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Working Paper
RR-FiME-17-02

January 2017

DAUPHINE UNIVERSITÉ PARIS

CREST Centre de Recherche en Économie et Statistique

ÉCOLE POLYTECHNIQUE

eDF

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November 16, 2016

Abstract

In this paper, I examine how financialization affects the term structure of risk premia by using an equilibrium model for commodity futures markets. I define financialization as the entry of cross-asset investors, who are exposed to a commodity risk, into a commodity market. Qualitatively, the model shows that the financialization decreases the segmentation between commodity markets and the stock market. It also shows that speculators and investors both provide and consume liquidity and that the *investment pressure* from investors creates new risk premia. Further the model shows that financialization affects the entire term structure of risk premia. Quantitatively, these effects depend on the physical characteristics of the commodity market under study.

JEL Classifications: G11; G12; G13
Keywords: Commodity Markets; Financialization; Futures Prices; Risk premia.

1 Introduction

Since 2000, commodity futures markets have experienced an in-depth modification in their trading participation, also known as financialization. This evolution is characterized by the entry of new investors and is symptomatic of the recent prevailing view of commodities as a financial asset class. As estimated by the CFTC [2008], these new investors have led to the transfer of $200 billions in investment flows from traditional asset classes to various commodity futures markets between 2000 and 2008. The reasoning behind this appetite for commodity markets is "low-cost" diversification. The opportunities for diversification in these markets come from the development of new investment vehicles for index investing (Commodity Index Traders or CITs, Exchange Traded Funds or ETFs...)

*This article is based on work supported by the Chair Finance and Sustainable Development and the FIME Research Initiative. I thank Delphine Lautier, Bertrand Villeneuve, Franck Moraux, Michel Robe and Evgenia Passari for their helpful comments.

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and from the historical segmentation of commodity markets with traditional asset classes.

The focus of this paper is to theoretically examine the consequences of this financialization process for commodity futures markets and their participants. The focus is on the risk sharing function of these markets. This is important because financial investors see commodity markets through the lens of index investments. Therefore, they may have an aggregated view of commodities as another financial asset class. However, commodity markets are complex economic systems which fulfill a role in the global economy through their risk sharing and price discovery functions. Moreover, they have some particularities. First, no single unique commodity market exists, instead there are multiple heterogeneous markets with their own specific physical characteristics. These characteristics are the most important determinants of the prices and risk premia. As a consequence, the dynamic behaviors of commodity prices have different patterns across markets (e.g., very volatile electricity prices versus very stable gold prices). Second, for each commodity there are multiple futures contracts with different maturities trading simultaneously. This is known as the term structure of the futures prices. This structure allows commodity markets to perform their fundamental economic functions (risk sharing and price discovery). This maturity component is well-known in the economics literature dedicated to commodity markets but has largely been ignored in the literature regarding financialization. This gap exists because the investment strategies for commodity indices rely on taking important positions on short-term futures contracts and rolling them.

Because of these specific features of commodity markets, financialization naturally raises questions: What is the effect on the risk sharing function of commodity markets? Do the determinants of the risk premia evolve with the trading of cross-asset investors? Do these new investors act as the suppliers or consumers of liquidity? Does the heterogeneity of commodity markets make the effects of the financialization market specific? Another natural question is whether financialization changes the level of segmentation both between commodity markets and between commodity markets and other asset classes? Further, it is important to know if the financialization changes the shape of the term structure of the risk premia. In other words, are the risk premia for different maturities affected equally by the specific investment behaviors of outside investors?

The answers to these questions are of great interest for a variety of agents that range from traditional market participants to regulators. First, industrial agents use commodity futures markets daily to hedge their physical exposure to commodity prices. The existence and the good functioning of these markets allow them to secure their activity, by accepting to pay a cost of hedging: the risk premium. As a consequence, any structural modification on commodity futures markets due to the financialization process, good or bad, affects them. Therefore, they may have to adjust their behavior, for instance by using more short- or long-term futures contracts, if the modification affects the shape of the term structure of the risk premia. Thus, any change in the cost of hedging to industrial agents is likely to spillover to consumers. Second, these questions are useful to understand the evolution of the market making industry in commodity markets. This industry is composed of specialized speculators providing liquidity to hedgers in exchange for the risk premia. Therefore, the study of the role of cross-asset investors helps in understanding whether financialization increases the competition among traditional speculators (market makers) or whether it creates new profit opportunities for them. Further, by being in charge of the well-being of the economy, regulators need to have a good understanding of the implications of the financialization process in commodity markets. For instance, they have to make decisions relative to the regulation of investments or the optimal design of clearing houses. They may face a trade-off between having more or less segmented markets. On the one hand, less segmentation can cause more efficient risk sharing but on the other hand it can reinforce spillover effects between markets and increase the systemic risk of the global system.

To answer these questions, I develop a three-date equilibrium model of commodity futures markets with limited participation. This model follows Hirshleifer [1988] and Boons, De Roon, and Szymanowska [2014] in which traditional agents (producers and speculators) can face new cross-asset investors who hold a commodity risk. All agents in the economy are risk averse and try to maximize their expected utility under the mean-variance framework by choosing their optimal positions on the futures markets. The specialized speculators and cross-asset investors have short-term horizons. The producers, who have random production, have a long-term horizon and a preferred habitat. There are three risky assets: two futures contracts on the same commodity with different maturities (the term structure) and one stock market index. Because the focus of the paper is on the study of the behavior of commodity futures markets, the model of the stock market is basic.

To study the effect of financialization on the term structure of risk premia in commodity markets, I adopt a multistage process. First, the model is solved for a pre-financialization economy in which only the producers and the speculators can trade in the futures markets. This economy provides a good comparison to the main model and also identifies known and new results regarding the determinants of the risk premia in commodity markets when a term structure exists. Then, the model is solved for two post-financialization economies by adding (un)constrained cross-asset investors to the analysis. In the first post-financialization economy, the investors are constrained to a position on the front-month contract only. In the second one, the investors are unconstrained and can trade all of the futures contracts available (both the front-month and the deferred contracts). The modeling of constrained investors is motivated by the fact that index investors hold most of the time positions in short-term futures contracts that they roll from month to month. In other words, the cross-asset investors use the majority of the investment flows to trade short-term futures contracts and ignore the other maturities. The modeling of the unconstrained investors accounts for the new, more sophisticated investment strategies that use contracts with longer maturities. These strategies have been developed in response to the recent durable situations of contango in the crude oil market. Indeed, in such a market configuration, a strategy based on rolling over short-term futures contracts leads to important roll losses. Buyuksahin, Haigh, Harris, Overdahl, and Robe [2009] describe this evolution in the WTI crude oil futures market between 2000 and 2008 as "open interest at maturities greater than one year grew nearly twice as fast as open interest at shorter maturities".

