilon_2} \tag{3.36}$$

Technical traders enter at the second period and increase the demand of counterparts with their (long) position ($n_C\, F_1$). If the hedging pressure at time $t = 1$ is positive (so net short according to our definition) but the position of the technical traders is greater, the risk premium will be negative at time $t = 2$. It means that even the hedgers will provide risk bearing (or liquidity) to the technical traders. It is consistent with Kang et al. (2017), who argue that:

> "One premium paid by hedgers to speculators for obtaining price insurance and one premium paid by speculators to hedgers for accommodating their short-term liquidity needs. The opposite sign of these two premiums implies that the cost of short-term liquidity consumption paid by speculators partially erodes the insurance premium they receive from hedgers for providing price insurance."

The long demand arising from trend-following strategies at time $t = 2$ diminishes the expected profit from speculation. It is consistent with Koutmos (1997) which pointed out on stock markets:

> "During volatile periods positive feedback traders exert a greater influence on price movements and the degree of autocorrelation and hence predictability rises. This does not necessarily imply excess-profits because the higher volatility (risk) makes it harder for rational risk-averse investors to exploit the predictable pattern of stock prices."

The long commitment of technical traders drives the futures price upward at the intermediate period (F_2). Thus, the cost of holding a long position increases, which reduces the expected payoff for agents holding a long position.

At the intermediate period, time $t = 2$, speculation positions are long (short) if the expected payoff ($E_2[P_3]$) is higher than the current futures price (F_2). Nonetheless, speculative positions can be short (long) in the initial period, if the expected intermediate PNL of the futures position is negative. Thus, even if the expected payoff at time $t = 1$ ($E_1[P_3]$) is higher (lower) than the current futures price (F_1), speculation positions can be short (long). This result is the same as Anderson and Danthine (1983b) and is consistent with the "rational destabilization" described by De Long et al. (1990). Rational speculation positions are long in the first period, giving the impulse for a bubble in the second period. Then, speculation positions become short because the expected payoff is lower than the futures price that bubbles.

This paper's model describes as well the feedback from the futures market (price and quantity) to the spot market (price and quantity). When the spot demand elasticity is negative, the spot price at maturity crashes. While if the demand is rising with the price, the spot price keeps rising.

3.7.2 Resolution of the equilibrium

The resolution of the equilibrium is backward. Subsubsection 3.7.2.1 solves the second period, and then, subsubsection 3.7.2.2 the first period. Eventually, subsubsection 3.7.2.3 defines the equilibrium.

3.7.2.1 Second period

The resolution of the second period is similar to Ekeland et al. (2019). The moments of the spot price at maturity are quite simple:

$$E_2[P_3] = \frac{1}{m}(E[\xi_3] - \text{HP} - \tilde{\mu}) \quad (3.37)$$

$$\text{Var}_2[P_3] = \frac{1}{m^2}\text{Var}[\xi_3] \quad (3.38)$$

The clearing equation (3.34) gives the solution of the intermediate futures prices (F_2) given prices at the initial period (F_1, P_1).

3.7.2.2 First period

The moments of the spot price at maturity are more complicated in the first period than in the second period because of the inter-temporal components:

$$E_1[P_3] = \frac{1}{m}(E[\xi_3] - \mathrm{HP} - E[\mu]) \tag{3.39}$$

$$\mathrm{Var}_1[P_3] = \frac{1}{m^2}(\mathrm{Var}[\xi_3] + \mathrm{Var}[\mu]) \tag{3.40}$$

We compute $\mathrm{Cov}_1[P_3, P_3 - F_2]$. First, we inject the expectation of the spot price at maturity in the second period (3.37) in the risk premium for the same period (3.36):

$$F_2 = \frac{1}{m}(E[\xi_3] - \mathrm{HP} - \tilde{\mu}) - \frac{\mathrm{HP} - n_C F_1}{\Upsilon_2} \tag{3.41}$$

We inject the expectation of the spot price at the second period for the third period (F_2)(3.41) in the expression of the spot price at maturity (3.35) to get the following result for the covariance at the first period between the price of the futures in the next period and its payoff:

$$\mathrm{Cov}_1[P_3, F_2] = \frac{\mathrm{Var}[\mu]}{m^2} \tag{3.42}$$

The covariance is the product of the squared inverse spot demand elasticity and the variance of the changing investment opportunity. The higher is the priced risk of the changing investment opportunities, the smaller is the mean-variance component of the speculation positions in the first period.

3.7.2.3 Definition and computation of the equilibrium:

The sensitivity of the futures price to hedging pressure is : $\phi_t := 1 + \frac{m}{\Upsilon_t}$. The definition of the equilibrium is:

Definition 3.7.1 (Equilibrium) *An equilibrium is a family of quantities and prices* $(s^{I^*}, s^{P^*}, P_1, F_1, F_2, I$ *such that:*

1. *The nonnegativity constraint of quantities is fulfilled :* $(s^{I^*}, s^{P^*}) \in \mathbb{R}^2_+$

2. *Prices are nonnegative:* $F_1 \geq 0$, $P_1 \geq 0$, $F_2 \geq 0$ *and* $P_3 \geq 0$ *almost surely.*

3. *The market-clearing conditions for the spot and futures markets at $t = 1$ are fulfilled :*

$$\begin{cases} mP_1 - n_I s^{I^*} = \xi_1 \\ m(F_1 + ISP) + \phi_1\, HP = E[\xi_3] - E[\mu] \end{cases} \tag{3.43}$$

4. *The market-clearing condition for the futures market at $t = 2$ is fulfilled :*

$$mF_2 + \phi_2\, HP - \frac{n_C}{\Upsilon_2} F_1 = E[\xi_3] - \tilde{\mu} \tag{3.44}$$

5. *The market-clearing condition for the spot market at $t = 3$ is fulfilled:*

$$P_3 = \frac{1}{m}(\tilde{\xi}_3 - \tilde{\mu} - HP) \tag{3.45}$$

There are four regions as in Ekeland et al. (2019), summarized in Figure 1:

- Region 1, where $F_1 > P_1$ and $Z > F_1$, so both kinds of commercials are hedging.
- Region 2, where $F_1 > P_1$ and $Z < F_1$, so storers are hedging only.
- Region 3, where $F_1 < P_1$ and $Z < F_1$, so no one is hedging.
- Region 4, where $F_1 < P_1$ and $Z > F_1$, so processors are hedging only.

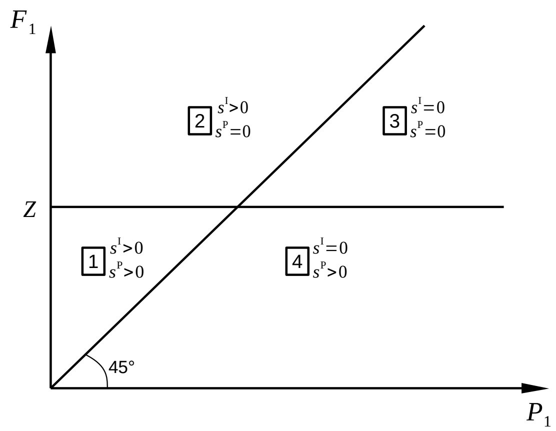


Figure 1: Physical and financial decisions in space (P_1, F_1): the four regions defined by Ekeland et al. (2019)

Now, we can summarize the steps to solve the equilibrium. At each step, we inject the results of the previous step:

1. Computation of the expectations of the spot price at maturity for the second period ($E_2[P_3]$) as a function of prices (F_1,P_1,F_2,P_2).

2. Solving the equilibrium of the intermediate period to get the futures prices (F_2) as a function function of prices (F_1,P_1).

3. Computation of the expectation of the spot price maturity at the first period ($E_1[P_3]$) as a function of prices (F_1,P_1).

4. Computation of prices which depend on the ISP (F_1,P_1,F_2).

5. The ISP is the solution of a fixed-point equation which is described by a second-degree polynomial. We can compute both roots. Nonetheless, the discriminant is intractable. Therefore, we have to compute the ISP numerically by plugging values to exogenous parameters. Nonetheless, all the other endogenous variables are functions of the ISP and exogenous variables so they can be computed directly.

6. Computation of prices which depend on the ISP computed above (F_1,P_1,F_2,P_3).

The multiplicity of equilibria arises because of the nonlinearity of the system solved in step 5. Because of the variance in the expected utility (3.1), we have to solve an endogenous moment of order two (Spiegel, 1998). Thus, there is a second-order polynomial with two roots for the intertemporal speculative pressure which is the covariance between the payoff of a long position in the first period and the profit of positions taken in the second period[9]. These two solutions can be valid equilibria.

Intertemporal Speculative Pressure (ISP) is given by (3.26). This term is the covariance between the spot price at maturity and the profit of positions taken in the second period. The ISP measures how the profit from speculation in the second period varies with the spot price at maturity. Agents adjust their speculative positions by taking into account the ISP in the first period (3.8). For example, if ISP is negative (which seems to be the rule as we will see further), the profit of the speculative positions taken in the second period and the spot price at maturity are negatively correlated. Speculative positions in the first period go longer because they expect the profit of a long position to be positive in the intermediate period and negative at maturity. All positions are marked-to-market. This result means rational agents expect to go short at the intermediate period. As we will see further, positive feedback trading

[9] If ISP was a squared matrix of dimension K, the second-order polynomial would give 2^K solutions. This would be the case if there were K securities available to speculators (Spiegel, 1998).

amplifies this phenomenon. Higher is the weight of technical traders, more negative is ISP, longer rational agents in the first period are, and higher the upward pressure on the futures price in the second period is. This is when rational destabilization is at play. In this paper's model, the futures market generates feedback on the spot market. This bullish dynamic on futures price is not without consequence for the spot price at maturity.

The second-order polynomial of the fixed-point equation of ISP exhibits two roots. If both solutions are equilibria, they stand for a high and a low regime of covariance between the profit of the speculative positions taken in the second period and the spot price at maturity. Rational agents can believe either ISP is negative a little bit or very much. Both match their belief system and are self-fulfilling prophecies. As section 3.8 shows beneath, the variation of the futures price in the second period does not vary in the same way according to the regime of ISP and the levels of spot prices differ.

Hence, there are potentially two equilibria within each region.

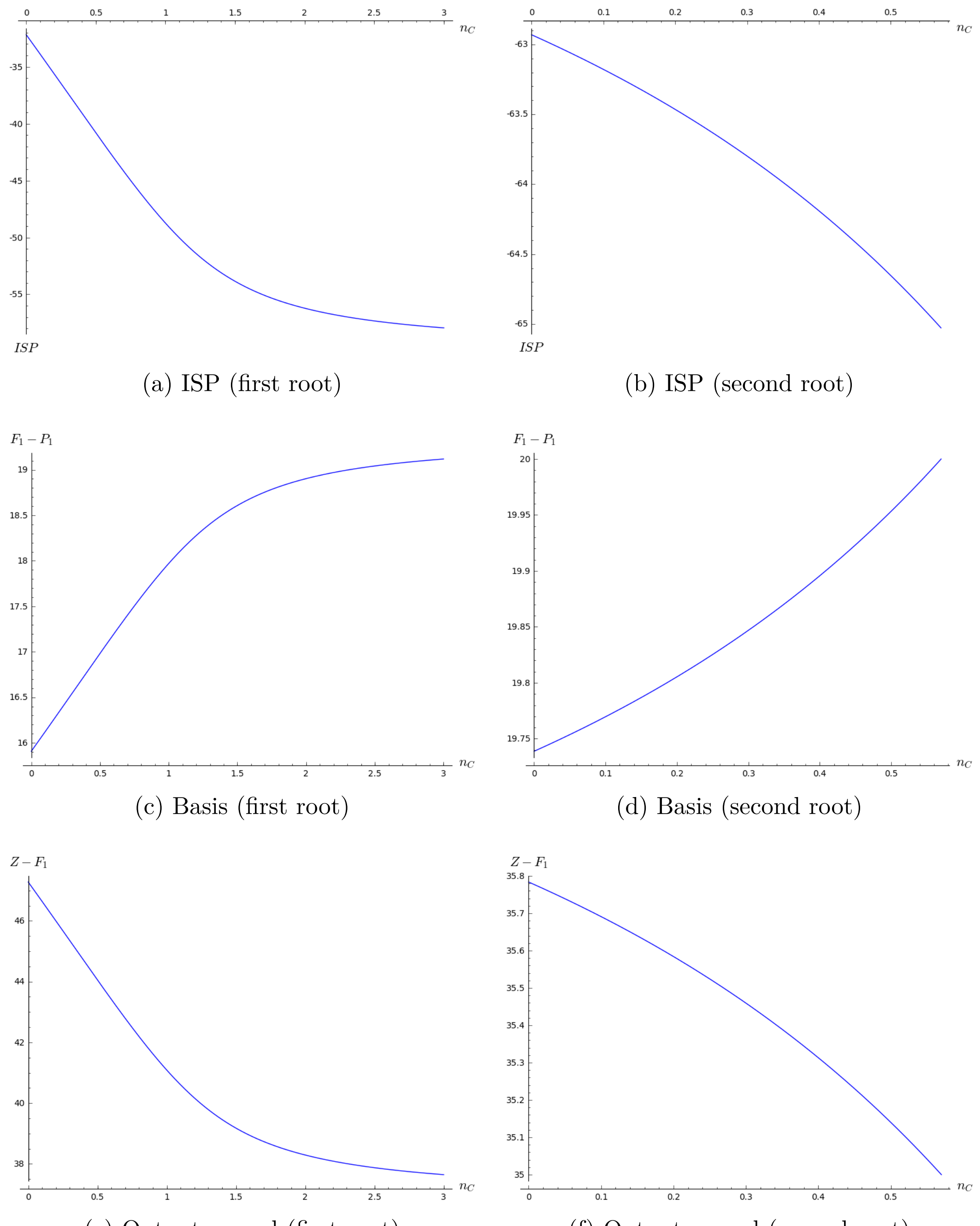
3.8 The multiplicity of equilibrium: Simulations and discussions

3.8.1 Futures and Spot pricing

Let us be in region 1 as it is the most complex and representative case. We simulate with ex-post values equal to their expectations. There are two roots of ISP consistent with the existence of equilibrium inside the same region. Figures 2a and 2b depict respective low and high regimes of ISP. They are both strictly decreasing with the size of technical traders. Therefore, the basis and output spread vary in a monotonous way.

More massive is the weight of technical traders, the lower is ISP (subfigures 2a and 2b). Rational agents speculate on longer positions in the first period. This positive demand shock on the derivatives market increases the futures price more than the spot price. Basis increases (subfigures 2c and 2d). This dynamics benefits to storers whose margins increase, so they rise the inventory level. At the opposite, processors are hurt by this hike which decreases their output spread (subfigures 2e and 2f), so they reduce their hedge. Hedging pressure becomes shorter so its value increases, as shown in subfigures 3a and 3b.

The risk premium does not always exhibit the same sign as hedging pressure. In the case of a high regime of ISP, the risk premium and hedging pressure have opposite signs, as we



(a) ISP (first root)

(b) ISP (second root)

(c) Basis (first root)

(d) Basis (second root)

(e) Output spread (first root)

(f) Output spread (second root)

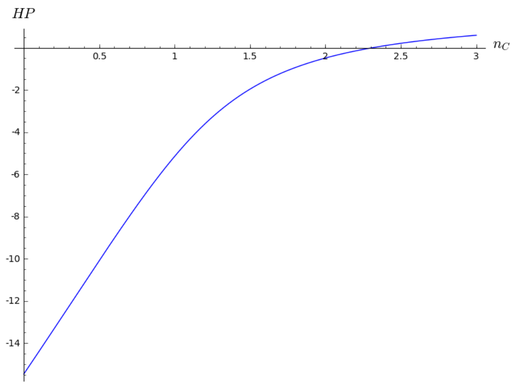
Figure 2: Link Between ISP and hedging. On the left, the variations are according to the first root. On the right, it is for the second root. Parameters are: $n_I = 2, n_P = 1, \frac{N_I}{\alpha_I} + \frac{N_P}{\alpha_P} + \frac{N_S}{\alpha_S} = 6$, $m = 1,\ \tilde{\xi_1} = 5,\ E[\xi_3] = 6,\ \text{Cov}_1[\xi_3, \mu],\ \forall n \in [\![1, 3]\!], E[\mu^n] = 1,\ V[\xi_3] = \frac{1}{10},\ V[\mu] = \frac{1}{30}$, and $Z = 100$.

can see in figures 3b and 3d. For both roots, hedging pressure and the risk premium vary in the opposite direction. The core result of Ekeland et al. (2019) does not hold with technical traders. Moreover, speculative positions in the first period can be long while the risk premium is negative, consistent with Anderson and Danthine (1983b). Rational agents manage their intertemporal risk by adjusting their futures position in the first period to the covariance between the payoff of a long position and the profit of speculative positions at time $t = 2$. The expected utility of the speculators' profit is:

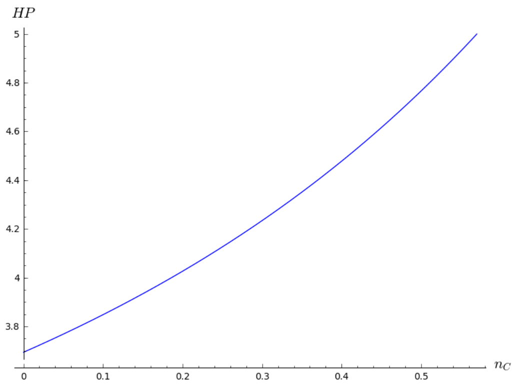
$$EU_1^S\left(\pi_S\right) = \left(E_1\left[P_3\right] - F_1\right) f_1^S + E_1\left[(P_3 - F_2) f_2^S\right] - \frac{\alpha_S}{2}\left(\left(f_1^S\right)^2 \mathrm{Var}_1\left[P_3\right] + \underbrace{2 f_1^S \mathrm{Cov}_1\left[P_3, (P_3 - F_2) f_2^S\right]}_{\text{Intertemporal risk}}\right) \tag{3.46}$$

The intertemporal risk is two times the product of the position at the first period and the covariance between the payoff of a long position and the profit of speculative positions at period $t = 2$. The more the weight of technical traders increases, the more the covariance is negative. Hence, rational agents speculate longer. There are two possible cases. First, speculative positions in the first period are short (i.e., $E_1[P_3] - F_1 - \mathrm{ISP} < 0$). The intertemporal risk is positive, so rational agents diminish the risk they bear. Thus, absolute hedging pressure decreases until sign changing, as in figure 3a. Second, speculators increase their exposition to risk if they are long at the initial period. Therefore, absolute hedging pressure increases.

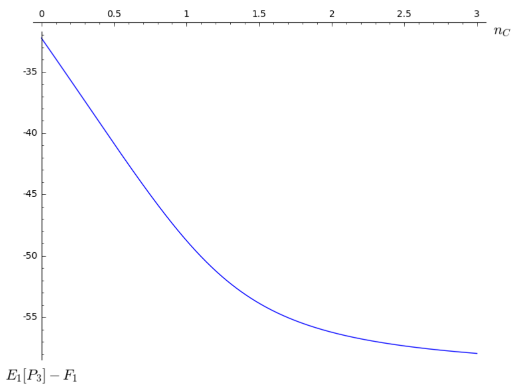
The impact on asset pricing at the initial period is monotonous. Both spot (subfigures 4a and 4b) and futures (subfigures 4c and 4d) prices rise similarly. While ISP has an ambiguous effect on the futures price at the intermediate period. A variation of ISP is either absorbed by hedging pressure or the risk premium in the first period. Furthermore, the hedging pressure is transported to the equation of the risk premium in the second period (3.36). Two cases are possible: First, hedging pressure increases more than the positions of technical traders. The risk premium in the second period decreases with a diminishing futures price. This phenomenon happens for the first root until the weight of technical traders reaches a tipping point, as shown in subfigure 4e. Second, the futures price increases if the hedging pressure effect is lower than the direct effect of the chartists on the futures price, as in subfigure 4f and subfigure 4e after the tipping point. More chartists generate a higher hedging pressure, which amplifies a downward trend in the spot price, as shown in subfigures 4g and 4h.



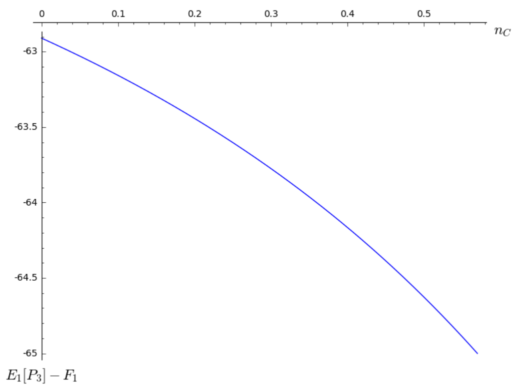
(a) HP (first root)



(b) HP (second root)

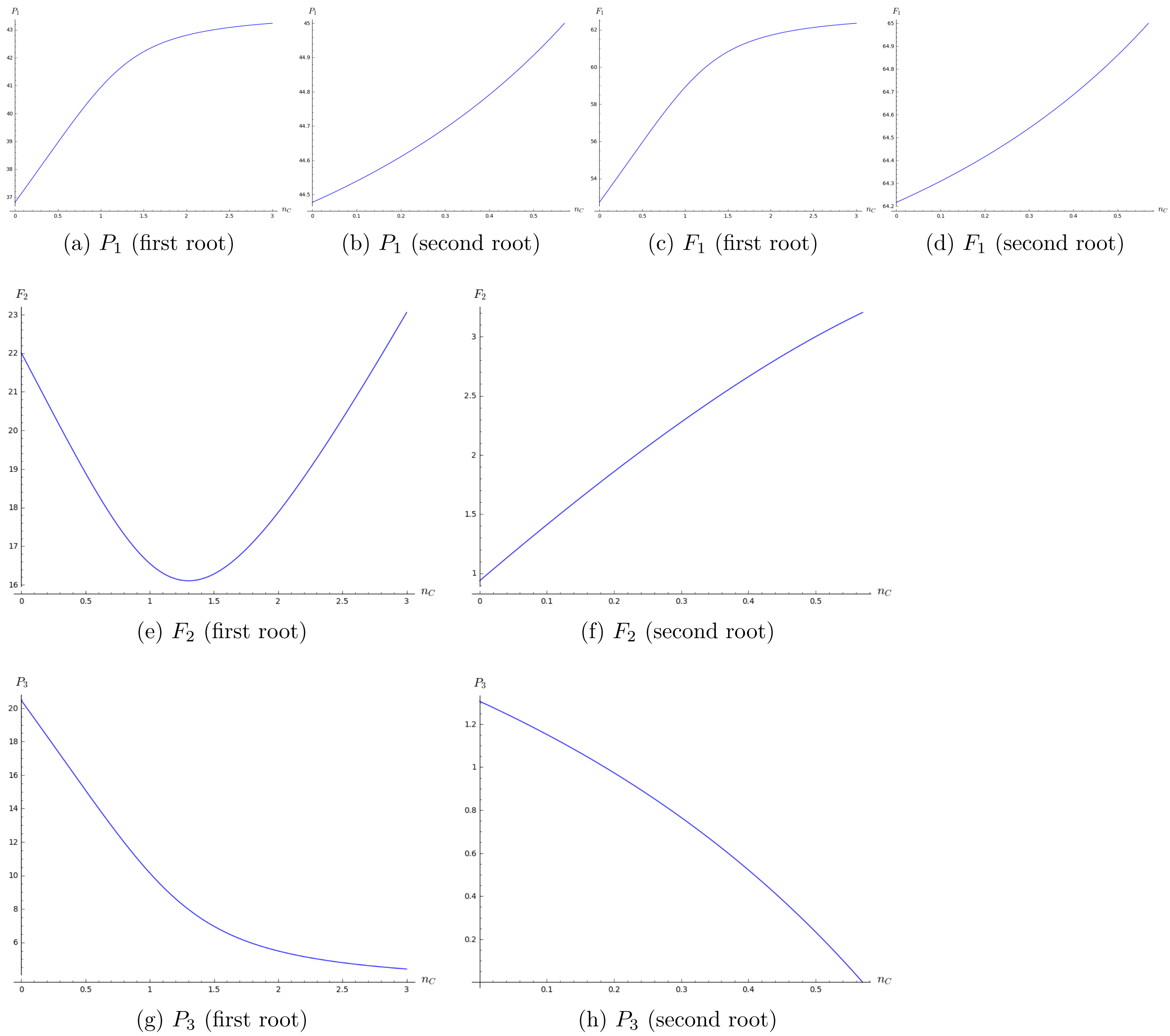


(c) Risk premium (first root)



(d) Risk premium (second root)

Figure 3: Link between hedging pressure (HP) and the risk premium. On the left, the variations are according to the first root. On the right, it is for the second root. Parameters are: $n_I = 3$, $n_P = 1$, $\frac{N_I}{\alpha_I} + \frac{N_P}{\alpha_P} + \frac{N_S}{\alpha_S} = 1$, $m = 0.05$, $\tilde{\xi_1} = 1$, $E[\xi_3] = 3$, $\text{Cov}_1[\xi_3, \mu] = 0.5$, $\forall\, n \in [\![1, 3]\!]$, $E[\mu^n] = 1$, $V[\xi_3] = \frac{1}{10}$, $V[\mu] = \frac{1}{30}$, and $Z = 50$.



(a) P_1 (first root) (b) P_1 (second root) (c) F_1 (first root) (d) F_1 (second root)

(e) F_2 (first root) (f) F_2 (second root)

(g) P_3 (first root) (h) P_3 (second root)

Figure 4: Asset pricing. On the left, the variations are according to the first root. On the right, it is for the second root. Parameters are: $n_I = 3$, $n_P = 1$, $\frac{N_I}{\alpha_I} + \frac{N_P}{\alpha_P} + \frac{N_S}{\alpha_S} = 1$, $m = 0.05$, $\tilde{\xi_1} = 1$, $E[\xi_3] = 3$, $\text{Cov}_1[\xi_3, \mu] = 0.5$, $\forall n \in [\![1, 3]\!], E[\mu^n] = 1$, $V[\xi_3] = \frac{1}{10}$, $V[\mu] = \frac{1}{30}$, and $Z = 50$.

3.8.2 Futures and Spot variations

We consider destabilization to be the increase of a price's variability by a rising variable (for instance the rising synthetic weight of technical traders). We measure price variability with the Euclidean distance between prices in time. There are only two values for the spot price, so the Euclidean distance is equal to the Manhattan distance, which is the absolute variation ($|P_3 - P_1|$). This is equivalent to a volatility measure of differences centered to a null mean.

Definition 3.8.1 (Spot-price destabilizing) *A variable x is said to be spot-price destabilizing if $\frac{\partial |P_3 - P_1|}{\partial x} > 0$.*

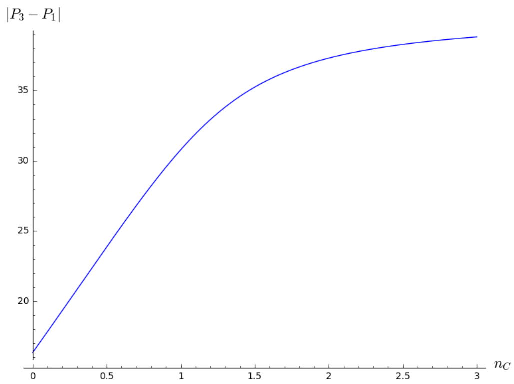
Definition 3.8.2 (Futures-price destabilizing) *A variable x is said to be futures-price destabilizing if $\frac{\partial \sigma_F}{\partial x} > 0$ with $\sigma_F = \frac{1}{2}\sqrt{\sum_{t=2}^{3}(F_t - F_{t-1})^2}$ and $F_3 = P_3$.*

In the spot market, the widening spread between the prices at the initial and final periods rises the variability (subfigures 5a and 5b). The effect on the futures volatility is ambiguous. An interesting result is that the rising weight of technical traders can stabilize the futures market while destabilizing the spot market, as shown by figures 5b and 5d. Nonetheless, in this case, variations are small compared to the other ones.

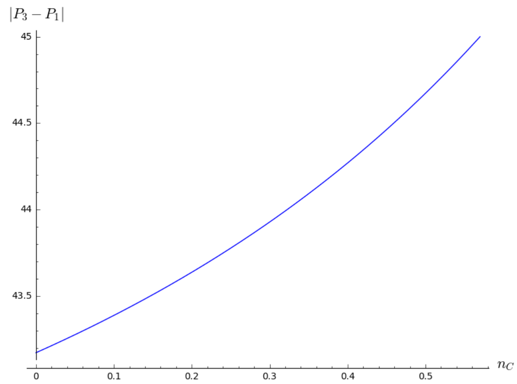
This paper highlights how the rational destabilization of the spot market works. Shorter hedging pressure generates a negative demand shock at maturity, driving the spot price up at maturity and down at maturity and pushing up spot price variability. This phenomenon works even without storage when the basis is negative[10]. The reduction of long hedging is sufficient for spot price destabilization. This result confirms the intuition of Kocagil (1997) that excluding processors create a bias towards spot price stabilization by futures speculation.

Our model keeps the stabilizing property of an increasing market tolerance (or speculative intensity) from Ekeland et al. (2019). More numerous or less risk-averse rational speculators increase the risk tolerance, which thus decreases the risk premium at the initial and intermediate periods. For each period t, Υ_t increases. The risk premium in the second period, defined by equation (3.36) decreasing with Υ_2, the expected payoff at the second period leans toward zero. Therefore, so does the ISP (that is the covariance between the expected profit in the second period and the spot price at maturity). Moreover, the impact of hedging pressure on the futures price in the first period diminishes as well because of Υ_1 that increases, as shown

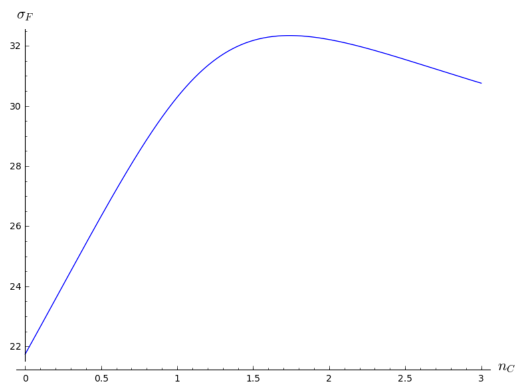
[10] We show this in the appendix 1.A



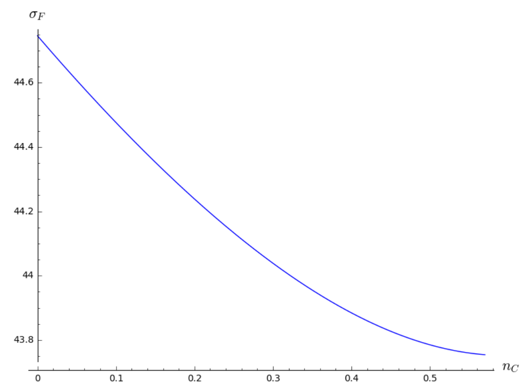
(a) Spot absolute variation (first root)



(b) Spot absolute variation (second root)



(c) Futures standard deviation (first root)



(d) Futures standard deviation (second root)

Figure 5: Futures and spot variations. On the left, the variations are according to the first root. On the right, it is for the second root. Parameters are: $n_I = 3$, $n_P = 1$, $\frac{N_I}{\alpha_I} + \frac{N_P}{\alpha_P} + \frac{N_S}{\alpha_S} = 1$, $m = 0.05$, $\tilde{\xi}_1 = 1$, $E[\xi_3] = 3$, $\text{Cov}_1[\xi_3, \mu] = 0.5$, $\forall\, n \in [\![1, 3]\!], E[\mu^n] = 1$, $V[\xi_3] = \frac{1}{10}$, $V[\mu] = \frac{1}{30}$, and $Z = 50$.

by equation (3.33). Therefore, we get the stabilizing effect highlighted by Ekeland et al. (2019) on the spot price. Values at first and last period converge. Our model does not include storage (Driskill et al., 1991; Kawai, 1983) or production shocks Newbery (1987), which could make the increase of market tolerance destabilizing.