The model is solved analytically, but because of the complexity of the equilibrium equations, most of the analysis is done through visual representations (figures) of the risk premia for a specific set of parameters. These parameters are based on assumptions and on an empirical calibration of the crude oil market for the commodity futures market and on the S&P 500 for the stock market.

In the pre-financialization economy, I find the following: i) commodity markets are segmented from the stock market, that is, the performance of the stock market does not affect the risk premia in commodity futures markets; ii) the existence of a *hedging pressure* from producers is a necessary condition for the existence of risk premia that lead specialized speculators to enter the commodity markets only to allow the producers to share their risk; iii) speculators link the futures contracts for different maturities, particularly when producers have a preferred habitat and trade only some maturities; and iv) speculators act both as providers and consumers of liquidity because they have optimal diversified portfolios with futures contracts of different maturities.

In the post-financialization economies, I find the following: i) commodity markets become less segmented from the stock market; ii) regardless of the maturity, the *investment pressure* from investors creates a risk premium, even without hedging pressure from the producers. Therefore, the commodity markets do not exist only for the benefit of producers but also for the cross-asset investors who can hedge their commodity risk; iii) the financialization affects all of the risk premia along the term structure even if investors are constrained to trade only the front-month contract. In other words, the optimal trading behaviors of the other agents in general and of the speculators in particular lead to a spillover of the stock market risk along the term structure. The intensity of the spillover depends on the level of integration of the prices for different maturities; and iv) investors act both as providers and consumers of liquidity.

More generally, my model emphasizes that the effect of financialization on the term structure of risk premia is market specific. That is, each commodity market according to its physical characteristics reacts differently to the financialization. As a consequence, some may profit from it and some may suffer.

The article is organized as follows: Section 2 has a review of the relevant literature. In Section 3 I describe the economic setting of the model. The optimality conditions and the equilibrium analysis are developed in Sections 4 and 5. Sections 6 and 7 contain the numerical analysis of the model and Section 8 concludes.

2 Related literature

This paper contributes to different strands of the literature on commodity futures markets. The first one is the important literature on the behavior of commodity prices. Theoretical papers by Anderson and Danthine [1983a,b], Hirshleifer [1988, 1989a,b], Acharya, Lochstoer, and Ramadorai [2013], Ekeland, Lautier, and Villeneuve [2016b] and Ekeland, Jaeck, Lautier, and Villeneuve [2016a] study the economic mechanisms underlying the joint process of spot and futures prices in static and dynamic frameworks. These models focus on the existence and the determinants of the risk premia for a commodity market without a term structure. They aim to replicate the empirical stylized facts of commodity markets described in important empirical studies like Fama and French [1987], Deaton and Laroque [1992] and Bhardwaj, Gorton, and Rouwenhorst [2015] for commodity prices and De Roon, Nijman, and Veld [2000] and Szymanowska, De Roon, Nijman, and Goorbergh [2014] for risk premia.

I contribute to this literature by extending the analysis of the determinants of the risk premia in a commodity market with a term structure. Indeed, for tractability reasons most of the papers that model both active spot and futures markets with heterogeneous risk-averse agents focus their analysis on one maturity. An equilibrium analysis with a term structure can be found in Routledge, Seppi, and Spatt [2000], but the risk neutral framework, by construction, makes any study of the risk premium impossible.

Second, this paper contributes to the literature dedicated to the *Preferred Habitat Theory*. This theory was introduced by Modigliani and Sutch [1966] for the term structure of interest rates as an extension of the *Market Segmentation Hypothesis* emphasized by Culbertson [1957]. According to these authors, in the *Market Segmentation Hypothesis* the hedgers have different time preferences and only trade futures contracts of a specific maturity. As a consequence, the futures prices (and risk premia) for different maturities are determined in separate markets by their own supply and demand schedules. They are independent. In the *Preferred Habitat Theory*, hedgers can when it is economically profitable, trade futures contracts with a different maturity than the one they prefer. Therefore, the arbitrage behavior of the hedgers links the risk premia for different maturities together. These theories have been adapted to commodity markets by Gabillon [1995], Lautier [2005], and Buyuksahin et al. [2009]. They have shown that segmentation exists in at least two parts of the term structure of crude oil futures prices.

My paper offers an alternative extension to the *Market Segmentation Hypothesis*. It shows that, even if producers do not exit their preferred habitat, the risk premia are not independent. This is because of the arbitrage behavior of the speculators.

Further, my paper contributes to the emerging literature regarding the so-called financialization of commodity markets. This literature has emerged as a consequence of the boom and bust cycles around 2008 in many commodities (crude oil and agricultural products) in parallel with an in-depth modification of the structure and the functioning of commodity markets (electronization, entry of new agents in the markets, development of new investment vehicles). Michael Master established the link between investment flows via the Commodity Index Traders (CITs) and the boom/bust cycle in his 2008 testimony to the US Senate. This link has motivated a lot of empirical studies that look for direct evidence of price distortion due to investment flows into commodity markets (see, e.g., Brunetti and Buyukşahin [2009], Buyukşahin and Harris [2011], Singleton [2013], Hamilton and Wu [2015] and Cheng and Xiong [2014] for a complete literature review). These studies have mixed results mainly because of the difficulty in finding a proper econometric procedure to tackle this kind of issue. As a consequence, this literature focuses now on how the financialization of commodity markets can modify their two fundamental economic functions: risk sharing and information discovery.