3.8.3 Welfare outcome

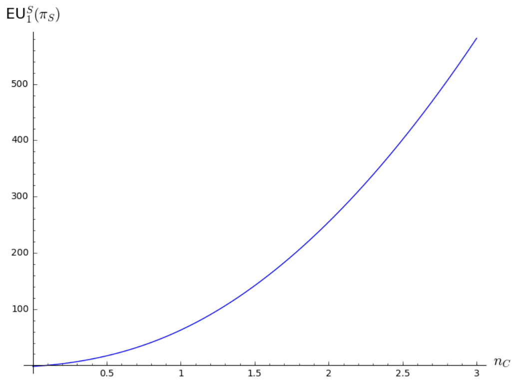
Technical traders raise the absolute risk premium in the second period. Rational operators speculate short to benefit from a negative risk premium. Rational speculators make a profit at the expense of technical traders so the expected utility of the former rises (subfigures 6a and 6b). Moreover, the long positions of technical traders offset the short positions of storers. The latter enjoy the profit from both speculation and storage (subfigures 6c and 6d). The effect on the short hedgers, or processors, is ambiguous. Technical traders damage long hedging, but they generate speculation profits. If the loss of hedging is greater in absolute value than the profit from speculation, the expected utility of processors is decreasing, as in 6f. If the balance is reversed, processors enjoy more utility as in subfigure 6e after a threshold is reached.

3.8.4 Discussing empirical measures

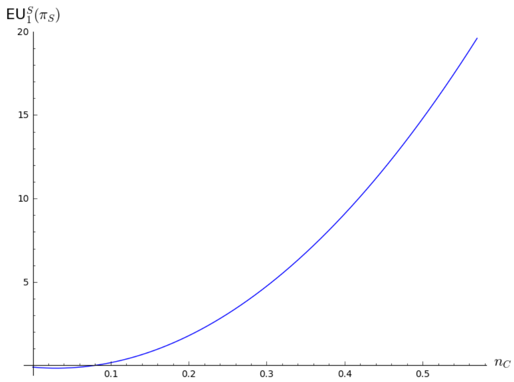
This subsection discusses the validity of empirical measures to evaluate how they fit their reference concepts. The simulations show the existence of biases between measured and exact values. First, let us examine hedging pressure. The true value is given by (3.21) that gives the net hedge position on the futures market in our model. Nonetheless, this value cannot be observed directly. Therefore, literature uses the following empirical measure denoted by:

$$HP'_t = -(N_I f_t^I + N_P f_t^P) \tag{3.47}$$

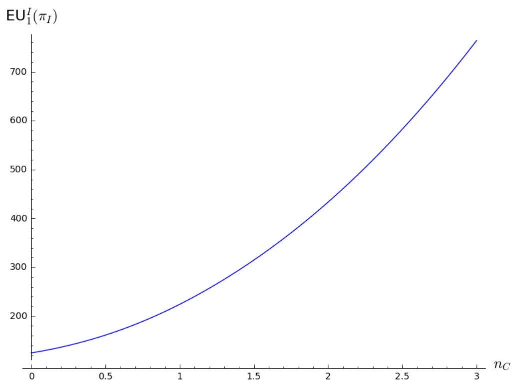
As highlighted by Ekeland et al. (2019), the empirical hedging pressure includes the speculative component of the commercials' positions on the futures market. While hedging is quite stable, speculative positions are more volatile. This result explains why commercials' positions vary so much (Cheng & Xiong, 2014b). In our model, the bias is proportional to the true value in the first period. The sign is the same. Nonetheless, commercials go short very strongly in the second period for speculative purposes. While the true hedging pressure is constant for both periods, the variation of the empirical measure, between the first and the second period, becomes wider with the increasing weight of technical traders. Figure 7



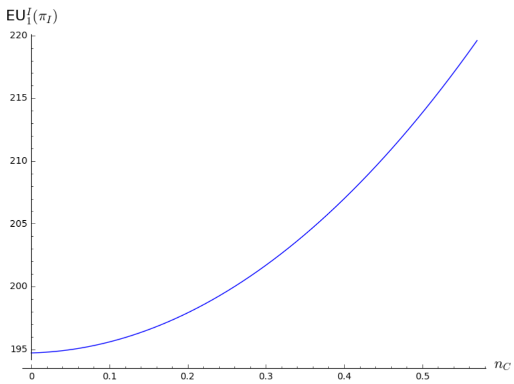
(a) $EU_1^S(\pi_s)$ (first root)



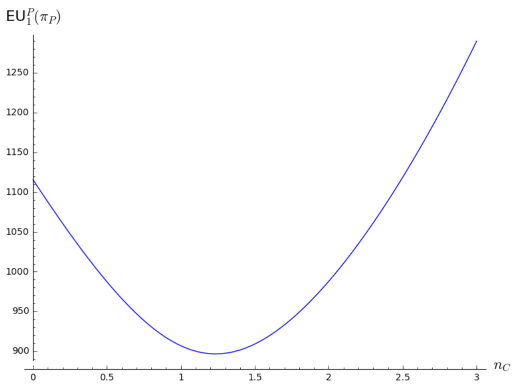
(b) $EU_1^S(\pi_s)$ (second root)



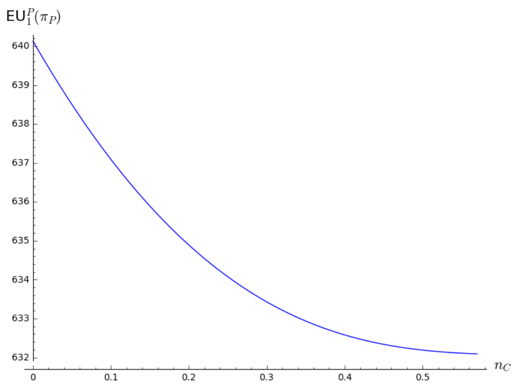
(c) $EU_1^I(\pi_I)$ (first root)



(d) $EU_1^I(\pi_I)$ (second root)



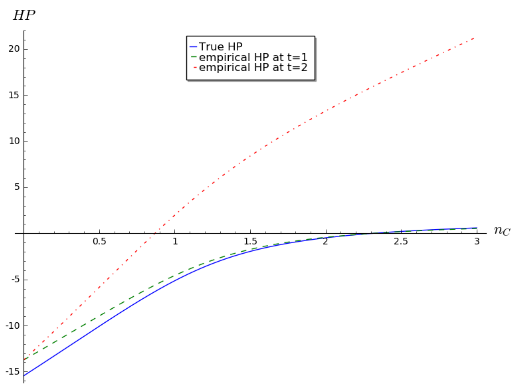
(e) $EU_1^P(\pi_P)$ (first root)



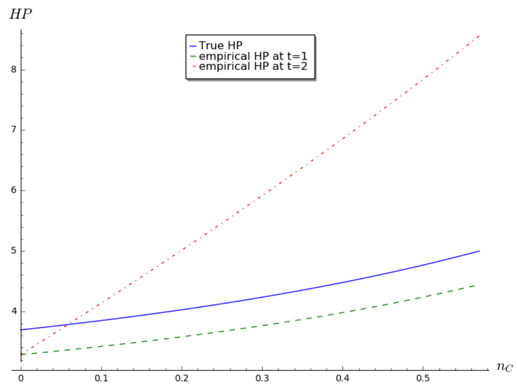
(f) $EU_1^P(\pi_P)$ (second root)

Figure 6: Expected utilities at the initial period of rational speculators, storers and processors. On the left, the variations are according to the first root. On the right, it is for the second root. Parameters are: $n_I = 3$, $n_P = 1$, $\frac{N_I}{\alpha_I} + \frac{N_P}{\alpha_P} + \frac{N_S}{\alpha_S} = 1$, $m = 0.05$, $\tilde{\xi_1} = 1$, $E[\xi_3] = 3$, $\text{Cov}_1[\xi_3, \mu] = 0.5$, $\forall\, n \in [\![1, 3]\!]$, $E[\mu^n] = 1$, $V[\xi_3] = \frac{1}{10}$, $V[\mu] = \frac{1}{30}$, and $Z = 100$.

illustrates this dynamic. The increasing short positions of commercials in the second period follows the linear form of the positions of technical traders ($n_C F_1$).



(a) Empirical HP (first root)



(b) Empirical HP (second root)

Figure 7: Benchmark of measured and true values of hedging pressure. On the left, the variations are according to the first root. On the right, it is for the second root. The solid blue line is the true HP. The green dashed line and the red dashed-dotted line are respectively the values of the HP at t=1 and t=2. Parameters are: $n_I = 3$, $n_P = 1$, $\frac{N_I}{\alpha_I} + \frac{N_P}{\alpha_P} + \frac{N_S}{\alpha_S} = 1$, $m = 0.05$, $\tilde{\xi_1} = 1$, $E[\xi_3] = 3$, $\text{Cov}_1(\xi_3, \mu) = 0.5$, $\forall n \in [\![1, 3]\!], E[\mu^n] = 1$, $V[\xi_3] = \frac{1}{10}$, $V[\mu] = \frac{1}{30}$, and $Z = 50$.

Commercials can be net short while the correct hedging pressure is net long as in subfigure 7a. This outcome is consistent with hedgers acting as contrarians providing risk-bearing to technical traders (Kang et al., 2017). Moreover, when the weight of technical traders is null, the empirical hedging pressure remains constant through time. Commercials trade much more than their hedging need for speculative purposes (Cheng & Xiong, 2014b). Speculative trades distort the empirical measure of hedging pressure. The use of measures relying on the empirical hedging pressure like the Working's T should be looked with caution. Furthermore, the clearing equation (3.30) for the futures market at the first period implies a value of the Working's T equal to one. However, the ISP reveals that speculating agents take positions to speculate about the arrival of technical traders in the next period.

3.9 Conclusion

To conclude, this chapter presents a three-period model adding technical traders in a theoretical frame unifying hedging pressure and storage theories. This paper's model enables to study the repercussion of technical traders on both spot and futures prices which are the outcome of an endogenous loop. This work shows a fixed-point equation (which is a second-degree polynomial) determines the existence of equilibrium. Therefore, there is a potential multiplicity of equilibria, which is a source of instability in itself.

This study shows the risk management of technical traders by rational operators modify market fundamentals. Technical traders decrease the covariance between the spot price at maturity and the profit of the positions taken in the second period. Speculating agents go longer at the initial period in reaction to this expected additional risk at the next period. This longer speculative pressure at the first period drives futures price upward hurting long hedging and inciting short hedging. This dynamic raises the spot price too in the first period. Then, the shorter hedging pressure generates a negative net demand shock at maturity. Therefore, spot prices at maturity decrease. Finally, spot price variability increases with the rising weight of technical traders.

This paper also shows both empirical measures of hedging pressure and speculation are not always accurate. Technical traders generate a second kind of risk premium. Commercials can act as contrarians providing risk-bearing to technical traders. Empirical measures of hedging pressure and Working's T exhibit caveats according to the results of simulations.

This article focuses on intertemporal speculative pressure and sets the intertemporal aspects of commercials' hedging decisions aside. Including revisions of hedging decisions would shed new light on the spot-futures loop. Furthermore, an extension to an infinite period would tell about dynamic evolution paths.

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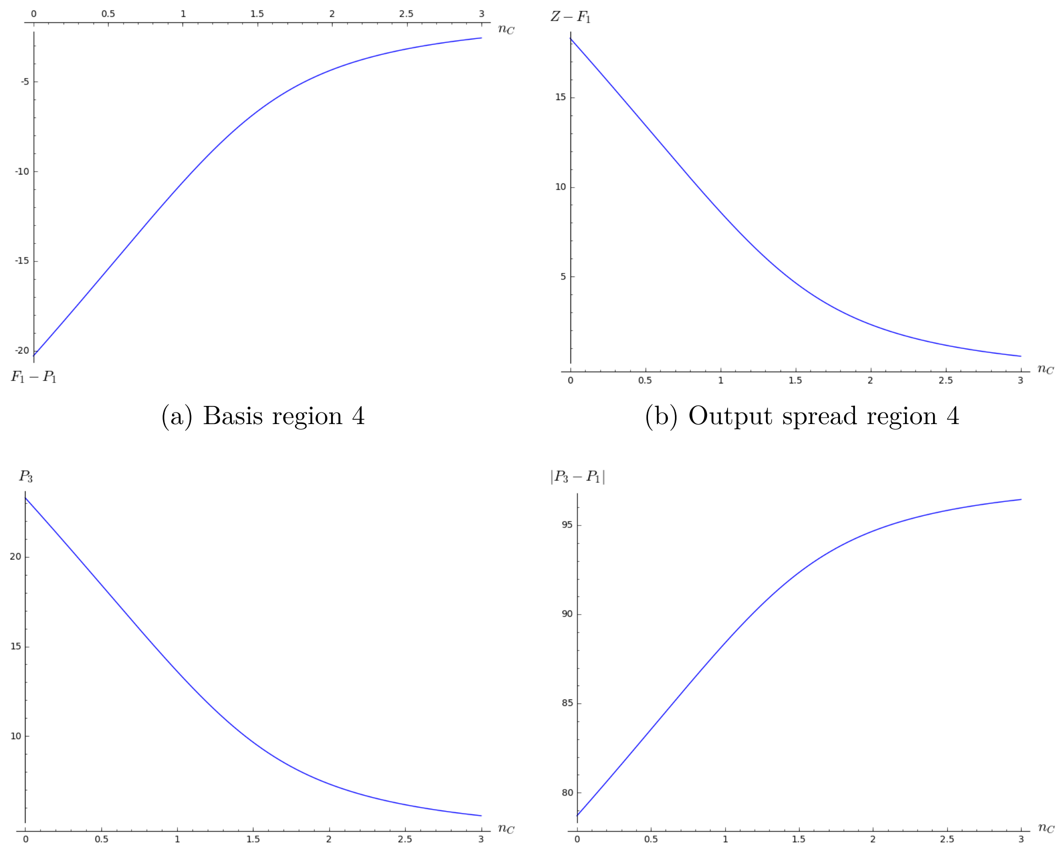
Appendix

1.A Destabilization without storage

Figure 1.A1 shows that the destabilization of spot price happens without storage in region 4, which corresponds to backwardation with active long hedging. The absolute basis and the output spread decrease because of the rising futures price in the first period, as shown in subfigures 1.A1a and 1.A1b. Short hedging remains null while long hedging is decreasing. The latter effect creates a negative demand shock at maturity on the spot market. Therefore, the spot price decreases at maturity, and variability increases (subfigures 1.A1c and 1.A1d).



(a) Basis region 4

(b) Output spread region 4

(c) Spot price at maturity region 4

(d) Spot price variability region 4

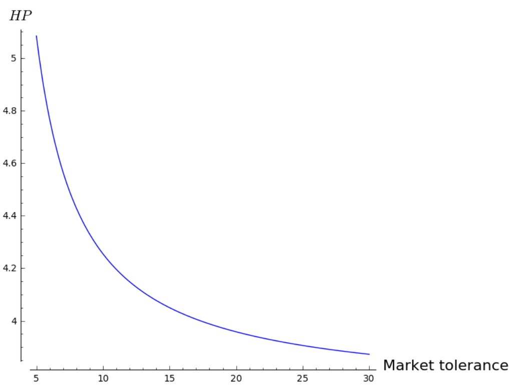
Figure 1.A1: Impact of technical traders in region 4 when processors only are hedging. Parameters are: $n_I = 0$, $n_P = 1$, $\frac{N_I}{\alpha_I} + \frac{N_P}{\alpha_P} + \frac{N_S}{\alpha_S} = 2$, $m = 1$, $\tilde{\xi_1} = 102$, $E[\xi_3] = 6$, $\forall\, n \in [\![1, 3]\!]$, $E[\mu^n] = 1$, $V[\xi_3] = \frac{1}{10}$, $V[\mu] = \frac{1}{100}$, and $Z = 100$.

1.B Stabilizing effect of increasing market tolerance on the spot price

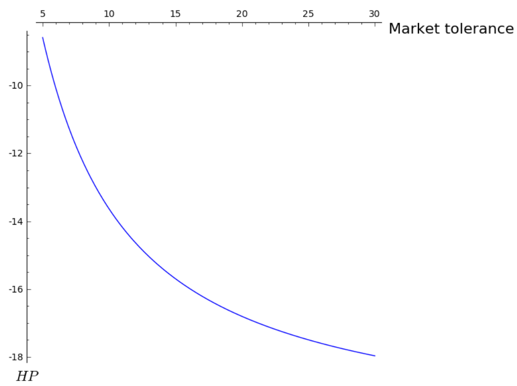
We consider a fixed weight of technical traders ($n_C = 0.5$) which is valid for both roots in our numerical simulation for region 1 in figures 1.A2 and 1.A3. An increasing market tolerance absorbs the effect of technical traders. The futures price is closer to the expected price. Therefore, there is less incentive to speculate respectively long and short in the first and second periods. The futures price decreases thus in the first period, which diminishes the spot price (to a lesser extent) and the basis. Hedging pressure decreases and leans toward its value for a perfectly elastic risk premium (subfigures 1.A2a and 1.A2b). This phenomenon generates a positive net demand shock at maturity. The spot price at maturity increases. There is a shrinking spread between the spot prices at the initial and last periods (subfigures 1.A3a and 1.A3b).