My paper sheds light on the link between the financialization and the modification of the risk sharing function in commodity markets. Historically, commodity markets have always been seen as segmented markets with little co-movements both between commodities[1] (Erb and Harvey [2006]) and between commodities and other asset classes (Gorton and Rouwenhorst [2006]). As a consequence, they are characterized by inefficient risk sharing. Indeed, this inefficiency in the risk sharing function of futures markets is one way to interpret the *theory of normal backwardation* of Keynes [1930]. It states that, because of unbalanced hedging needs, hedgers have to pay a premium to give outside speculators an incentive to enter the market and bear the risk. Hirshleifer [1988] formalizes this inefficient view in a model based on limited participation by outside speculators. Based on that, the question is whether the financialization helps to reduce the inefficiencies and the segmentation or whether it reinforces them. My paper, by studying the effect of the entry of investors bearing a commodity risk into futures markets on the term structure of risk premia, reinforces and complements the following results in the literature: i) Regarding the inefficiencies of the futures markets, both Hamilton and Wu [2014] and Baker [2016] show that financialization has helped to reduce the risk premia in the crude oil market. Hamilton and Wu [2014] justify this result by showing that the important investment flows from the commodity index funds take the opposite side of the hedgers. Baker [2016], on a model in the spirit of Hirshleifer [1988], focuses on the entry of households into commodity futures markets. Moreover, based on the trading of the commodity index traders, Brunetti and Reiffen [2014] reach the same conclusion for agricultural markets. Finally, the static model of Ekeland et al. [2016b] and its dynamic counterpart by Ekeland et al. [2016a] show that, even without the entry of a new agent, the risk premium decreases if the risk bearing capacity of the existing speculator increases. ii) Regarding the integration of commodity markets, the empirical studies show that after financialization, the commodity markets are more integrated because of the investment in commodity indices (see Tang and Xiong [2012]) and with other asset classes (see Silvennoinen and Thorp [2013], Buyuksahin and Robe [2014] and Boons et al. [2014]). Moreover, Basak and Pavlova [2016] provide a theoretical framework which confirms the previous empirical evidence and details clear economic mechanisms through which correlations can increase between equity and a commodity and among commodities. In this model, the financialization is described as the trading in commodity futures markets by institutional investors with index dependent preferences (the utility depends on the performance of a benchmark).

3 Economic setting

The time, the assets, and the markets: There are three dates in the model ($t = 0, 1, 2$), and agents have to make decisions during the two first. There are three different assets: The first is a risk free asset with a null risk free rate. The second is an index

[1] However, Pindyck and Rotemberg [1990] identify periods of excess co-movement between commodity prices.

representing the stock market. As in Hirshleifer [1988, 1989a], I model the financial market through a representative index to focus on the results that link to the commodity markets. This index is traded by the investors at $t = 0, 1$, but the clearings of these markets are not under the scope of this paper. The return, expected return, and the variance of the stock index between $t-1$ and t are respectively R_{r_t}, μ_{r_t}, and $\sigma^2_{r,t}$. The third is a term structure of futures contracts. At $t = 0$, two futures contracts written on the same commodity are traded, one with maturity $t = 1$ (the front-month contract) and one with maturity $t = 2$ (the deferred contract). At $t = 1$, only one contract stays alive because the first futures contract matures. Then, the second contract that matures at $t = 2$ becomes the front-month contract. These contracts lead to the clearing of three different markets: two markets at $t = 0$ for the front-month contract and the deferred contract and one market at $t = 1$ for the contract with maturity $t = 2$. The return, expected return, and the variance of a futures contract with maturity T between $t-1$ and t are respectively $R_{F_{t,T}}$, $\mu_{F_{t,T}}$, and $\sigma^2_{t,T}$.

This modeling with three dates and two futures contracts of different maturities is the simplest way to accommodate both the existence of a term structure of prices and the tractability of the model.

The risk-averse agents: There are three different risk-averse agents with different time horizons and available sets of investments. The assumption of risk-averse agents has been extensively used in the literature (see, e.g., Hirshleifer [1988, 1989a,b], Boons et al. [2014], Ekeland et al. [2016b,a], and Baker [2016]). As emphasized by Bessembinder and Lemmon [2002], the corporate risk management literature motivates its use for the producers. As emphasized by Acharya et al. [2013], the limits to arbitrage literature motivates its use for the speculators. This assumption enables the solving of the model under the mean-variance framework.

The risk-averse agents are the following: First are the N_p *producers with a preferred habitat*[2]. There are two types of producers: one is short term and exists between $t = 0$ and $t = 1$, has random production at $t = 1$, and trades only the front-month contract at $t = 0$. The other is long term and exists at all three dates, has random production only at $t = 2$, and can trade only the futures contract maturing at $t = 2$ (i.e., the deferred contract at $t = 0$ and the front-month contract at $t = 1$). These producers are identical in terms of number and risk aversion and trade on the futures market for hedging purposes. At $t = 0, 1$, they choose their positions $f^p_{t+1,T}$ in the futures contract with maturity T to hold until $t+1$. This idea of the existence of producers with heterogeneous time preferences dates back to the *Preferred Habitat Theory* of Modigliani and Sutch [1966] on the term structure of interest rates.

Second are the N_s *specialized speculators*. There are two successive generations of short-term speculators that trade only on the futures markets. They do not have physical exposure to the commodity. At $t = 0, 1$, they choose position $f^s_{t+1,T}$ in the futures contract

[2] Another version of the model is developed in Appendix C. In this case there is only one long-term producer who exists at all three dates, has random productions at $t = 1$ and $t = 2$, and can trade all futures contracts without liquidity or regulatory issues. The results are qualitatively the same.

with maturity T to hold until $t+1$. The first generation exists between $t=0$ and $t=1$ and has access at $t=0$ to both the front-month and the deferred contracts. All positions that are initiated in the deferred futures contract which does not mature at $t=1$ have to be canceled on the markets at $t=1$. The second generation exists between $t=1$ and $t=2$ and has access at $t=1$ to the remaining front-month contract.

The third are the N_{in} *cross-asset investors*. There are two successive generations of short-term investors. Initially, they only trade on the stock market but begin to trade on the futures markets with the financialization. They hold a commodity risk and then have an incentive to trade in the futures markets for hedging purposes. At $t=0,1$, they choose position $f^w_{t+1,T}$ in the futures contract with maturity T to hold until $t+1$, and they choose position w_t on the stock market index. I successively model two versions of investors in this paper: i) The constrained investors who only trade the front-month contracts, that is, at $t=0$ ($t=1$) they trade the contract maturing at $t=1$ ($t=2$). This case is motivated by the predominance of CITs in the futures markets during a long time period. ii) The unconstrained investors who can trade all of the futures contracts, that is, the first generation of investors at $t=0$ can trade both the front-month and the deferred contracts. Furthermore, at $t=1$, there is no difference between these cases because only one futures contract can be traded.

The modeling of hedgers in the commodity futures markets as producers is made for tractability reasons but is consistent with the literature. Indeed, the articles by Hirshleifer [1988], Acharya et al. [2013], and Boons et al. [2014] are based on the same assumption. Moreover, in the spirit of the *theory of normal backwardation* of Keynes [1930], the empirical studies (see Cheng and Xiong [2014]) show that aggregated hedgers on the futures markets more often short a commodity than go long. This fact can be explained by the predominance of producers on the futures market who have a natural long exposure to the commodity but a short position on the futures markets.

Finally, the modeling of speculators and investors with a short-term horizon is motivated by Kang, Rouwenhorst, and Tang [2014]. They show that the trading behavior of speculators and hedgers is different and more precisely that the former trade more impatiently.