Hedging pressure is going longer if initially net long. In this case, the hedging pressure effect is stronger than the direct effect of technical traders. The futures price increases in the second period. Increasing market tolerance is both stabilizing for futures and spot markets (subfigures 1.A2d and 1.A2f).

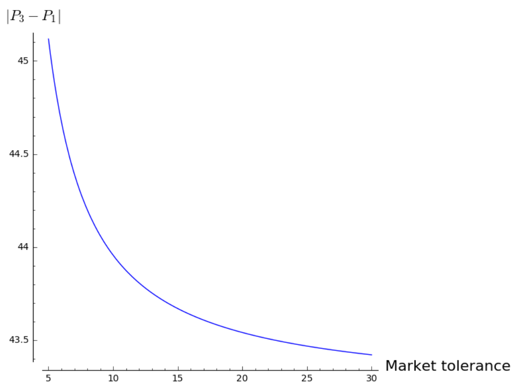
However, if hedging pressure is initially net short, its absolute value decreases. The hedging pressure effect is lower than the direct effect of technical traders. There is a divergence between futures price at the initial and intermediate periods. In this situation, increasing market tolerance is futures destabilizing but still spot stabilizing (subfigures 1.A2c and 1.A2d).



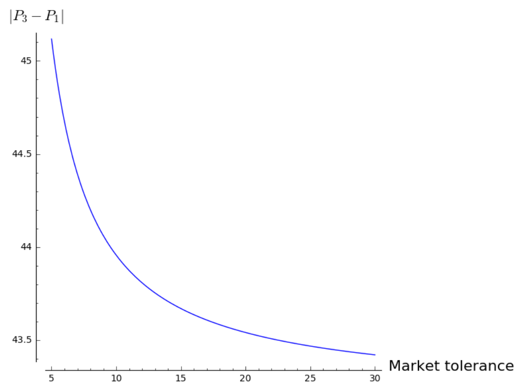
(a) Hedging pressure (first root)



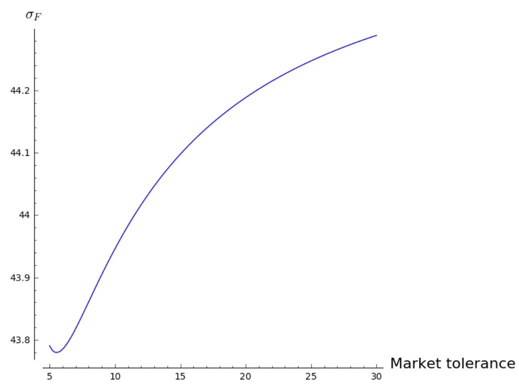
(b) Hedging pressure (second root)



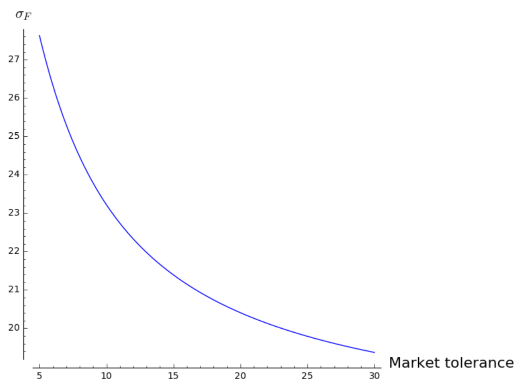
(c) Spot price variation (first root)



(d) Spot price variation (second root)

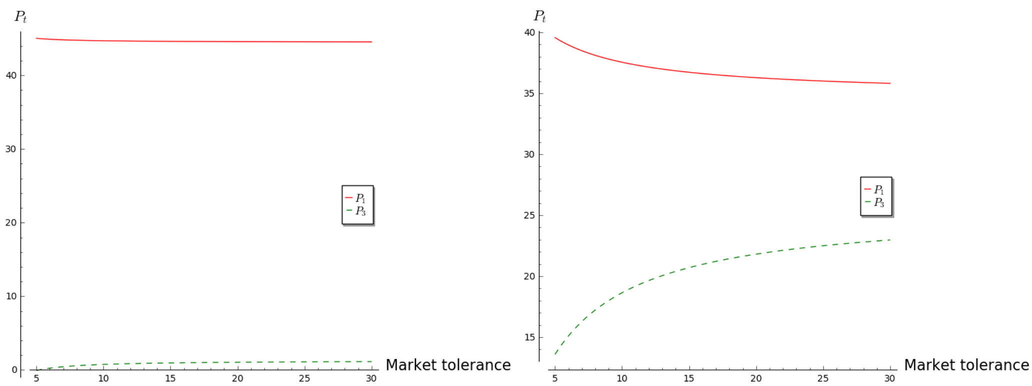


(e) Futures price standard deviation (first root)



(f) Futures price standard deviation (second root)

Figure 1.A2: Impact of market tolerance in region 1. On the left, the variations are according to the first root. On the right, it is for the second root. Parameters are: $n_I = 2$, $n_P = 0$, $n_C = 0.5$, $m = 0.1$, $\tilde{\xi_1} = 5$, $E[\xi_3] = 10$, $\forall\, n \in [\![1, 3]\!], E[\mu^n] = 1$, $V[\xi_3] = \frac{1}{10}$, $V[\mu] = \frac{1}{10}$, and $Z = 60$.



(a) Spot prices (first root) (b) Spot prices (second root)

Figure 1.A3: Benchmark of the impact of market tolerance in region 1 on the spot prices through time. On the left, the variations are according to the first root. On the right, it is for the second root. The solid red line and the green dashed line are respectively the values of the spot price at t=1 and t=3. Parameters are: $n_I = 2$, $n_P = 0$, $n_C = 0.5$, $m = 0.1$, $\tilde{\xi_1} = 5$, $E[\xi_3] = 10$, $\forall n \in [\![1, 3]\!]$, $E[\mu^n] = 1$, $V[\xi_3] = \frac{1}{10}$, $V[\mu] = \frac{1}{10}$, and $Z = 60$.

General Conclusion

Contents

This dissertation is an exercise of financial economics aiming to study the circulation interaction between the futures and spot markets. Derivatives are bets on events about asset prices. The dependency of the futures contract to the underlying spot is trivial. A sports bet depends on the outcome of the underlying sport event as well. What is less obvious is the feedback from the futures price to the spot price. The circularity arises because economic agents use derivatives as insurance against market risk. Therefore, the behaviors of operators active in the futures market matter. Their strategies depend on their information and their beliefs. Heterogeneous agents with different beliefs and information compose the futures markets. This difference is not without impact over risk-sharing and so the economic activity. This Ph.D. thesis tackles this heterogeneity to highlight the outcomes for asset pricing and hedging.

Chapter 1 presents a two-period model adding private information in a theoretical frame unifying hedging pressure and storage theories. This chapter's model enables to study how prices aggregate the different pieces of information spread among market operators. This model's outcome is that the futures price is a biased but efficient predictor of the spot price in the next period. Thus, the market is strongly efficient because the futures price always reveals all the information.

The futures price bias, which is the conditional risk premium, varies directly through the futures price and indirectly when the equilibrium regime changes. The coefficients of the regression relationship vary with the basis and the spread between the output price and the futures price. Therefore, estimating the coefficients of the unconditional risk premium, or expected risk premium, to compute the risk premium can be misleading. Moreover, in practice, the spread with the output price is not always known. Therefore, the estimation of the conditional risk premium is harder.

New signals increase the precision of the futures price. Thus, the lower risk gives an incentive to speculate more, which increases the competition among speculators. The risk premium is driven down, and the absolute hedging pressure increases as financialization does. Better price informativeness creates two opposite effects. First, better information decreases risk, which generates a negative impact on risk sharing. Second, More precise information helps hedgers to make decisions which increase the risk sharing. A «Hirshleifer effect» might occur if the negative impact on risk sharing dominates such as the well being of every operator is hurt. Therefore, hedgers and speculators can be both opponents of policies like the market monitor of the AMIS when their lower benefits of speculation make their utility decrease.

An interesting extension would be to introduce noise generated by the equity portfolio of speculators. This setting would generate a Partially Revealing Rational Expectation Equilibrium (PRREE). This property would enable studying more realistically the effect of additional signals.

Chapter 2 estimates the influence of trend-followers on the Nymex, the US gas natural futures markets, and the feedback from the latter on Henry Hub, the physical market, from February 2000 to July 2015. The data set splits into two subperiods. The first one is from 2000 to 2008, including the period before and during the spike. The second one is after the spike from 2009 to 2015. Results are consistent with the existence of a significative impact of the trend-following strategies on the US natural gas futures and spot markets.

The estimation of the parameters of the futures equations shows a dominating role of trend-following speculation for weekly variations on the Henry Hub and Nymex from February 2000 to July 2015. This is consistent with the trend-followers affecting the US natural Gas futures market.

The feedback effect from the futures market to the spot market is confirmed. 2008 has been a pivotal year. The period 2000-2008 exhibits a sensitivity of the spot price to the futures price lesser but close to one. After 2008, there is not a stable relationship anymore between the spot and the futures prices.

The chapter's findings are consistent with speculation exacerbating trends on the futures market and generating feedback to the spot market. This situation can lead the US natural gas prices to spike and crash as in 2008 or 2014.

Further studies are needed to investigate the existence of an informational effect, in particular around 2008. Moreover, it would be interesting to look at methodologies able to capture the time-varying aspect of the sensitivity of the spot price to the futures price.

Chapter 3 presents a three-time model adding technical traders in a theoretical frame inspired by chapter 1. The model enables to study the repercussion of chartists on both spot and futures prices, which are the outcome of an endogenous loop. This chapter shows that a fixed-point equation (which is a second-degree polynomial) determines the existence of equilibrium. Therefore, there is a potential multiplicity of equilibria, which is a source of instability.

A key message is the risk management of technical traders by rational operators modify market fundamentals. Chartists decrease the covariance between the spot price at maturity and the profit of the positions taken in the second period. Speculating agents go longer at the initial period in reaction to this expected additional risk at the next period. The longer speculative pressure at the first period drives futures price upward, which hurts long hedging and incites short hedging. This dynamic raises the spot price too in the first period. The shorter hedging pressure generates a negative net demand shock at maturity. Therefore, spot prices at maturity decrease. Finally, spot price variability increases with the rising weight of technical traders. Empirical simulations show that empirical measures of hedging pressure and speculation are not always accurate. Technical traders generate a second kind of risk premium. Commercials can act as contrarians providing risk-bearing to chartists. Empirical measures of hedging pressure and Working's T exhibit caveats.

This article focuses on intertemporal speculative pressure and sets the intertemporal aspects of commercials' hedging decisions aside. Including revisions of hedging decisions would shed new light on the spot-futures loop. Furthermore, an extension to infinite time would tell about dynamic evolution paths.

Prospectives

Chapter 3 shows that the activity of technical traders affects the spot price through feedback from the futures market. As Kholmeyer (1984) (manager of the futures department for the commodity marketing division of Cargill, Inc., of Minneapolis, MN) told a Senate hearing in 1984 :

> "[What] I would like to stress is that fundamentals are not hard and fast facts. Events are reshaping them all the time. Perhaps more important, the term fundamentals refers to opinions about supply and demand, not known facts. They reflect informed estimates. As such, they can and do change as new information on price, weather, political events, and the like emerges. They also are estimates that are modified as old estimates are replaced with actual production and consumption figures that may confirm or alter past beliefs but become starting points for new estimates."

Fundamentals move with the derivatives market. There is no real economy on one side and financial activities on the other side. There is a one only world which is real and where every one of us inhabits. With financialization, financial traders take the lion's share of the open interest. Chapter 2 shows that noncommercial traders represent roughly 60% of the open interest over time, and commercial traders act as contrarians. This result is consistent with the literature on the topic and shows there is a transfer from economic to financial activities.

Physical operators use their treasury to share risk with trend-followers by acting as contrarians. There is an issue with the self-fulfilling aspect of trend-following and momentum strategies which can exacerbate volatility. Already in the 1920s, Hardy (1923) notices speculators are ready to pay for risk. He adds the stabilizing influence of the market is depends on the share of purely speculative trades (both parts of the contract speculate).

This whole dissertation connects dots between commodity markets, "*the real effects of financial markets*" (Bond et al., 2012) and behavioral economics. Researchers have to deal with this track to understand the derivatives-spot feedback in a financialized world. For example, the study of strategic behaviors with information asymmetry is fruitful. Glebkin (2018) shows how market power can make illiquidity and information efficiency complementary. This result has implications for oligopolistic markets like crude oil. Another example is Fung and Hsieh (2001) who replicate sophisticated trend-following strategies with loopback options. Financial economic modeling to the commodity markets could include agents following this kind of portfolio strategy.

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Présentation de la thèse en français

Black (1976) compare les contrats de dérivés à des paris sportifs. Ils ont en commun de refléter les anticipations des résultats d'un événement futur. Si les joueurs d'un événement sportif ne sont pas soudoyés, le résultat est indépendant des paris. Les instruments dérivés sont des "*contrats financiers dont le prix est dérivé de celui d'un actif sous-jacent tel qu'un taux de change, un taux d'intérêt, un risque de crédit ou une matière première*" (Lautier, 2013). Il existe plusieurs types de contrats dérivés, mais cette thèse de doctorat porte sur les contrats à terme, qui sont les plus courants dans les marchés réglementés. Ces derniers sont des accords standardisés synallagmatiques[1] entre deux parties. Ils sont négociés sur des marchés organisés régis par une chambre de compensation. Le prix de la matière première sous-jacente s'appelle le prix au comptant. Le prix à terme fait référence au prix du contrat à terme sur l'actif sous-jacent. Black (1976) suppose que le prix au comptant est exogène des prix des produits dérivés. Quand il écrivait dans les années 70, les marchés dérivés représentaient un volume d'échange beaucoup plus faible qu'aujourd'hui. Selon Black, la plupart des risques étaient transférés par l'intermédiaire des entreprises[2] et les stocks stabilisaient les marchés. Néanmoins, depuis les années 80, qui ont vu émerger les politiques de libéralisation financière et l'automatisation des marchés, le marché des produits dérivés s'est considérablement développé. En 2000, le Commodity and Futures Modernization Act (CFMA) a initié la libéralisation des produits dérivés, entraînant une croissance exponentielle du volume des échanges. Le volume des dérivés négociés en bourse est environ trente fois plus élevé que la production physique de métaux (Domanski and Heath, 2007). En 2003, le volume des positions ouvertes (qui est le nombre total de contrats à terme en cours) sur les contrats à terme du pétrole brut WTI était égal à la demande mondiale de pétrole. En 2008, le premier est devenu quatre fois plus élevé que le second (Hache and Lantz, 2013). De plus en plus de transactions sur les marchés des dérivés de matières premières proviennent des institutions financières. Le marché à terme est donc exposé à des chocs financiers non liés au marché physique. Or Black (1976) souligne que les prix à terme guident les décisions des agents économiques, y compris le stockage. Se crée alors une relation circulaire entre le prix au comptant et le prix à terme où interagissent acteurs physiques et financiers.

Les institutions financières diversifient leur portefeuille en prenant des positions sur le marché à terme des matières premières. Elles en deviennent des acteurs majeurs : ainsi, la part des fonds de pension dans les positions ouvertes de contrats à terme sur l'énergie est

[1] Un contrat synallagmatique en Droit est une convention par laquelle les parties s'obligent réciproquement l'une envers l'autre.