The randomness and the physical market: The productions $\tilde{q}_t$ of the producers at time $t=1,2$ are random. The modeling of physical decisions (production or storage) is not under the scope of this article. The $\tilde{q}_1$ and $\tilde{q}_2$ are assumed to be independent and normally distributed. At the market level, the aggregated production at time t is $\tilde{Q}_t = N_p * \tilde{q}_t$. On the spot market, this supply faces the linear demand of consumers characterized by the inverse demand function $Q^D_t = g(S_t)$ for the commodity. Therefore, the spot price S_t depends on the available quantity on the spot market and is such that $\tilde{Q}_t = Q^D_t$. The return and variance of the spot price between $t-1$ and t are respectively $R_{s,t}$ and $\sigma^2_{s,t}$

The notations used in the paper are all described in Appendix A.

4 Optimal behavior of the agents

The first step of the analysis is to find the optimal positions of the different risk-averse agents in a mean-variance framework. That is, agent i with risk aversion γ_i at t maximizes his expected utility by solving the following problem:

$$\max_{f^i_{t+1,T}} \; E_t[\pi_{t+1}] - \frac{\gamma_i}{2} Var_t[\pi_{t+1}] \tag{1}$$

4.1 Short-term specialized speculators

As mentioned in Section 3, there are two successive generations of short-term speculators trading only on the futures markets without constraints on the traded contracts. They choose their position $f^s_{t,T}$ in the futures contract with maturity T to hold until t. Because the set of investments available for the first generation is bigger than those for the second generation, the profits at $t = 1$ and $t = 2$ of speculators from the first and the second generation are respectively $\pi_1 = R_{F_{1,1}} f^s_{1,1} + R_{F_{1,2}} f^s_{1,2}$ and $\pi_2 = R_{F_{2,2}} f^s_{2,2}$.

Without loss of generality, the two generations of speculators are assumed to be identical in terms of number and risk aversion, that is, $N^1_s = N^2_s = N_s$ and $\gamma^1_s = \gamma^2_s = \gamma_s$.

At $t = 1$, solving the problem (1) for a speculator of the second generation gives the following optimal position:

$$f^{s\star}_{2,2} = \frac{\mu_{F_{2,2}}}{\gamma_s \sigma^2_{2,2}} \tag{2}$$

This position is a pure speculative position, which is well-known in the literature on commodity derivative markets with one period and one commodity (see, e.g., Anderson and Danthine [1983a], Ekeland et al. [2016b,a], and Boons et al. [2014]). The speculator takes a long (short) position whenever the risk premium is positive (negative), that is, whenever he thinks that the expected spot price is higher (lower) than the futures price. This speculative position is adjusted by the risk aversion of the speculator and by the risk of the futures contract.

At $t = 0$, solving the problem (1) for a speculator of the first generation gives rise to a more general result:

$$f^{s\star}_{1,1} = \frac{\mu_{F_{1,1}} \sigma^2_{1,2} - \mu_{F_{1,2}} \sigma_{[11,12]}}{\gamma_s (\sigma^2_{1,1} \sigma^2_{1,2} - \sigma^2_{[11,12]})} \tag{3}$$

$$f^{s\star}_{1,2} = \frac{\mu_{F_{1,2}} \sigma^2_{1,1} - \mu_{F_{1,1}} \sigma_{[11,12]}}{\gamma_s (\sigma^2_{1,1} \sigma^2_{1,2} - \sigma^2_{[11,12]})} \tag{4}$$

where $\sigma_{[t_1 T_1, t_2 T_2]}$ is the covariance between the returns $R_{F_{t_1,T_1}}$ and $R_{F_{t_2,T_2}}$.

The optimal position in each futures contract has two components: i) a traditional speculative component which depends on the risk premium and the riskiness of the contract; and ii) a diversification component which depends on the risk premium attached to the other contract, on the covariance with the other contract, and on its riskiness. In other words, because of the existence of a term structure, the speculator does not allocate all of his wealth to one contract but creates an optimal portfolio of futures contracts.

4.2 Producers with a preferred habitat

As the speculators, the producers trade only on the futures market, but they hold a physical exposure to the commodity through their random production $\tilde{q}_t$. As a consequence, they choose their position $f^p_{t,T}$ in the futures contract with maturity T to hold until t primarily for hedging purposes.

My modeling is based primarily on the *Market Segmentation Hypothesis* because the producers can never trade in the other futures contract, that is, there are two producers: one short-term and one long-term. They are assumed to be identical in terms of number and risk aversion, that is $N_p^{sh} = N_p^l = N_p$ and $\gamma_p^{sh} = \gamma_p^l = \gamma_p$.

Optimal position of the short-term producer: At $t = 0$, solving the problem (1) with the producer's profit $\pi_1 = \tilde{q}_1 R_{s,1} + R_{F_{1,1}} f^p_{1,1}$ leads to the following result:

$$f^{p\star}_{1,1} = \frac{\mu_{F_{1,1}}}{\gamma_p \sigma^2_{1,1}} - \frac{\rho_{[1,11]}}{\sigma^2_{1,1}} \tag{5}$$

where $\rho_{[t,t_1T_1]}$ is the covariance between the physical revenue between $t-1$ and t and the return $R_{F_{t_1,T_1}}$.

This position has two components and is well-known in the literature on commodity derivative markets (see, e.g., Anderson and Danthine [1983a], Ekeland et al. [2016b,a], and Boons et al. [2014]). The first one is a speculative component and is exactly the position of the speculator in the same period. The second component is the hedging component. It depends on both the riskiness of the futures contract and on the physical exposure of the producer to the commodity. This exposure is characterized by the covariance $\rho_{[1,11]}$ of its physical revenue with the futures price. If this covariance is positive, then the futures price increases when the producer's revenue increases. Therefore, in order to be hedged the producer must short the futures contract. Then, if the futures price decreases, his gains on buying back the futures contract will compensate for the losses on the spot market. Because a producer typically has a long exposure to the commodity market, this covariance is assumed to be positive. As a consequence, the producer is naturally short on the futures market.

Optimal positions of the long-term producer: This producer maximizes the expected utility at the final date $t = 2$ which comes from his profit $\pi_2 = \pi_1 + \tilde{q}_2 R_{s,2} + R_{F_{2,2}} f^p_{2,2}$ with $\pi_1 = R_{F_{1,2}} f^p_{1,2}$.

At $t = 1$, solving the problem (1) with the producer's profit $\pi_2 = \pi_1 + \tilde{q}_2 R_{s,2} + R_{F_{2,2}} f^p_{2,2}$ leads to the following optimal position:

$$f^{p\star}_{2,2} = \frac{\mu_{F_{2,2}}}{\gamma_p \sigma^2_{2,2}} - \frac{\rho_{[2,22]}}{\sigma^2_{2,2}} \tag{6}$$

This is the traditional speculative/hedging position when there is only one futures contract available in a one period setting.

At $t = 0$, the long-term producer solves the following problem:

$$\max_{f^p_{1,2}} \; E_0[\pi_2] - \frac{\gamma_p}{2} Var_0[\pi_2] \tag{7}$$

Which leads to the following optimal position $f^{p\star}_{1,2}$:

$$f^{p\star}_{1,2} = \frac{\mu_{F_{1,2}}}{\gamma_p \sigma^2_{1,2}} - \frac{\mu_{F_{2,2}} \sigma_{[12,22]}}{\gamma_p \sigma^2_{1,2} \sigma^2_{2,2}} + \frac{\rho_{[2,22]} \sigma_{[12,22]}}{\sigma^2_{1,2} \sigma^2_{2,2}} - \frac{\rho_{[2,12]}}{\sigma^2_{1,2}} \tag{8}$$

This futures position has three components: i) the speculative component; ii) an intertemporal diversification component which depends on the expected return of the same futures contract one period ahead and on the auto-correlation of the futures contract; and iii) an intertemporal hedging component which depends on the covariance of the futures contract with the physical revenue at the next period.

This hedging strategy by a producer implies an evolution of the hedging position over time.

4.3 Short-term cross-asset investors

There are two successive generations of short-term investors who hold a commodity risk (φ). As pointed out by Boons et al. [2014], the existence of this commodity risk can be motivated by at least two arguments: i) the inflation risk of the investor because commodity prices are an important and volatile component of inflation; and ii) the importance in terms of the investment-consumption decisions of the commodity prices. Following the literature (see Driesprong, Jacobsen, and Maat [2008]) and the idea that inflation decreases the real returns, investors are assumed to have a negative exposure to the commodity ($\varphi < 0$).

Initially, investors only trade on the stock market via a representative index[3]. Two costs can explain this non-diversification across assets (see Hirshleifer [1988] and Boons et al. [2014]). It can be an explicit cost of entry on alternative investments based on physical assets or an implied cost of becoming informed. Then, for exogenous reasons (for instance the decrease in the explicit entry cost on futures market thanks to the development of ETFs or CITs), investors start to trade on the futures markets. This entry of investors describes the financialization of commodity markets.

4.3.1 Optimal positions pre-financialization

This subsection first considers the optimal positions in the stock market index of the investors who do not participate in the futures market. The two successive generations of investors adopt the same behavior because they have the same set of investments (the stock market index) and the same kind of risks (commodity risk).

[3]The use of an index does not qualitatively change the results because the focus of this article is on understanding the effect on commodity markets and not on the cross-section of the stock market.

An investor who lives between $t-1$ and t solves the problem (1) over his position w_t in the stock market index, with his profit $\pi_t = w_t R_{r_t} + \varphi_t R_{s,t}$ and optimally chooses the following position in the stock market index:

$$w_t^{\star} = \frac{\mu_{r_t}}{\gamma_{in}\sigma_{r,t}^2} - \frac{\varphi_t \sigma_{[r_t,s_t]}}{\sigma_{r,t}^2}, \ \forall t = 1, 2 \tag{9}$$

where $\sigma_{[r_t,s_t]}$ is the covariance between the returns of the stock index and of the spot price between $t-1$ and t.

This optimal position, due to the use of a stock market index, is a simplified version of the one in Boons et al. [2014]. The investor first invests in the stock market for speculative reasons. Then, because he is prevented from investing in the futures market, the investor hedges his commodity exposure by adjusting his position in the stock market index. The investor adjusts his position according to the risk φ and the covariance between the index and the spot price of the commodity.

4.3.2 Optimal positions of constrained investors

This subsection now considers the first type of financialization. In this case, investors trade only on the short-term part of the term structure of commodity futures prices (front-month contract). As before, the two successive generations of investors have the same behavior because they have the same set of investments (the stock market index and the front-month futures contract) and the same kind of risks (commodity risk).

The investors who live between $t-1$ and t solve the problem (1) over their positions w_t in the stock market index and $f_{t,t}^w$ in the futures contract to hold until its maturity in t. With profit $\pi_t = w_t R_{r_t} + \varphi_t R_{s,t} + f_{t,t}^w R_{F_{t,t}}$ they optimally choose the following positions:

$$w_t^{\star} = \frac{\mu_{r_t}\sigma_{t,t}^2 - \mu_{F_{t,t}}\sigma_{[r_t,F_{t,t}]}}{\gamma_{in}(\sigma_{t,t}^2\sigma_{r,t}^2 - \sigma_{[r_t,F_{t,t}]}^2)} + \frac{\varphi_t\left\{\sigma_{[r_t,F_{t,t}]}\sigma_{[s_t,F_{t,t}]} - \sigma_{t,t}^2\sigma_{[r_t,s_t]}\right\}}{(\sigma_{t,t}^2\sigma_{r,t}^2 - \sigma_{[r_t,F_{t,t}]}^2)}, \ \forall t = 1, 2 \tag{10}$$

$$f_{t,t}^{w\star} = \frac{\mu_{F_{t,t}}\sigma_{r,t}^2 - \mu_{r_t}\sigma_{[r_t,F_{t,t}]}}{\gamma_{in}(\sigma_{t,t}^2\sigma_{r,t}^2 - \sigma_{[r_t,F_{t,t}]}^2)} + \frac{\varphi_t\left\{\sigma_{[r_t,F_{t,t}]}\sigma_{[r_t,s_t]} - \sigma_{r,t}^2\sigma_{[s_t,F_{t,t}]}\right\}}{(\sigma_{t,t}^2\sigma_{r,t}^2 - \sigma_{[r_t,F_{t,t}]}^2)}, \ \forall t = 1, 2 \tag{11}$$

where $\sigma_{[s_t,F_{t_1,T_1}]}$ is the covariance between the return of the spot price between $t-1$ and t and the return $R_{F_{t_1,T_1}}$; and $\sigma_{[r_t,F_{t_1,T_1}]}$ is the covariance between the return of the stock index between $t-1$ and t and the return $R_{F_{t_1,T_1}}$.

The investors create an optimal portfolio with the stock index and the futures contract. Each position includes: i) A speculative part in which their position on the stock index (futures contract) is first dedicated to speculation on the stock (futures). ii) A diversification part in which they adjust their position on the stock index (futures contract) according to their position on the other contract and its covariance. iii) A hedging part in which unlike in the article by Boons et al. [2014], the investors do not hedge their commodity risk entirely by using the futures contract but use the two assets according to their covariance.