[2] Le risque représenté par les actifs d'une entreprise repose sur les détenteurs de son passif, notamment les actionnaires.

passée de 10% à 35% entre 2000 et 2008 (Buyuksahin and Robe, 2011). Isleimeyyeh (2017) montre qu'il y a eu une rupture dans la composition du volume des positions ouvertes sur les contrats à terme de matières premières vers 2002. Avant cette année, le pourcentage de positions ouvertes des commerciaux est plus élevé que celui des non commerciaux[3]. Après 2002, la part des positions non commerciales a grimpé en flèche. Les contrats à terme de matières premières deviennent alors une catégorie d'actifs dont le marché est dominé par les traders financiers. Ce processus s'appelle la financiarisation. Cheng and Xiong (2014) soulignent que "*pour comprendre l'impact de la financiarisation sur les prix des matières premières, il faut se concentrer sur la façon dont elle affecte les mécanismes économiques des marchés de matières premières.*" Ce programme de recherche établi par Cheng and Xiong (2014) comprend plusieurs axes. D'abord, les auteurs recommandent de modéliser directement les motifs de partage des risques plutôt que de classer les acteurs selon des rôles prédéfinis comme spéculateur ou industriel en demande de couverture. Ensuite, ils suggèrent de prendre en compte le rôle et la circulation de l'information pour comprendre l'évolution des prix des matières premières. Selon eux, il est important de comprendre le rôle de ces deux facteurs dans le fonctionnement des marchés de matières premières qui sont un élément indispensable de l'économie mondiale. L'idée est d'étudier les effets réels du marché à terme. Pour cette raison, tous les travaux inclus dans ma thèse relâchent l'hypothèse de Black d'un impact nul du marché à terme sur le marché au comptant.

Ces axes de recherche développés précédemment par Cheng and Xiong (2014) sont d'actualité. Le commerce des matières premières est au cœur de l'économie de marché. Une matière première[4] est vaguement définie comme "*un produit qui est largement reconnu et qui se négocie sur des marchés dont les prix sont basés sur des produits homogènes*" (Gordon et al., 1999). Aucune différenciation de qualité n'est possible, de sorte que chaque opérateur sur un marché de matières premières vend des produits standardisés similaires. La standardisation de la qualité est appliquée par les spécifications des contrats à terme (Lautier, 2013). Ironiquement, les marchés des matières premières peuvent être considérés comme le paroxysme de ce que Marx (1875) appelle le "*fétichisme de la marchandise*", où les relations sociales sont intermédiées par les objets, les matières premières et l'argent, dans les échanges commerciaux. Néanmoins, les impacts sociaux des marchés des matières premières sont réels même s'ils ne sont pas visibles par les traders de matières premières. "*À un niveau plus profond, les épisodes de volatilité*

[3]Dans la classification de la CFTC, les opérateurs commerciaux sont parties prenantes sur le marché physique. Les non-commerciaux regroupent les opérateurs actifs uniquement sur le marché à terme.

[4]Certains préféreront peut-être le mot de marchandise qui traduit commodity plus fidèlement mais le terme de matière première est conservé car c'est le mot le plus usité en Français.

soutenue génèrent beaucoup d'incertitude. Ils engendrent des risques accrus dans les activités productives et compromettent la sécurité alimentaire et la croissance économique dans les pays en développement" (Prakash, 2011). Les prix élevés des matières premières sont associés à une plus grande volatilité (Deaton and Laroque, 1992). Cette dernière est décroissante par rapport au niveau de stockage, qui joue le rôle de tampon. De plus, les stocks augmentent l'offre, ce qui fait baisser le prix au comptant. Plus la maturité du contrat à terme est grande, moins le prix est sensible aux nouvelles concernant les perturbations du marché au comptant (Samuelson, 1965). Ce phénomène s'appelle "*l'effet Samuelson*".

Une modélisation systématique capable d'expliquer comment les prix et les quantités varient nécessite un cadre théorique où les prix à terme et les prix au comptant sont tous les deux endogènes. Le modèle théorique sous-jacent de cette thèse est tiré de Ekeland et al. (2018).

Cadre conceptuel : La boucle terme-comptant

Comprendre le fonctionnement de la financiarisation nécessite une modélisation à la fois économique et financière. Chaque chapitre se concentre sur la boucle entre le marché à terme et le marché au comptant. La première tâche consiste à démêler les motivations économiques et financières. Pour résoudre ce problème, j'utilise le cadre théorique de Ekeland et al. (2018). Ce modèle montre comment la spéculation et la couverture interagissent grâce aux rétroactions réciproques entre les prix à terme et au comptant. Les deux sont endogènes. Il s'agit d'un modèle à deux périodes avec un marché au comptant et un marché à terme. Sur le marché au comptant, il y a des traders au comptant et des industriels en demande de couverture. Dans ce modèle, la couverture comprend les stockeurs qui sont naturellement courts et les transformateurs qui sont naturellement longs. Le stockage s'effectue de la première à la deuxième période. Les transformateurs achètent des intrants pour leur production au cours de la deuxième période, mais ils peuvent décider de les couvrir au cours de la première période. Ainsi, la pression à la couverture, qui est la différence nette entre les positions courtes et longues de couverture, peut être courte ou longue. L'un des principaux résultats de ce modèle est que la financiarisation profite aux opérateurs dans le sens de la pression à la couverture.

Le modèle d'équilibre de Ekeland et al. (2018) est une économie de production où il y a une rétroaction entre les prix au comptant et à terme, qui sont tous deux endogènes. Une économie de production est un équilibre intertemporel où les agents peuvent transférer un

bien d'une période à l'autre[5]. Par conséquent, l'anticipation du prix au comptant à l'échéance est également endogène. Ekeland et al. (2018) montrent qu'un poids croissant de spéculateurs diminue le profit de la spéculation en raison de la concurrence accrue entre eux. Les opérateurs dans le sens de la pression à la couverture s'en portent mieux parce qu'ils paient moins cher pour le service de transfert des risques. La prime de risque rend la couverture moins coûteuse pour les industriels en demande de couverture dominants. La demande de ces derniers pour le transfert de risque augmente. Le bien-être des spéculateurs et des industriels en demande de couverture dominés diminue, tandis que les industriels en demande de couverture dominants en sortent gagnants. Dans le modèle de Ekeland et al. (2018), il y a une matière première, un numéraire et deux marchés :
le marché au comptant aux moments t = 1 et t = 2 et un marché à terme sur lequel les contrats sont négociés en t = 1 et réglés en t = 2. Le modèle permet des positions courtes sur le marché à terme. Lorsqu'un agent vend (ou achète) des contrats à terme, sa position est courte (ou longue) et le montant des contrats à terme qu'il détient est négatif (ou positif). Sur le marché au comptant, les positions courtes ne sont pas autorisées. Les stocks sont positifs. En d'autres termes, le marché à terme est financier, tandis que le marché au comptant est physique. Il existe trois types d'opérateurs qui prennent des décisions intertemporelles :

- Les *stockeurs ou détenteurs de stock (I)* qui ont une capacité de stockage et peuvent utiliser cette capacité pour acheter le produit en t = 1 et le vendre en t = 2. Ils négocient sur le marché au comptant en t = 1 et en t = 2. Les stockeurs opèrent également sur le marché à terme. Ils peuvent ainsi couvrir la vente de leurs stocks en seconde période lors de la première période sur le marché à terme. Ils sont naturellement longs sur le marché au comptant.

- Les *Transformateurs (P)*, ou utilisateurs industriels, utilisent le produit pour produire d'autres biens qu'ils vendent aux consommateurs. En raison de l'inertie de leur processus de production et parce que toute leur production est vendue à terme, ils décident en t = 1 de la quantité à produire en t = 2. Comme ils ne peuvent pas stocker la matière première, ils doivent acheter tous leurs intrants sur le marché au comptant en t = 2. Ils se négocient également sur le marché à terme. Ils peuvent ainsi couvrir l'achat de leurs intrants pour la deuxième période sur le marché à terme au cours de la première période. Ils s'engagent naturellement à acheter sur le marché au comptant.

[5]Le transfert peut s'accompagner d'un rendement positif ou nul. Le dernier cas correspond au stockage.

- Les *spéculateurs (S)*, ou gestionnaires de fonds, utilisent le prix des matières premières comme source de risque pour tirer profit de leurs positions sur les contrats à terme. Ils ne négocient pas sur le marché au comptant. Les spéculateurs supportent le risque des opérateurs en couverture. Ils s'attendent à une rémunération appelée prime de risque.

Chacun des groupes décrits ci-dessus a un poids $(N_j)_{j \in \{I,P,S\}}$. Chaque agent (à l'exception des traders au comptant) est supposé être un maximiser son utilité intertemporelle averse au risque. Ils prennent leurs décisions en t = 1 selon leurs anticipations pour t = 2. Les traders au comptant ne participent pas au marché à terme. Pour les petites entreprises comme les exploitations agricoles, l'apprentissage de la négociation des contrats à terme et des coûts de transaction peut être un facteur dissuasif important pour négocier des contrats à terme (Hirshleifer, 1988). Ainsi, certains opérateurs sur le marché au comptant renoncent à participer au marché à terme.

En outre, les marchés à terme et au comptant fonctionnent dans une sorte de cadre d'équilibre partiel : en arrière-plan, il y a d'autres vendeurs de la matière première, ainsi que les transformateurs. Ces agents supplémentaires sont appelés traders au comptant, et une fonction de demande décrit leur effet global. J'utilise la notation $\sim$ pour les valeurs réalisées des variables aléatoires de la période 2. Tous les opérateurs prennent leurs décisions au moment t = 1, sous réserve des informations disponibles pour t = 2. Le calendrier est le suivant :

- En t = 1, les marchés au comptant et à terme sont ouverts. Les traders au comptant fournissent ω_1 et demandent $\mu_1 - mP_1$. Le prix au comptant est P_1, le prix à terme est F et m est l'élasticité de la demande au comptant.

- En t = 2, le marché au comptant est ouvert et les contrats à terme sont réglés. Les traders au comptant fournissent $\tilde{\omega}_2$ et demandent $\tilde{\mu}_2 - mP_2$. Le prix au comptant est de P_2. Les contrats à terme standardisés sont ensuite réglés. Je suppose qu'il y a une convergence parfaite de la base[6] à l'expiration du contrat à terme. Ainsi, à l'instant t = 2, la position sur le marché à terme est réglée au prix de P_2 qui prévaut sur le marché au comptant.

Ce cadre théorique repose sur des besoins de couverture hétérogènes. Le résultat de cette dernière est une pression à la couverture, ce qui permet le trading. Sinon, il n'y aurait aucun risque de transfert. Il n'y aurait pas d'échanges commerciaux. Comme Kenneth Arrow le

[6]La base est la différence entre le prix à terme et le prix au comptant.

dit, l'hétérogénéité est ce qui engendre les échanges (Colander et al., 2004). Il ajoute que l'hétérogénéité dépend de la façon dont l'information est partagée par les agents. C'est ce qui rend la modélisation difficile.

La littérature sur le marché des actions souligne l'hétérogénéité des croyances des traders (Scheinkman and Xiong, 2004). Ce dernier phénomène est à l'origine de désaccords, ce qui génère un volume d'échanges supplémentaire et une hausse des prix des actifs ainsi qu'une volatilité accrue parce que les agents n'évaluent pas de la même façon le prix des actifs. Avec la financiarisation, de plus en plus de spéculateurs sont actifs sur les marchés à terme de matières premières.

La question de recherche de cette thèse de doctorat porte sur les conséquences de l'hétérogénéité des opinions des traders engagés dans des activités spéculatives sur le marché à terme, sur le marché physique. Ces croyances et informations hétérogènes influencent les prix. Ces dernières modifient également les anticipations, ce qui engendre une rétroaction. Cette circularité se situe en haut de la boucle au comptant-futures du cadre théorique de cette thèse. Le problème est difficile à résoudre, tant d'un point de vue économique que d'un point de vue mathématique. Les équations deviennent rapidement insolubles, et il y a beaucoup de mécanismes économiques à démêler.

Le chapitre 1 examine le rôle informationnel des prix des matières premières. Les opérateurs financiers apportent des informations complémentaires. De plus, les autorités fournissent des prévisions publiques pour ancrer les anticipations dans les fondamentaux. En 2011, le G20 a créé le Système d'information sur les marchés agricoles (AMIS) pour améliorer l'information mise à la disposition des acteurs du marché. La question est de savoir comment l'information s'agrège pour donner un prix plus informatif, et si une valeur informative croissante améliore le fonctionnement du marché.

Deuxièmement, cette thèse étudie aussi l'hétérogénéité des croyances. Des croyances faisant l'objet d'une confiance excessive peuvent même engendrer des bulles (Scheinkman and Xiong, 2003). Sur les marchés de matières premières, le trading technique suscite l'intérêt de la littérature (Joëts, 2015; ter Ellen and Zwinkels, 2010). Les traders techniques sont pour la plupart des adeptes du trading systématique. Cette méthodes consiste à suivre des règles mécaniques qui s'appuient sur l'évolution des prix passés. A partir de ces derniers, ils tentent d'extrapoler une tendance qu'ils suivent. Leurs croyances sont des prophéties auto-réalisatrices. S'ils croient que le prix augmentera, ils achètent tous, ce qui peut faire augmenter le prix. Un phénomène de bulle est donc possible. Selon la base de données BarclaysHedge, les actifs sous gestion des traders systématiques sont passés de 22,9 milliards de dollars 1999 à 316,4 milliards de dollars 2013. Au premier semestre de 2019, le volume des actifs sous gestion s'élève à 303 milliards de dollars. Le chapitre 2 estime l'impact des tendances sur le gaz naturel américain. Ce travail empirique examine les preuves de l'impact des traders techniques sur les prix à terme ainsi que sur le marché au comptant par le biais de l'estimation de la rétroaction du prix à terme sur le prix au comptant. Le chapitre 3 élargit cette question avec un modèle théorique pour comprendre l'impact potentiellement déstabilisant des traders techniques sur le marché physique.

Agrégation d'informations hétérogènes

Définir l'information

L'information et les croyances sont les deux ingrédients qui font l'opinion des êtres humains. La définition suivante de l'information s'inspire de Quéré (2000). L'information a besoin d'un support. Le plus courant dans la modélisation économique est le signal, qui est un message contenant une information. L'information a une signification donnée par contrainte qui établit une relation de cause à effet. Par exemple, l'annonce d'une récolte plus abondante sur un marché de cultures implique un choc d'offre positif qui fait baisser les prix. Cet exemple montre également qu'un fait ne donne pas d'informations sur lui-même mais sur un autre fait. Ici, le volume de la récolte donne des informations sur le prix de la récolte. L'information peut porter sur des événements éloignés dans l'espace et dans le temps. En un mot, l'information est une donnée traitée. Par-dessus tout, l'information affecte le comportement (Quéré, 2000). Les signaux aident les agents à prendre des décisions économiques. Ils peuvent être privés, connus seulement par un groupe limité de personnes. Au contraire, ils peuvent être publics, ce qui signifie qu'ils sont de notoriété publique. Le signal public le plus connu est le prix. Hayek (1945) a décrit le premier cette intuition. Le prix véhicule des informations. Elles ont des implications pour les agents économiques en raison de leur connaissance locale de l'économie. Par exemple, un agent immobilier sait comment fonctionne son marché. Par conséquent, les prix diffusent l'information et aident les agents économiques à s'adapter les uns aux autres. L'approche de Hayek ne repose pas sur les anticipations rationnelles et est compatible avec une rationalité limitée. Chaque agent suit une heuristique et transmet des informations à travers les échanges selon Hayek (1945). La vision de Hayek est différente de la modélisation des anticipations rationnelles et se rapproche de la théorie de l'action sociale de sociologues comme

Parsons et Luhmann ou de la modélisation basée sur les agents qui suppose la rationalité du système entier plutôt que la rationalité des individus (Boldyrev, 2013). Au contraire, cette thèse suit la méthode habituelle des anticipations rationnelles utilisées en économie. Les agents sont supposés être cohérents en maximisant leur utilité ou leur profit avec toute l'information disponible. Ce comportement est appelé "rationnel". Par conséquent, l'anticipation rationnelle d'une variable est non biaisée et constitue la meilleure estimation. Les agents ont les mêmes a priori qui viennent de la connaissance du fonctionnement de l'économie. Selon le théorème de l'accord d'Aumann, les agents ayant les mêmes a priori et qui obtiennent les mêmes informations, ne peuvent accepter d'être en désaccord (Aumann, 1976). Les prix sont fonction de l'information diffusée parmi les opérateurs parce qu'ils commercent en tenant compte de ce qu'ils savent. Ainsi, les prix sont fonction des signaux des agents. Les agents rationnels connaissent le processus d'établissement des prix de sorte qu'ils peuvent utiliser les prix pour distinguer les différents signaux aboutissant à ces prix. Grossman (1977) montre comment, dans un équilibre avec un marché à terme, les traders peuvent utiliser le prix au comptant et le prix à terme pour obtenir l'exhaustivité de l'information diffusée dans l'économie. Dans cette situation, toute l'information est transférée des agents informés aux agents non informés. Ils ont donc les mêmes anticipations (Aumann, 1976). L'équilibre des anticipations rationnelles (REE) reflète l'idée que se fait Hayek de l'agrégation de l'information par les prix. Un REE est un ensemble de quantités et de prix qui remplit les conditions de régularisation du marché sans que les agents n'aient le désir de conclure un nouveau contrat (Grossman, 1981). Néanmoins, le raisonnement est différent. Hayek (1945) soutient que les prix transmettent des informations aux agents qui sont connectés mais qui ont une connaissance partielle du fonctionnement de l'économie. A l'opposée, les agents rationnels ont une connaissance complète du processus de fixation des prix. Dans ce cas, la divulgation complète des prix équivaut à la diffusion de toutes les informations dans l'économie (Grossman, 1981). Le cadre théorique du REE semble moins réaliste avec des agents rationnels représentatifs, mais ce modèle présente l'avantage de la maniabilité. Je choisis ce type de modélisation pour étudier l'information sur les prix des matières premières, c'est-à-dire le contenu informatif des prix.