For instance, if the covariance between the stock market index and the spot price of the commodity is null ($\sigma_{[r_t,s_t]} = 0$), then the investors hedge their commodity risk with the futures contract $(-\varphi_t \sigma^2_{r,t} \sigma_{[s_t, F_{t,t}]})$ and hedge the mismatch of their position on the futures contract with the stock market index $(\varphi_t \sigma_{[r_t, F_{t,t}]} \sigma_{[s_t, F_{t,t}]})$.

4.3.3 Optimal positions of unconstrained investors

This subsection addresses the second type of financialization. In this case, cross-asset investors trade on the futures markets without a constraint on the traded contracts. Empirically, Buyuksahin et al. [2009] justify this evolution after 2004 by the switch from backwardation to contango on the crude oil market[4]. This situation created important roll losses for the investors. Therefore, the set of investments available for the first generation is bigger than the one for the second generation. The profits at $t = 1$ and $t = 2$ for investors from the first and second generations are respectively $\pi_1 = w_1 R_{r_1} + \varphi_1 R_{s,1} + f^w_{1,1} R_{F_{1,1}} + f^w_{1,2} R_{F_{1,2}}$ and $\pi_2 = w_2 R_{r_2} + \varphi_2 R_{s,2} + f^w_{2,2} R_{F_{2,2}}$.

At $t = 1$, solving the problem (1) with profit $\pi_2 = w_2 R_{r_2} + \varphi_2 R_{s,2} + f^w_{2,2} R_{F_{2,2}}$ leads to the positions (10) and (11) at $t = 2$. These positions result because there is only one contract to trade at $t = 1$, and the investor lives for only one period.

At $t = 0$, solving the problem (1) with profit $\pi_1 = w_1 R_{r_1} + \varphi_1 R_{s,1} + f^w_{1,1} R_{F_{1,1}} + f^w_{1,2} R_{F_{1,2}}$ leads to optimal positions that are more complex versions of equations (10) and (11). However, these positions, which are displayed in Appendix B, contain the same elements: i) A speculative part where the position of the investor on the stock index (futures contracts) is first dedicated to speculation on the stock (futures). ii) A diversification part where the investor adjusts his position on the stock index (futures contracts) according to his position on the other contracts and their covariances. iii) A hedging part where the investor hedges his commodity risk using not only the futures contracts but the three available assets according to their covariances.

5 Pre- and post-financialization equilibria

This section contains the equilibrium analysis of the model before and after the financialization. The model is first solved for the pre-financialization economy, that is, without investors. Then, it is solved for the two post-financialization economies with constrained and unconstrained investors. This order provides the possibility to draw general results on the functioning of commodity markets when there is a term structure. Then, it shows exactly how these markets are affected by the entry of new investors. To solve the model, regardless of the economy, three futures markets at two dates have to be cleared, that is, at $t = 0$ the market for the contract maturing at $t = 1$ (front-month contract) and for the contract maturing at $t = 2$ (deferred contract), and at $t = 1$ the market for the contract maturing at $t = 2$ (the new front-month contract).

[4] Buyuksahin et al. [2009]: "(...) the growth of swap dealers' backdated positions accelerated in the second half of 2004 (at the time when the WTI futures market contangoed, after a long period of backwardation)."

5.1 Equilibrium pre-financialization

In pre-financialization, three types of market participants are trading on the futures markets: the N_s short-term speculators and the N_p short- and N_p long-term producers who are identical. The clearing equations are the following:

$$\begin{aligned} &\text{t=0, maturing in 1: } N_s f_{1,1}^{s\star} + N_p f_{1,1}^{p\star} = 0 \\ &\text{t=0, maturing in 2: } N_s f_{1,2}^{s\star} + N_p f_{1,2}^{p\star} = 0 \\ &\text{t=1, maturing in 2: } N_s \left(f_{2,2}^{s\star} - f_{1,2}^{s\star}\right) + N_p \left(f_{2,2}^{p\star} - f_{1,2}^{p\star}\right) = 0 \end{aligned}$$

Using the optimal positions of the agents from equations (2), (3), (4), (5), (6), and (8); the equilibrium expected returns or risk premia are:

$$\mu_{F_{1,1}}^{\star} = \frac{\lambda_p\gamma_p \left\{(\lambda_p+\lambda_s)\sigma_{2,2}^2 \left[\rho_{[1,11]}\left((\lambda_p+\lambda_s)\sigma_{1,1}^2\sigma_{1,2}^2 - \lambda_p\sigma_{[11,12]}^2\right) + \lambda_s\sigma_{1,1}^2\rho_{[2,12]}\sigma_{[11,12]}\right]\right.}{} \quad \frac{\left. -\lambda_s^2\sigma_{1,1}^2\sigma_{[11,12]}\sigma_{[12,22]}\rho_{[2,22]}\right\}}{(\lambda_p+\lambda_s)\sigma_{2,2}^2\left[(\lambda_p+\lambda_s)^2\sigma_{1,1}^2\sigma_{1,2}^2 - \lambda_p^2\sigma_{[11,12]}^2\right]} \tag{12a}$$

$$\mu_{F_{1,2}}^{\star} = \frac{\lambda_p\gamma_p \left\{(\lambda_p+\lambda_s)\sigma_{2,2}^2 \left[\rho_{[2,12]}\left((\lambda_p+\lambda_s)\sigma_{1,1}^2\sigma_{1,2}^2 - \lambda_p\sigma_{[11,12]}^2\right) + \lambda_s\sigma_{1,2}^2\rho_{[1,11]}\sigma_{[11,12]}\right]\right.}{} \quad \frac{\left. -\lambda_s\rho_{[2,22]}\sigma_{[12,22]}\left((\lambda_p+\lambda_s)\sigma_{1,1}^2\sigma_{1,2}^2 - \lambda_p\sigma_{[11,12]}^2\right)\right\}}{(\lambda_p+\lambda_s)\sigma_{2,2}^2\left[(\lambda_p+\lambda_s)^2\sigma_{1,1}^2\sigma_{1,2}^2 - \lambda_p^2\sigma_{[11,12]}^2\right]} \tag{12b}$$

$$\mu_{F_{2,2}}^{\star} = \frac{\lambda_p\gamma_p\rho_{[2,22]}}{(\lambda_p+\lambda_s)} \tag{12c}$$

where $\lambda_i = \frac{N_i}{\gamma_i}$ is the elasticity of agent i.

Result 1 synthesizes the main results from equations (12a), (12b), and (12c). Its two first points and the fourth one can be developed.