Chapitre un : l'impact de l'information sur les prix des marchés à terme

Le chapitre examine comment plus d'information affecte la demande nette des industriels en demande de couverture sur le marché au comptant et l'activité de prise de risque des agents spéculateurs. Le but est notamment d'étudier les conséquences de la redistribution du partage des risques sur le bien-être des opérateurs. L'approche du chapitre est théorique en appliquant la théorie bayésienne à un modèle d'équilibre. J'introduis de l'information dans le modèle de Ekeland et al. (2018). Chaque groupe d'agents, qu'ils soient spéculateurs, stockeurs ou transformateurs, est doté d'un signal commun sur la demande nette à l'échéance. Dans ce cadre théorique, un marché efficient est défini comme un équilibre des anticipations rationnelles pleinement révélateur (FRREE) des signaux (Grossman, 1977). Connaître le prix équivaut à connaître toutes les informations privées. Un FRREE unique existe si la pression à la couverture est linéaire. Deux théorèmes de Grossman (1978) et Bray (1981) sont étendus avec une pression à la couverture linéaire pour prouver l'existence et le caractère unique de l'équilibre. Je montre que le FRREE implique que le prix à terme est le seul prédicteur du prix au comptant. C'est une statistique exhaustive. Cela signifie qu'elle contient tout ce dont les agents ont besoin de savoir. Dans un marché efficient, le prix à terme est un estimateur biaisé mais efficace du prix au comptant à l'échéance du contrat. Le biais est le gain attendu de la spéculation, qui est la différence entre le prix au comptant attendu à l'échéance et le prix à terme. Le biais du prix à terme est appelé prime de risque. Cette valeur est aussi le revenu demandé par les opérateurs spéculateurs comme contrepartie du partage des risques.

Je distingue les informations privées des informations publiques. L'information privée est un contenu qui n'est connu que d'une partie de la population des opérateurs. Dans le modèle de ce chapitre, chaque groupe (spéculateurs, stockeurs et transformateurs) est doté d'un signal commun à chacun de ses membres. Un signal qui n'est connu que d'un groupe spécifique est donc considéré comme privé. A la période t = 1, les opérateurs reçoivent un signal $(s_j)_{j\in\{I,P,S\}}$ commun au groupe auquel ils appartiennent. Ce signal est non biaisé tel que :

$$\forall\, j \in \{I, P, S\},\ s_j = \tilde{\xi}_2 + \varepsilon_j \quad \text{avec } \varepsilon_j \sim N(0, \sigma_j^2) \tag{3.48}$$

La production de la matière première est inélastique: ω_1 et $\tilde{\omega}_2$ qui arrivent sur le marché au comptant aux moments t = 1 et t = 2 sont exogènes au modèle. Les opérateurs connaissent ω_1 et μ_1, et partagent le même a priori concernant $\tilde{\omega}_2$ et $\tilde{\mu}_2$. Les opérateurs qui prennent des décisions intertemporelles (stockeurs, transformateurs et spéculateurs) mettent à jour leur décision en fonction des informations publiques et privées mises à leur disposition. Cet ensemble d'informations comprend le signal reçu par l'opérateur en fonction de son groupe et l'information publique au temps t = 1. Je définis l'information publique comme le contenu connu de l'ensemble de la population des opérateurs. Chaque opérateur du marché connaît les prix. Ces derniers sont des variables endogènes qui sont le résultat d'équations d'équilibre. Les prix sont le résultat des positions des agents sur la base de leurs informations. Ainsi, les opérateurs peuvent déduire les informations privées des autres agents à partir des prix. Par conséquent, nous pouvons écrire l'ensemble d'informations ($(\mathcal{F}_j)_{j\in\{I,P,S\}}$) tel que :

$$\forall\, j \in \{I, P, S\},\ \mathcal{F}_j = (s_j, F, P_1) \tag{3.49}$$

Tout d'abord, je montre comment l'information peut modifier la relation structurelle entre le prix au comptant à l'échéance (P_2) et le prix à terme (F). Mathématiquement, cette dernière est représentée par une équation linéaire telle que $P_2 = \alpha + \beta\, F + \varepsilon$ qui décrit une régression. α et β sont des coefficients tandis que ε est un terme d'erreur. Le biais du prix à terme, qui est la prime de risque conditionnelle ($E[P_2|F] - F$), varie directement en fonction du prix à terme et indirectement lorsque le régime d'équilibre change. Les coefficients de la relation de régression (α et β) varient selon la base et l'écart entre le prix à terme et le prix du produit final. La prime de risque conditionnelle et la prime de risque inconditionnelle ($E[P_2 - F]$) peuvent être structurellement différentes. Leurs équations peuvent être écrites comme telles :

$$E[P_2|F] - F = \alpha + (\beta - 1)F \tag{3.50}$$

$$E[P_2 - F] = E[\alpha] + E[\beta\, F] - E[F] \tag{3.51}$$

Même si $F = E[F]$, les coefficients peuvent différer. Par conséquent, l'estimation des coefficients de la prime de risque inconditionnelle pour calculer la prime de risque peut être trompeuse. En outre, dans la pratique, l'écart avec le prix à la production n'est pas toujours connu. L'estimation de la prime de risque conditionnelle est donc plus difficile. L'analyse de la spéculation par Ekeland et al. (2018) est toujours valable. La liquidité augmente, de sorte que la prime de risque diminue. Ce résultat est cohérent avec Chinn and Coibion (2014) qui montrent que la hausse de la liquidité n'améliore pas l'efficacité du prix à terme en tant qu'estimateur du prix au comptant à l'échéance.

Deuxièmement, des prix plus informatifs augmentent l'élasticité de la pression à la couverture à la prime de risque, exactement comme lorsque le poids des spéculateurs augmente. Les deux intensifient la concurrence entre les agents spéculateurs, de sorte que le gain d'une position spéculative (ou prime de risque) diminue. La prise de risque est moins coûteuse et la valeur absolue de la pression à la couverture augmente.

Enfin, j'apporte un nouvel éclairage sur les conditions dans lesquelles l'information plus précise est nuisible pour tout agent. Dans cette situation, tout le monde est perdant à cause d'un gain décroissant provenant de la spéculation. Ce dernier effet est connu sous le nom "*d'effet Hirshleifer*". Une information plus précise diminue le montant du risque transféré sur le marché à terme pour un montant donné de positions de couverture. Cette dernière devient moins risquée. La prime de risque gagnée par les spéculateurs diminue. Par conséquent, une meilleure information peut être préjudiciable à tous les agents en détruisant les opportunités de couverture. Les opérateurs sont moins bien lotis parce qu'ils s'attendent à un profit moindre. La divulgation publique de l'information ajoute un risque distributif qui réduit le bien-être global. Hirshleifer (1971) montre que l'information n'a aucune valeur sociale dans une économie d'échange pure. Par conséquent, les agents dans une économie d'échange pure avec des dotations aléatoires peuvent en pâtir. Une meilleure information diminue la quantité de risques à partager. Il y a donc moins de transactions sur le marché du partage des risques. Ce phénomène se produit sur les marchés financiers (Goldstein and Yang, 2017). Si les agents échangent moins de biens entre eux, cela signifie qu'ils ont plutôt tendance à consommer leurs dotations initiales. Ainsi, la nouvelle répartition des risques devient Pareto inférieure à celle sans information. Schlee (2001) montre qu'une condition suffisante (pour que la meilleure information soit inférieure à Pareto dans une économie de change pure) est que "*tous les agents ont une aversion au risque et l'économie a un agent représentatif qui satisfait l'hypothèse d'utilité prévue avec une fonction concave différentielle de von Neumann-Morgenstern.*" Dans ce cas, la concavité de la fonction d'utilité dans les croyances fait que les agents n'aiment pas l'information dans une économie d'échange pure. Dans ce chapitre, tous les agents ont une fonction d'utilité constante d'aversion au risque absolue (CARA) qui satisfait au critère d'agent représentatif. Cela implique que les prix d'équilibre reflètent une sorte de moyenne des aversions au risque et des variances conditionnelles de chaque agent en fonction de leurs informations et préférences (Lintner, 1969). Néanmoins, l'équilibre du modèle n'est pas une économie de dotation. Les stockeurs peuvent transférer une quantité de matières premières d'une période à une autre. Mon modèle est une économie de production parce que les stockeurs peuvent transférer une unité de la première à la dernière période. Une meilleure information peut aider les producteurs à prendre de meilleures décisions concernant leur niveau de production (Eckwert and Zilcha, 2001). J'obtiens deux effets contraires : la diminution de l'activité à risques partagés qui nuit aux opérateurs alors que l'amélioration des décisions de production peut améliorer le bien-être. Par conséquent, l'information peut augmenter ou diminuer le bien-être des agents. Avant la publication des signaux, les traders ne savent pas dans quelle direction les prix vont évoluer. Lorsque la pression à la couverture est déjà très élastique, l'augmentation du montant couvert est trop faible pour compenser toute perte causée par une prime de risque moindre. Ainsi, un effet Hirshleifer se produit. Le bien-être de tout le monde diminue.

Une extension intéressante serait d'introduire le bruit généré par le portefeuille d'actions des spéculateurs. Il en résulterait un équilibre partiellement révélateur des anticipations rationnelles (PRREE). Cette propriété permettrait d'étudier de façon plus réaliste l'effet de signaux supplémentaires. La conséquence du théorème de l'accord d'Aumann est que les agents ne peuvent pas être en désaccord dans un REE s'ils ont les mêmes informations. Si cette dernière n'est pas pleinement révélée, les agents ont des anticipations différentes. Néanmoins, ils s'entendent toujours sur le modèle sous-jacent de l'économie. Il n'y a pas de place pour les traders techniques (aussi appelés "chartistes") qui suivent les tendances ou la dynamique. Le développement des plates-formes commerciales électroniques et de la technologie informatique dans les années 1980 a entraîné l'arrivée massive des systèmes commerciaux techniques guidés par ordinateur (Lukac et al., 1988). Le problème est que ce "noise trading" peut se développer avec une plus grande liquidité qui pourrait perturber les marchés en générant une volatilité excessive (Lautier, 2013). L'influence déstabilisatrice du commerce technique automatique a fait l'objet d'un débat controversé lors d'une audition au sénat américain dans les années 1980 (Bradford and Galbraith, 1984; Brorsen and Irwin, 1987). Il y a un "*Effet Clochette*" de ces stratégies. Leurs effets existent parce que les traders croient en leur existence. Si les traders achètent lorsque le prix est à la hausse, le prix sera maintenu à la hausse et vice-versa. Les stratégies de suivi des tendances contribuent à la volatilité et peuvent générer des schémas de bulles. De Long et al. (1990) montrent que pour les actions, le prix peut varier quelle que soit la valeur fondamentale de l'actif. La prophétie auto-réalisatrice est activée pour qu'une *"spéculation déstabilisatrice rationnelle"* puisse se produire. Tokic (2011) suggère une généralisation pour les marchés à terme. Les spéculateurs rationnels qui prennent des positions importantes génèrent une variation considérable des prix. Si les adeptes de la tendance sont actifs sur le marché, ils exacerbent la tendance, ce qui accroît la volatilité. De plus, les contrariens sont contraints d'abandonner en raison d'appels de marge trop coûteux. Il y a un effet potentiellement déstabilisant des différentes croyances si certaines d'entre elles peuvent générer des tendances en raison d'impulsions diverses de la part d'un petit groupe de traders.

Prix des actifs avec des croyances hétérogènes : un facteur de déstabilisation rationnelle ?

Définir ce qu'est une croyance

Les psychologues McGuire and McGuire (1991) suggèrent que les gens font face aux situations qu'ils rencontrent dans la vie quotidienne en essayant d'expliquer les événements passés et de prévoir leur occurrence dans le futur (Wyer and Albarracín, 2005). L'une de ces stratégies d'adaptation est celle de la maximisation de l'utilité. "*La pensée de la personne au sujet de la désirabilité d'un événement central (souvent appelée son attitude) est son jugement évaluatif du caractère souhaitable de la survenue de l'événement*" (McGuire and McGuire, 1991). Les auteurs ajoutent que ce principe peut être résumé dans la maxime biblique " *C'est à leurs fruits que vous les reconnaîtrez*". (Matt 7:16). L'économie n'a gardé que cette stratégie de maximisation de l'utilité pour étudier les comportements. Cette méthodologie a un sens à la lumière de la définition de l'économie donnée par Robbins (1932) : "*L'économie est la science qui étudie le comportement humain en tant que relation entre les fins et les moyens limités qui ont des utilisations alternatives.*" Les agents économiques ne s'intéressent qu'à l'opportunité des résultats de leurs actions. Leurs croyances sont les probabilités des événements qui affectent les résultats de leurs décisions. L'opérateur de probabilité est $P(\cdot)$. Par exemple, les spéculateurs sur le blé tiennent compte de la prévision de la prochaine récolte car elle détermine l'offre et donc le prix au comptant à maturité. Ce dernier est le gain d'une position acheteur sur contrats à terme. Un agent rationnel, doté d'un élément d'information I sur un événement E, met à jour sa croyance antérieure sur l'occurrence de l'événement ($P(E)$) pour adopter une nouvelle croyance informée ($P(E|I)$). La règle de Bayes décrit ce processus de mise à jour :

$$P(E|I) = \frac{P(I|E)P(E)}{P(I)}P(I) \tag{3.52}$$

$P(I|E)$ est la probabilité de l'information. Plus la probabilité est élevée, plus l'événement est probable. La probabilité augmente la croyance de l'occurrence de l'événement E. Au contraire, plus la probabilité d'obtenir cette information est élevée, moins on lui accorde de poids.

L'information précieuse est plausible et rare. Vives (2010, p. 79) explique que les anticipations rationnelles sont des anticipations d'équilibre. Il y a un effet de rétroaction des actions des agents rationnels sur les croyances de leurs pairs. L'équilibre est le point fixe d'une application reliant croyance et croyances optimales. Ainsi, les anticipations rationnelles utilisent l'information de façon optimale.

Dans un REE, les opérateurs ont les mêmes croyances préalables. Selon le théorème d'accord d'Aumann, un PRREE implique des croyances postérieures différentes. Ce cadre théorique a été fructueux pour étudier le phénomène de "*concours de beauté*" (Goldstein and Yang, 2017). Keynes (1936) décrit le marché boursier avec une analogie basée sur un concours de magazine fictif. Les gagnants sont ceux qui choisissent les photos de visages les plus populaires parmi tous les participants. Le joueur n'a pas à choisir les meilleurs visages en fonction de ses goûts. Il doit deviner ce que les autres choisiraient. Cette logique peut être poussée un degré plus loin. Il s'agit de deviner le raisonnement qui conduit les autres à penser quels seraient les visages les plus populaires. Il est même possible d'ajouter encore des degrés supplémentaires. Les marchés financiers fonctionnent de la même manière que le concours de beauté de Keynes parce que le trader, qui devine l'opinion du marché avant tout le monde, peut faire le bon choix. Sur le marché des actions, la question du concours de beauté sur les décisions des entreprises est soulevée après la bulle Internet en 2000 (Hirshleifer et al., 2006). Goldstein et al. (2013) montrent que les frénésies boursières peuvent se produire lorsqu'il y a un effet de rétroaction du cours de l'action sur l'investissement réel de l'entreprise. Les spéculateurs sont incités à se précipiter dans la même direction parce qu'un cours boursier plus élevé augmente l'investissement, ce qui augmente la valeur de l'entreprise.