Result 1 (Pre-financialization risk premia)
Without investors, the risk premia: i) exist only if there are risk-averse producers ($\lambda_p \neq 0$ and $\gamma_p \neq 0$) in the markets with associated hedging pressures (covariances between the physical revenues and the returns of the futures prices); ii) can decrease or increase with the speculators (number and risk aversion) because of their diversification behavior; iii) depend on the riskiness of the futures contracts (variances) and on the link between the contracts (covariances); and iv) the front-month futures contract maturing at $t = 1$ is affected by the long-term variables.

First, the result i) is well-known in the literature on commodity markets and justifies the existence of a risk premium because of the hedging needs of the physical hedgers. This view of the risk premia on commodity futures markets has been initiated by the *theory of normal backwardation* (Keynes [1930]) and has been reinforced more recently by De Roon et al. [2000], Bessembinder and Lemmon [2002], and Ekeland et al. [2016b,a].

Second, the result ii) goes against most of the theoretical papers on the determinants of the risk premia using a mono-commodity framework (Anderson and Danthine [1983a] and Ekeland et al. [2016b,a]) which conclude that speculators by being a counterpart to the physical hedgers decrease the risk premia. This is not the case in my model because of the existence of a term structure of futures contracts. This term structure gives the opportunity to the speculator to trade both for speculative (as in the literature) and diversification reasons. Therefore, when the speculators trade to diversify their portfolios they might become consumers of liquidity and not providers. This result has been empirically illustrated by Kang et al. [2014].

Third, the result iv) goes against an important result of the *Market Segmentation Hypothesis* and complements the *Preferred Habitat Theory* of Modigliani and Sutch [1966]. Indeed, according to the former, because some agents naturally hedge in the short term and others in the long term, the two parts of the term structure should be governed by different state variables. According to the latter, the two parts of the curve should be integrated because the agents can move out of their preferred habitat if extreme differences exist. However, my result shows that even if producers stay in their preferred habitat, the risk premia are affected by the same state variables because of the speculators. Indeed, they play an important role in integrating the different parts of the term structure.

5.2 Equilibria post-financialization

In post-financialization, four types of market participants are trading on the futures markets: the N_s short-term speculators, the N_p short- and N_p long-term producers and the N_{in} (un)constrained investors. The clearing equations in the two types of financialization are:

With constrained investors:

$$\begin{aligned} &\text{t=0, maturing in 1: } N_s f_{1,1}^{s\star} + N_p f_{1,1}^{p\star} + N_{in} f_{1,1}^{w\star} = 0 \\ &\text{t=0, maturing in 2: } N_s f_{1,2}^{s\star} + N_p f_{1,2}^{p\star} = 0 \\ &\text{t=1, maturing in 2: } N_s \left(f_{2,2}^{s\star} - f_{1,2}^{s\star}\right) + N_p \left(f_{2,2}^{p\star} - f_{1,2}^{p\star}\right) + N_{in} f_{2,2}^{w\star} = 0 \end{aligned}$$

With unconstrained investors:

$$\begin{aligned} &\text{t=0, maturing in 1: } N_s f_{1,1}^{s\star} + N_p f_{1,1}^{p\star} + N_{in} f_{1,1}^{w\star} = 0 \\ &\text{t=0, maturing in 2: } N_s f_{1,2}^{s\star} + N_p f_{1,2}^{p\star} + N_{in} f_{1,2}^{w\star} = 0 \\ &\text{t=1, maturing in 2: } N_s \left(f_{2,2}^{s\star} - f_{1,2}^{s\star}\right) + N_p \left(f_{2,2}^{p\star} - f_{1,2}^{p\star}\right) + N_{in} \left(f_{2,2}^{w\star} - f_{1,2}^{w\star}\right) = 0 \end{aligned}$$

Results 2 and 3 synthesize the results obtained from the clearing of the markets with constrained and unconstrained investors respectively, using the optimal positions of the agents from equations (2), (3), (4), (5), (6), (8), (11), (16), and (17).

Result 2 (Risk premia with constrained investors)

With constrained investors, the risk premia for front-month contracts: i) are affected by the same factors as without investors (hedging pressure, number and risk aversion

of the traditional agents...); ii) can exist even without producers because of the hedging/speculative demand from investors; iii) can decrease or increase with the investors because of their hedging, speculative, and diversification demands; and iv) become dependent on financial variables (expected return, variance, and covariance with the stock index).
With constrained investors, the risk premium for the deferred contract: i) is affected by the same factors as without investors (hedging pressure, number and risk aversion of the traditional agents...); ii) can exist even without producers because of the hedging/speculative demand from investors; iii) can decrease or increase with the investors because of their hedging, speculative, and diversification demands; and iv) becomes dependent on financial variables (expected return, variance, and covariance with the stock index).

Equations (13a), (13b), and (13c) show the equilibrium expected returns with constrained investors and $\lambda_p = 0$. They are obtained from the clearing of the markets with constrained investors by using the optimal positions of the agents from equations (2), (3), (4), (5), (6), (8), and (11).

$$\mu_{F_{1,1}}^{\star,\lambda_p=0} = \frac{\lambda_{in}\sigma_{1,1}^2 \left\{\mu_{r_1}\sigma_{[r_1,F_{1,1}]} + \gamma_{in}\varphi_1\left(\sigma_{r,1}^2\sigma_{[s_1,F_{1,1}]} - \sigma_{[r_1,F_{1,1}]}\sigma_{[r_1,s_1]}\right)\right\}}{(\lambda_{in}+\lambda_s)\sigma_{1,1}^2\sigma_{r,1}^2 - \lambda_s\sigma_{[r_1,F_{1,1}]}^2} \tag{13a}$$

$$\mu_{F_{1,2}}^{\star,\lambda_p=0} = \frac{\lambda_{in}\sigma_{[11,12]} \left\{\mu_{r_1}\sigma_{[r_1,F_{1,1}]} + \gamma_{in}\varphi_1\left(\sigma_{r,1}^2\sigma_{[s_1,F_{1,1}]} - \sigma_{[r_1,F_{1,1}]}\sigma_{[r_1,s_1]}\right)\right\}}{(\lambda_{in}+\lambda_s)\sigma_{1,1}^2\sigma_{r,1}^2 - \lambda_s\sigma_{[r_1,F_{1,1}]}^2} \tag{13b}$$

$$\mu_{F_{2,2}}^{\star,\lambda_p=0} = \frac{\lambda_{in}\sigma_{2,2}^2 \left\{\mu_{r_2}\sigma_{[r_2,F_{2,2}]} + \gamma_{in}\varphi_2\left(\sigma_{r,2}^2\sigma_{[s_2,F_{2,2}]} - \sigma_{[r_2,F_{2,2}]}\sigma_{[r_2,s_2]}\right)\right\}}{(\lambda_{in}+\lambda_s)\sigma_{2,2}^2\sigma_{r,2}^2 - \lambda_s\sigma_{[r_2,F_{2,2}]}^2} \tag{13c}$$