L'autre intuition de Keynes (1936) sur les croyances du marché financier était ce qu'il appelle les "*esprits animaux*". Ce terme fait référence aux émotions et au sentiment d'excès de confiance qui peuvent animer les comportements humains. Hirshleifer et al. (2006) montrent que la présence d'investisseurs irrationnels affecte les cours des actions et les investissements des entreprises lorsqu'il y a un effet de rétroaction des cours des actions sur les flux de trésorerie. Ces traders, qui ont des croyances sans fondement, peuvent même engendrer des profits qui peuvent être plus importants que ceux des traders rationnels. Ainsi, ils en déduisent que les "esprits animaux" peuvent avoir des effets financiers et réels durables. Les traders irrationnels génèrent des fluctuations des fondamentaux même lorsque les marchés sont efficaces sur le plan de l'information et que les prix suivent une marche aléatoire. Les dynamiques auto-réalisatrices n'affectent pas seulement le prix du marché, mais aussi la valeur sous-jacente elle-même. C'est cette question que je veux aborder dans les chapitres suivants.

Chapitre deux : Les suiveurs de tendances sur le marché américain du gaz naturel

Tokic (2011) souligne que 90% des commodity trading advisors (CTA) enregistrés dans IASG.com utilisent uniquement les analyses technique et quantitative dans leurs approches de trading. Les CTA fournissent des conseils personnalisés aux clients qui souhaitent prendre position sur des contrats à terme ou des options sur matières premières. Ils peuvent être embauchés par un gestionnaire de fonds commun de matières premières pour prendre des décisions de placement. Les deux sont réglementés par la National Futures Association (NFA) et la Commodity Futures Trading Commission (CFTC). Le secteur de la gestion active des contrats à terme est devenu un acteur majeur sur les marchés à terme de matières premières. Entre 2007 et 2015, les opérateurs financiers ont représenté environ 60% du total des positions ouvertes (voir chapitre 2) sur le marché américain du gaz naturel. Le groupe le plus important est celui des gestionnaires de portefeuille qui compte pour la moitié du total des positions ouvertes. Le marché américain du gaz naturel est très déréglementé et il y a une présence massive de spéculateurs utilisant des méthodes de trading technique. Par conséquent, il est intéressant d'étudier l'impact des opérateurs, ayant des croyances différentes sur les tendances du marché, sur le prix du gaz naturel aux États-Unis.

Cet article suit l'approche de la prime de risque, qui évalue les différentes forces sous-jacentes qui contribuent à la tarification du gaz naturel aux États-Unis. De plus, j'examine les réactions du prix à terme au prix au comptant du marché américain du gaz naturel. Une première façon intuitive d'examiner les prix est d'étudier les principes fondamentaux. Il existe une abondante littérature sur la prime de risque, qui est le gain des spéculateurs pour supporter le risque global des couvreurs, qui est la pression à la couverture. Cette théorie de la pression à la couverture a quatre implications (Gorton and Rouwenhorst, 2004) :

1. Le gain attendu d'une position à terme est la prime de risque. Le gain réalisé est la prime de risque plus tout écart inattendu du prix au comptant futur par rapport au prix au comptant futur attendu.

2. On s'attend à ce qu'une position longue sur contrats à terme obtienne des rendements positifs (excédentaires) tant que le prix à terme est fixé au-dessous du prix au comptant futur prévu.

3. Si le prix à terme est fixé en dessous du prix au comptant futur attendu, les prix à terme auront tendance à augmenter avec le temps, offrant ainsi un rendement aux investisseurs dans le futur.
4. Les tendances prévues des prix au comptant ne peuvent pas être une source de rendement espéré pour un investisseur.

Dans ce cadre théorique, les spéculateurs prennent le contre-pied des industriels en demande de couverture. Les spéculateurs ont compensé la demande nette impliquée par la pression à la couverture. Ainsi, le marché s'équilibre. Par conséquent, les spéculateurs apportent de la liquidité selon ce cadre théorique. En effet, si la pression à la couverture est nette à découvert, les spéculateurs ont une position longue pour équilibrer le marché. Au contraire, si la pression à la couverture est longue sur les contrats à terme, les spéculateurs sont courts.

Néanmoins, Gorton et al. (2013) ne trouvent aucune preuve que les positions des participants prévoient des primes de risque sur les contrats à terme sur matières premières. Ils constatent que la pression à la couverture contemporaine est positivement liée aux rendements des contrats à terme. Toutefois, il n'y a pas d'influence significative de la pression à la couverture ex ante sur les rendements à terme. Les positions commerciales deviennent plus courtes alors que les positions non commerciales deviennent plus longues lorsque le prix des contrats à terme augmente. Ainsi, les sociétés non commerciales se comportent comme si elles suivaient une stratégie de momentum. Fishe and Smith (2018); Gorton et al. (2013); Kang et al. (2017); Rouwenhorst and Tang (2012) constatent que les traders non commerciaux suivent les tendances et que les traders commerciaux sont contrariens. L'implication est significative parce que les suiveurs de tendances sont aussi demandeurs de partage des risques, et qu'ils ont donc besoin de contreparties. Il existe donc deux types de primes de risque sur le marché, l'une pour les contreparties et l'autre pour les suiveurs de tendance (Kang et al., 2017). Ce fait change complètement la nature des interactions sur le marché car les traders commerciaux sont la contrepartie d'une demande de partage des risques émanant de spéculateurs qui veulent parier sur les tendances futures. Les rôles sont inversés. Le présent chapitre fait partie de cette littérature confirmant ces constatations. Dans cet article, j'ai mis au point une méthode pour estimer ces deux types de prime de risque en modifiant la régression de Schwarz (2012) pour saisir les stratégies de poursuite de tendance à une fréquence hebdomadaire. Le prix au comptant à l'échéance est également inclus pour saisir la spéculation rationnelle, comme dans Moosa and Al-Loughani (1995).

Les prix des matières premières sont des baromètres de l'économie. Ils transmettent l'information. Une hausse du prix des matières premières pourrait être la conséquence d'une hausse de la demande. Par conséquent, la demande pourrait augmenter parce que les agents anticipent une économie plus forte. Cet effet informationnel peut être suffisamment important pour compenser l'effet de coût. Ainsi, il existe deux cas différents de la valeur de l'élasticité-prix :

1. Le cas classique de la théorie de la pression à la couverture quand il n'y a pas d'influence de l'effet informationnel : la demande au comptant diminue strictement avec le prix. L'effet informationnel ne compense pas l'effet de coût. S'il y a un choc financier à la hausse, l'écart entre le prix à terme et le prix au comptant (appelé la *base*) augmente. L'effet diffère selon que la courbe des prix est en report ou en déport. Lorsque le prix à terme augmente avec l'échéance (report), le niveau de stockage augmente, ce qui constitue un choc de demande positif sur le marché au comptant. Par conséquent, la demande au comptant diminue en raison du prix au comptant plus élevé. Ce dernier effet atténue la hausse du prix au comptant. Le niveau de stockage remplace la demande au comptant. Ainsi, la sensibilité du prix à terme au prix au comptant est inférieure à un. Il y a une sous-rétroaction entre le prix à terme et le prix au comptant. Pour tout choc affectant directement le prix à terme, le prix au comptant variera moins que le prix à terme. La base s'élargit. Le niveau des stocks augmente. Cette dynamique génère un choc d'offre positif à l'échéance. L'écoulement des stocks, à l'expiration des contrats à terme, fait baisser le prix au comptant. Lorsque le prix à terme diminue avec l'échéance (déport), la base reste toujours négative. Le stockage n'augmente pas, mais la hausse du prix des contrats à terme rend la couverture coûteuse pour les industriels en demande de couverture à long terme. Ces derniers réduisent leurs positions de couverture, ce qui se traduira par un choc de demande négatif à l'échéance. Le prix au comptant est également réduit à l'échéance. Néanmoins, les stocks n'ont pas varié.

2. L'effet informationnel compense l'effet coût : la demande au comptant augmente avec le prix. L'effet informationnel compense l'effet de coût. S'il y a un choc financier qui fait monter le prix à terme, la hausse temporaire de la demande des stockeurs poussera le prix au comptant à la hausse. Par conséquent, la demande au comptant augmente en raison du prix au comptant plus élevé, ce qui décourage l'activité de stockage. Le prix au comptant augmente encore plus. Il y a donc une sur-rétroaction du prix à terme au prix au comptant. Pour tout choc affectant directement le prix à terme, le prix au comptant variera plus que le prix à terme. La base diminue. Les stocks s'amenuisent.

C'est la situation décrite par Sockin and Xiong (2015).

Deux objectifs guident ce chapitre. Tout d'abord, j'examine la sensibilité du prix au comptant au prix à terme pour vérifier s'il y a un signe d'un effet informationnel. Deuxièmement, la sensibilité du prix à terme aux valeurs passées est estimée. Dans chaque équation, d'autres variables sont mises comme contrôle.

La régression du prix à terme est directement inspirée de Schwarz (2012) qui se concentre toutefois sur les rendements. La relation de cointégration établie à la sous-section 2.3.3 permet d'estimer des séries chronologiques non différenciées, donc directement en niveaux. J'ajoute un second décalage entre la variable expliquée et le prix au comptant à l'échéance. Cette dernière variable provient de Moosa and Al-Loughani (1995). L'objectif est de mesurer le poids de la spéculation rationnelle, qui prend des positions en fonction du prix au comptant à échéance anticipé. Ce dernier est supposé être non biaisé.

Je teste empiriquement le système suivant :

$$P_t = a_{10} + a_{11} F_{T,t} + a_{12} Q_t + n_t \tag{3.53}$$

$$F_{T,t} = a_{20} + a_{23} \tilde{P}_T + a_{24} F_{t-\Delta t,T} + a_{25} F_{t-\alpha\Delta t,T} + a_{26} \mathrm{HP}_t + a_{27} \Delta \mathrm{HP}_t + v_t \tag{3.54}$$

P_t est le prix du gaz naturel sur le marché physique. $F_{T,t}$ est le prix à terme à échéance constante du gaz naturel. P_T est le prix au comptant du jour de l'échéance du contrat à terme. Q_t est le volume physique de gaz naturel échangé au Henry Hub. HP_t est la pression à la couverture (HP) qui est la différence entre les positions longues et courtes des traders commerciaux. Δ est l'opérateur mathématique de différence. n_t et v_t sont des termes d'erreur. L'étude se penche en particulier sur ces valeurs spécifiques :

- La sensibilité du prix au comptant au prix à terme (a_{11}). S'il est supérieur à un, il y a un effet informationnel qui compense l'effet de coût par une rétroaction excédentaire. La condition Sockin-Xiong serait donc remplie. La condition empirique d'un effet informationnel est l'équation (16).

- La sensibilité du prix à terme à sa valeur la semaine dernière (a_{24}) et la semaine précédente (a_{25} avec $\alpha = 2$). Δt est une variation d'une semaine. Un coefficient positif est cohérent avec l'existence de stratégies de suivi de tendance et de couverture courte. Je teste deux hypothèses alternatives pour les positions des suiveurs de tendance. La première est basée sur la différence entre le prix à terme de la semaine dernière et le prix de la semaine précédente, ou profit hebdomadaire (De Long et al., 1990). a_{24} et a_{25}

doivent être positifs. La seconde est basée uniquement sur le prix de la semaine dernière (Koutmos, 1997). a_{24} doit être positif seulement.

- La sensibilité à la pression à la couverture (a_{26}). Je calcule la pression à la couverture comme étant la différence entre la position courte et la position longue des industriels en demande de couverture. Selon la théorie de la prime de risque, la pression à la couverture diminue lorsque le prix du contrat à terme diminue, et inversement lorsque les industriels en demande de couverture prennent des positions plus longues (Bessembinder, 1992). Le bénéfice attendu de la spéculation doit être positif. Par conséquent, si les spéculateurs sont en position courte nette, le bénéfice attendu d'une position à terme doit être positif pour que les spéculateurs soient en position longue en tant que contreparties des spéculateurs de couverture. J'attends une valeur négative du coefficient a_{26}.

- La pression sur les prix (a_{27}). Si les opérations de couverture sont le moteur des échanges, une augmentation des opérations de couverture à découvert entraîne le prix à terme à la baisse. Cet effet de liquidité est temporaire. Dans cette situation, la valeur du coefficient a_{27} devrait être négative. Par la suite, cet effet temporaire serait inversé (De Roon et al., 2000). Dans le cas contraire, si le coefficient est positif, la pression à la couverture n'a pas d'influence sur les prix. Ainsi, les couvertures sont contraires et fournissent un partage des risques aux spéculateurs qui suivent la tendance.

Par conséquent, je m'attends à ce que le système réponde aux contraintes suivantes si la théorie de la pression à la couverture est vérifiée :

$$a_{11} \leq 1 \tag{3.55}$$
$$a_{24} = 0 \tag{3.56}$$
$$a_{25} = 0 \tag{3.57}$$
$$a_{26} > 0 \tag{3.58}$$
$$a_{27} < 0 \tag{3.59}$$

A l'inverse, si les traders techniques affectent la formation du prix à terme et sont à l'origine de la demande de partage des risques, comme décrit par Kang et al. (2017), les coefficients de variation de la pression à la couverture et des rendements passés sont positifs. Par conséquent, les conditions suivantes sont remplies :

$$a_{24} \in]0,1[\quad (3.60)$$

$$a_{25} \in [0,1[\quad (3.61)$$

$$a_{27} > 0 \quad (3.62)$$

Une telle situation signifie que les commerciaux sont contrariens et que les prix dépendent positivement de leur valeur passée. Par conséquent, un tel résultat implique qu'il y a un retour d'information positif entre les opérateurs non commerciaux.

La présence de frictions informationnelles, telles que définies par Sockin and Xiong (2015), implique :

$$a_{11} \geq 1 \quad (3.63)$$

Si la sensibilité du prix au comptant au prix à terme est supérieure à un, la demande augmente avec le prix au comptant. Un prix à terme en hausse augmente encore plus le prix au comptant. Ainsi, les deux prix peuvent augmenter en même temps avec un niveau de stockage constant ou décroissant. Cette analyse est possible grâce à la cointégration des variables de régression et des instruments.

J'estime l'influence des suiveurs de tendance sur le Nymex, les marchés à terme du gaz naturel américain, et le retour d'information de ce dernier sur Henry Hub, le marché physique, de février 2000 à juillet 2015. L'ensemble de données est divisé en deux sous-périodes. La première est de 2000 à 2008, y compris la période avant et pendant le pic. La deuxième est après le pic de 2009 à 2015. Les résultats concordent avec l'existence d'un impact des stratégies de suivi des tendances sur les marchés à terme et au comptant du gaz naturel aux États-Unis.

L'estimation des paramètres des équations des contrats à terme montre un rôle prépondérant de la spéculation suivant la tendance pour les variations hebdomadaires sur le Henry Hub et Nymex de février 2000 à juillet 2015. Le résultat est cohérent avec l'influence significative des suiveurs de tendance sur le marché à terme du gaz naturel aux États-Unis.

L'effet de rétroaction du marché à terme au marché au comptant est confirmé. 2008 a été une année charnière. La période 2000-2008 présente une sensibilité du prix au comptant au prix à terme inférieure mais proche de un. Après 2008, il n'y a plus de relation stable entre les prix au comptant et les prix à terme.

Mes constatations concordent avec le fait que la spéculation exacerbe les tendances sur le marché à terme et génère une rétroaction sur le marché au comptant. Cette situation peut conduire les prix du gaz naturel américain à grimper et à s'effondrer comme en 2008 ou 2014.

D'autres études sont nécessaires pour étudier l'existence d'un effet informationnel, en particulier vers 2008. De plus, il serait intéressant d'examiner des méthodologies permettant de saisir l'aspect variable dans le temps de la sensibilité du prix au comptant au prix à terme.

Chapitre trois : Déstabilisation rationnelle

Le secteur de la gestion active des contrats à terme a connu une croissance exponentielle depuis les années 1980, comme le montre la figure 4. En 1980, le secteur des contrats à terme standardisés pesait 0,31 milliard de dollars. En 2018, c'était 355,1 milliards de dollars. Le volume décolle en particulier après 2000, année de la ratification du Commodity Futures Modernization Act (CFMA).

Comme indiqué précédemment, les CTA (qui composent l'industrie des managed futures)

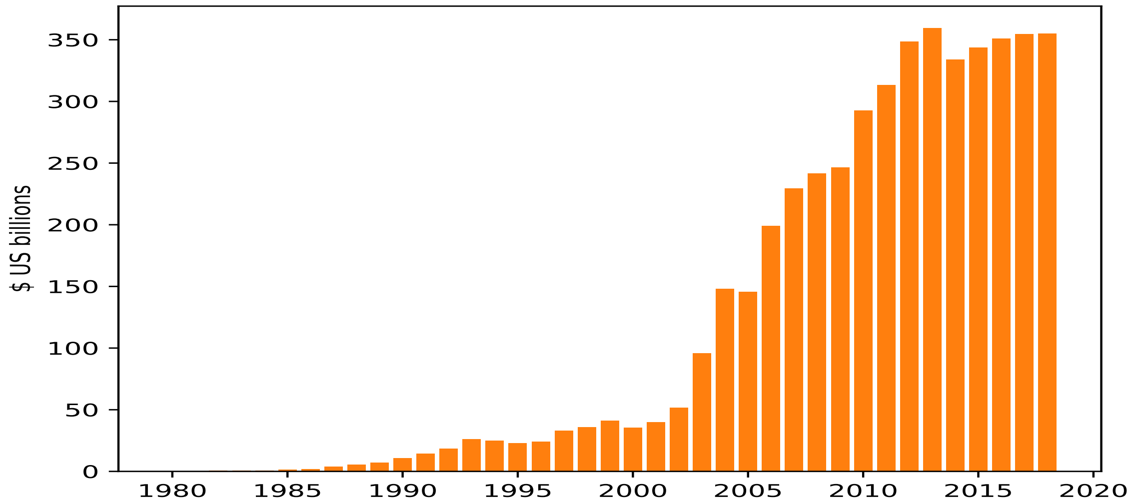

Figure 4: Actifs sous gestion - Gestion active des contrats à terme. Source : Barclays

sont composés en bonne partie d'adeptes de l'analyse technique. Ils suivent des tendances qui peuvent être impulsées par des comportements déstabilisateurs. De Long et al. (1990) montrent comment des spéculateurs rationnels peuvent impulser des tendances exacerbées par des mouvements de tendance sur le marché boursier. Tokic (2011) a élaboré une théorie pour les marchés des matières premières. Cependant, on ne trouve pas de modélisation de cette théorie dans la littérature. Le but de ce chapitre est de proposer un modèle. Ce travail évalue si le marché au comptant peut être déstabilisé par l'activité des traders techniques sur le marché à terme. Ce chapitre est théorique et a été écrit avec un co-auteur, David Batista Soares, doctorant à l'Université de Caen et Agro-Paris Tech. Dans ce chapitre, nous proposons un modèle de marché au comptant et à terme qui offre de nouvelles perspectives d'analyse de l'impact des traders techniques sur la volatilité et l'efficacité du marché. Entre autres résultats, ces travaux peuvent contribuer à l'explication de la flambée des prix des matières premières en 2008 et de la chute des prix de l'énergie en 2014. Nous contribuons à la littérature en créant le premier modèle qui montre comment les traders techniques sur le marché à terme peuvent avoir un impact indirect sur le marché au comptant pour un produit donné. Nous définissons la stabilisation des prix par une plus faible variabilité des prix. Si la variabilité des prix diminue lorsqu'une variable x augmente, la variable x a un effet stabilisateur sur le prix. Pour le résultat opposé sur le prix, la variable x est dite déstabilisatrice. Nous considérons à la fois les déstabilisations des contrats à terme et des prix au comptant en fonction du poids des traders techniques parmi les opérateurs sur le marché à terme. Nous montrons que les traders techniques déstabilisent le marché au comptant, et qu'ils ont un effet ambigu sur le marché à terme.

Le modèle que nous présentons est une extension du modèle introduit par Ekeland et al. (2018), avec ses principaux avantages. Ce cadre unifie de manière simple la théorie du stockage et la théorie de la pression à la couverture. Les prix à terme et au comptant sont tous deux endogènes dans un équilibre d'anticipations rationnelles (REE). Nous introduisons une période intermédiaire où les traders techniques entrent sur le marché en fonction du prix de la première période.

Par conséquent, notre modèle est un REE auto-réalisateur dynamique (horizon fini). Alors, "*comme le montre Spiegel (1998), lorsque l'équilibre existe, il n'est pas unique. La multiplicité résulte de la circularité de la boucle dynamique des anticipations rationnelles : la fonction de prix dépend de l'anticipation de la fonction de prix.*" (Biais et al., 2010). Spiegel (1998) explique que les agents ont besoin de séries de prix qui correspondent à leurs systèmes de croyances. Si plusieurs séries de prix correspondent à la définition de l'équilibre, on obtient des équilibres multiples. Ce résultat est bien connu de la littérature des générations imbriquées (Biais et al., 2010; Ganguli and Yang, 2009; Spiegel, 1998; Watanabe, 2008) et complète le travail de Lucas (1978). Ce dernier présente un équilibre général qui engendre des prix d'actifs, qui sont fonction du produit attendu du gain et d'un facteur d'actualisation. Dans un paramétrage dynamique, le gain de l'actif suivant dans la période suivante inclut le prix de la période suivante. Le règlement d'un contrat à terme avant chaque échéance est constitué seulement par son prix [7]. S'il n'y a pas de risque de base, le gain final est le prix au comptant à l'échéance. Lorsque les positions à terme sont révisées au cours de la période de détention du marché au comptant, la dynamique décrite par Lucas (1978) fonctionne. Il existe une relation entre le prix à terme de la première période et celui prévu pour la deuxième période. Comme dans le cas d'une période, le prix à terme de la première période dépend du gain attendu à l'échéance. Nous obtenons les deux boucles d'anticipations rationnelles mises en évidence par les modèles de génération imbriquées. Notre modèle ne met pas en scène d'agents dont les vies s'imbriquent. Cependant, les positions d'un contrat à terme donné se chevauchent parce qu'elles peuvent être initiées à des périodes différentes, mais elles expirent au même moment, à la même échéance.

Notre modèle présente même une troisième boucle d'anticipations rationnelles. Le sous-jacent et donc son anticipation sont endogènes dans notre modèle. Les deux boucles décrites ci-dessus ont une incidence sur le prix des contrats à terme et donc sur les opérations physiques par le biais de décisions de couverture. Par conséquent, le marché au comptant et le marché à terme sont entremêlés par l'intermédiaire de trois boucles d'anticipations rationnelles. Ainsi, l'activité financière sur le marché à terme a des conséquences sur le prix au comptant et ainsi de suite sur l'activité économique.

Nous présentons un modèle à trois périodes. Il y a une période initiale ($t = 1$), une intermédiaire ($t = 2$) et une finale ($t = 3$). Il y a deux marchés : un marché au comptant et un marché à terme associé avec une seule échéance et des prix respectifs de P_t et F_t au temps t. Toutes les valeurs aléatoires effectives seront notées avec le symbole $\sim$. À la période $t \in \{1, 3\}$, les traders au comptant engendrent un approvisionnement aléatoire exogène ω_t. Leur demande dépend positivement d'une variable aléatoire exogène (η_t) et négativement du prix au comptant (P_t). Le marché au comptant est soumis à une contrainte de stocks positifs. Sur les marchés à terme, un contrat peut être ouvert à la période initiale ou intermédiaire. Le marché à terme est le seul ouvert à la période intermédiaire. Nous justifions cette hypothèse de deux façons différentes. La première, qui suit Working (1953), est que les contrats à terme "*(....) servent principalement à faciliter la couverture et la spéculation en favorisant un confort et une économie exceptionnels des transactions*". Par conséquent, une activité plus fréquente des marchés à terme ne semble pas être une hypothèse restrictive. De plus, les positions à terme sont révisées au cours des périodes de détention sur le marché au comptant, comme dans Anderson and Danthine (1983a). Les implications de cette dernière sont cruciales si le marché

[7] Contrairement aux actions, il n'y a pas de dividende.

à terme donne un retour d'information au marché au comptant : la révision des positions à terme a un impact sur le gain final à l'échéance du marché au comptant. Ils sont réglés dans la dernière période. Lorsque les traders vendent (achètent) des contrats à terme, leur position est courte (longue) et le nombre de contrats à terme qu'ils détiennent est négatif (positif). Il n'y a pas de risque de base, donc au moment $t = 3$, $P_3 = F_3$. Trois types d'opérateurs prennent des décisions intertemporelles. Les deux premiers sont des opérateurs physiques. Ils couvrent leur activité sur le marché au comptant avec des contrats à terme. Le dernier type est celui des spéculateurs. Ils ne négocient que sur le marché à terme. Nous avons deux groupes myopes qui n'agissent que pour une seule période : les traders au comptant exogènes à chaque période et les traders techniques qui sont actifs à la période intermédiaire sur le marché à terme uniquement. Par conséquent, nous prolongeons Ekeland et al. (2018) de deux manières : nous ajoutons la période intermédiaire, avec le marché à terme ouvert, et nous introduisons des traders techniques. Cette extension est assez similaire à Anderson and Danthine (1983b) où les industriels en demande de couverture, dotés d'une technologie non stochastique, choisissent leurs positions physiques à couvrir dans la première période et une deuxième période avec la possibilité de changer leurs positions futures.

Au temps $t = 2$, nous introduisons des opportunités d'investissement changeantes (Breeden, 1979,8; Merton, 1971,7). Les opérateurs actifs sur le marché à terme prennent en compte la relation entre le gain des positions prises à la première période et celles prises à la deuxième période pour sélectionner leurs positions. Toutes les valeurs réalisées sont de notoriété publique pour tous les types d'agents. Soit μ, une variable représentant des nouvelles supplémentaires sur la récolte au temps $t = 3$ qui est révélé au temps $t = 2$. Il y a deux effets de cette information quantitative sur les opportunités d'investissement. Tout d'abord, cette information supplémentaire sur la récolte a un impact négatif sur le prix au comptant à maturité (P_3). Deuxièmement, $\text{Cov}[\mu, \xi_3] = 0$, ξ_t étant égal à la demande nette exogène du produit au moment t (voir ci-dessous). $\tilde{\mu}$ est un choc d'information indépendant qui apporte des informations sur la demande nette exogène à l'échéance. Cette fonction relie les prix au comptant entre eux à travers toutes les périodes.

Ce chapitre montre que l'existence d'un équilibre est déterminée par une équation à point fixe, qui est un polynôme du second degré. Il existe donc une multiplicité potentielle d'équilibres, source d'instabilité. La variance de l'utilité attendue nécessite de résoudre un moment endogène d'ordre deux (Spiegel, 1998). Ainsi, la résolution des conditions d'équilibre de marché s'effondre dans un polynôme du second ordre avec deux racines pour la pression spéculative intertemporelle qui est la covariance entre le gain d'une position longue dans la première période et le bénéfice des positions prises dans la seconde période[8]. Ces deux solutions peuvent être des équilibres valables.

La pression spéculative intertemporelle (ISP) est la covariance entre le prix au comptant à l'échéance et le bénéfice des positions souscrites dans la seconde période. L'ISP mesure comment le bénéfice tiré de la spéculation au cours de la deuxième période varie en fonction du prix au comptant à l'échéance. Les agents ajustent leurs positions spéculatives en tenant compte de l'ISP dans la première période. Par exemple, si l'ISP est négative (ce qui semble être la règle comme nous le verrons plus loin), le bénéfice des positions spéculatives émises à la deuxième période et le prix au comptant à l'échéance sont corrélés de façon négative. Les positions spéculatives de la première période sont plus longues parce que les spéculateurs s'attendent à ce que le bénéfice d'une position longue soit positif sur la période intermédiaire et négatif à l'échéance. Toutes les positions sont évaluées à la valeur de marché. Ainsi, les agents rationnels s'attendent à être courts sur la période intermédiaire. Les rétroactions positives amplifient ce phénomène. Plus le poids des traders techniques est élevé, plus l'ISP est négative, plus les agents rationnels sont longs dans la première période et plus la pression à la hausse sur le prix à terme est forte dans la seconde période. Une déstabilisation rationnelle est donc en jeu. Dans le modèle du chapitre, le marché à terme engendre un retour d'information sur le marché au comptant. Cette dynamique haussière du prix des contrats à terme n'est pas sans conséquence sur la maturité du prix au comptant.

Le polynôme du second ordre de l'équation à point fixe de l'ISP présente deux racines. Si les deux solutions sont des équilibres, elles représentent un régime de covariance élevé et un régime de covariance faible entre le bénéfice des positions spéculatives émises dans la deuxième période et le prix au comptant à l'échéance. Les agents rationnels peuvent croire que l'ISP est faiblement ou fortement négative. Les deux correspondent à leur système de croyances et sont des prophéties auto-réalisatrices. La variation du prix à terme dans la deuxième période ne varie pas de la même manière selon le régime des ISP et les niveaux des prix au comptant diffèrent.

Ce chapitre montre comment la gestion du risque que représente le trading technique, par les opérateurs rationnels, modifie les fondamentaux du marché. Les chartistes diminuent la covariance entre le prix au comptant à l'échéance et le bénéfice des positions prises dans la seconde période. Les agents spéculateurs deviennent plus longs à la période initiale en réaction

[8] Si l'ISP était une matrice carrée de dimension K, le polynôme du second ordre donnerait 2^K solutions. Ce serait le cas si les spéculateurs disposaient de K titres (Spiegel, 1998).

à ce risque supplémentaire attendu à la période suivante. La pression spéculative plus longue de la première période fait monter les prix des contrats à terme, ce qui nuit à la couverture des positions longues et incite à la couverture des positions courtes. Cette dynamique fait également grimper le prix au comptant au cours de la première période. La pression à la couverture devient plus courte, engendrant alors un choc de demande nette négatif à l'échéance. Par conséquent, le prix au comptant à l'échéance diminue. Enfin, la variabilité du prix au comptant augmente avec le poids croissant des traders techniques.

Nous montrons aussi que les mesures empiriques de la pression des opérations de couverture et la spéculation ne sont pas toujours exactes. Les traders techniques engendrent un deuxième type de prime de risque. Les commerciaux peuvent agir comme contrariens en se posant en contrepartie des chartistes. Les mesures empiriques de la pression à la couverture et du T de Working présentent des incertitudes.

Cet article se concentre sur les pressions spéculatives intertemporelles et met de côté les aspects intertemporels des décisions de couverture des commerciaux. L'inclusion des révisions des décisions de couverture apporterait un nouvel éclairage sur la boucle terme-comptant. De plus, une extension à une période infinie nous renseignerait sur l'évolution de la dynamique des marchés dans le temps.

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RÉSUMÉ

Le projet de thèse consiste à étudier l'hétérogénéité de l'information et des croyances parmi les opérateurs sur les marchés de matières premières pour s'attaquer aux puzzles de la volatilité et de la prime de risque sur ces marchés. La première étape a été d'introduire l'asymétrie d'information dans un modèle de stockage. Il en est ressorti que le marché est efficient et que l'on peut distinguer un effet informationnel aléatoire d'un effet physique déterministe. La deuxième étape est d'estimer empiriquement les paramètres d'une version modifiée du modèle théorique évoqué plus haut. L'hypothèse de rationalité économique est relâchée. Sont introduit des "chartistes" qui suivent les cours. Le but de ce papier est d'estimer leur influence sur la formation des prix. Le marché choisi pour l'étude empirique est le marché du gaz naturel américain Henry hub. La troisième étape est un modèle où agents rationnels et agents à rationalité limitée cohabitent dans un marché de matières premières. Ce dernier chapitre montre comment des traders suivant la tendance sur le marché à terme peuvent déstabiliser le marché physique.

MOTS CLÉS

Marchés à terme, pression de couverture, trading technique, destabilisation.

ABSTRACT

This Ph.D. project aims to study the heterogeneity of information and beliefs among speculators on commodity markets to tackle the issues of the risk premium and volatility puzzles. The first step was to introduce information asymmetry in a storage model. The output is an efficient market where it is possible to distinguish a random informational effect from a deterministic physical effect. The second step is to estimate empirically the parameters of a modified version of the theoretical model above. The rationality hypothesis is relaxed. "Chartists," who are trend-followers, are introduced. The goal of this paper is to estimate their influence on asset pricing. The chosen market for the empirical study is the Henry Hub natural gas market. The third step is a model where rational agents and bounded-rational agents interact together in a commodity market. This last chapter shows how trend-followers in the futures market can destabilize the spot market.

KEYWORDS

Futures market, hedging pressure, technical trading, spot destabilization.