The first part of Result 2 and Result 3 provide important results. That is, the determinants of the risk premia of the futures contracts that are traded by investors are different than those that are not. The points i) and iv) state that the risk premia are still subject to variables linked to the physical market and become subject to variables linked to the stock market. The most interesting result is that an investment pressure is associated with the trading of the investors. As shown by equations (13a) and (13c), as stated by the point ii) and as in Boons et al. [2014], this investment pressure leads to the existence of a risk premium even without risk-averse producers (and an associated hedging pressure). Moreover, these equations and the point iii) show that this investment pressure can either compensate (as in Hamilton and Wu [2014]) or reinforce the hedging pressure of the producers and then decrease or increase the risk premia. It is noteworthy that this investment pressure exists even without commodity risk ($\varphi_t = 0$) for the investors because of their diversification behavior.

Result 3 (Risk premia with unconstrained investors)
With unconstrained investors, the risk premia: i) are affected by the same factors as without investors (hedging pressure, number and risk aversion of the traditional agents...); ii) can exist even without producers, because of the hedging/speculative demand from investors; iii) can decrease or increase with the investors because of their hedging, speculative, and diversification demands; and iv) become dependent on financial variables (expected return, variance, and covariance with the stock index).

The second part of Result 2, illustrated by equation (13b), emphasizes the propagation effect of the financialization. It shows that, even without being traded by the investors, the deferred futures contract is affected by financial variables. This propagation is the consequence of the trading behavior of the speculators and the producers. In other words, the trading on the front-month contract by financial investors propagates to the entire term structure by the trading of the other agents. This idea of propagation to other contracts is the subject of an example in Hamilton and Wu [2014]. An interesting point in my model is that the intensity of the propagation depends on the level of integration of the term structure of prices. That is, a market like the crude oil market for which futures prices for different maturities tend to move together (important covariances) will see the effect of the investors propagate more rapidly than a market like the electricity market where futures prices for different maturities are more independent (small covariances) (see Section 7.1).

6 Numerical analysis of a representative market

This section, which is based on a calibrated version of the model, shows a quantification of the effect of financialization on the risk premia. This calibration is a static analysis to study the effect of the entry of new investors on a given specification of the market (ceteris paribus) and not a complete and dynamic analysis to study the effect of the entry of new investors on the specification of the market.

6.1 Calibration

Regarding the calibration, some parameters can be estimated using empirical data (e.g., variances and covariances). Some do not have an empirical counterpart and are chosen by assumption.

First, the parameters empirically estimated are gathered in Sub-table 1a. The estimation uses S&P500 prices as stock market parameters, prices of the WTI front-month contract as spot market parameters, prices of the WTI second nearby maturity as the parameters relative to the front-month contracts, and the prices of the WTI sixth maturity as the parameters relative to the deferred contract. The data are extracted from Datastream for the time period of January 2013 to February 2014. Moreover, the estimation relies on some assumptions: i) the descriptive statistics of the front-month contracts are stationary ($\sigma^2_{1,1} = \sigma^2_{2,2}$); ii) the descriptive statistics of the stock market are stationary ($\mu_{r_1} = \mu_{r_2}$ and $\sigma^2_{r,1} = \sigma^2_{r,2}$); and iii) the links between the different assets are stationary ($\sigma_{[r_1,F_{1,1}]} = \sigma_{[r_2,F_{2,2}]}$, $\sigma_{[s_1,F_{1,1}]} = \sigma_{[s_2,F_{2,2}]}$ and $\sigma_{[r_1,s_1]} = \sigma_{[r_2,s_2]}$).

More important than these values is that the parameters disclose some stylized facts about commodity futures markets. First, they show that the variance in the front-month contract is higher than that in the deferred contract ($\sigma^2_{1,1} = \sigma^2_{2,2} > \sigma^2_{1,2}$), which is known as the Samuelson effect (Samuelson [1965]). Second, they show that commodity markets are more volatile than the stock market ($\sigma^2_{1,1} = \sigma^2_{2,2} > \sigma^2_{r,1} = \sigma^2_{r,2}$). Third, these parameters show that the co-movement between the stock market and the commodity market is low compared to the co-movement between different maturities of the same commodity ($\sigma_{[s_1,F_{1,1}]} = \sigma_{[s_2,F_{2,2}]} > \sigma_{[r_1,s_1]} = \sigma_{[r_2,s_2]}$).

Parameters	Description	Value
$\sigma^2_{1,1}$, $\sigma^2_{2,2}$	Variance of the front-month futures contract	1.25
$\sigma^2_{1,2}$	Variance of the deferred futures contract	.98
$\sigma_{[11,12]}$	Cov between the front-month and the deferred futures contracts	1.07
μ_{r_1}, μ_{r_2}	Expected return of the stock market index	0.08
$\sigma^2_{r,1}$, $\sigma^2_{r,2}$	Variance of the return of the stock market index	.5
$\sigma_{[r_1,F_{1,1}]}$, $\sigma_{[r_2,F_{2,2}]}$	Cov between the front-month contract and the stock market	.31
$\sigma_{[r_1,F_{1,2}]}$	Cov between the deferred contract and the stock market	.29
$\sigma_{[s_1,F_{1,1}]}$, $\sigma_{[s_2,F_{2,2}]}$	Cov between the front-month contract and the spot market	1.26
$\sigma_{[s_1,F_{1,2}]}$	Cov between the deferred contract and the spot market	1.06
$\sigma_{[r_1,s_1]}$, $\sigma_{[r_2,s_2]}$	Cov between the spot and the stock markets	.3

(a) Empirically estimated parameters

Parameters	Description	Value
$\sigma_{[11,22]}$, $\sigma_{[12,22]}$	Cov between non-contemporaneous futures contracts	0
$\rho_{[1,11]}$, $\rho_{[2,22]}$	Cov between the physical revenue and the front-month contract	1
$\rho_{[1,12]}$	Cov between the physical revenue and the deferred contract	.7
$\rho_{[2,11]}$, $\rho_{[2,12]}$	Cov between the physical revenue and non-contemporaneous futures contracts	0
φ_1, φ_2	Commodity risk of the investors	-2
γ_i, γ_p, γ_s	Risk aversion of the agents	1
λ_s	Elasticity of the speculators	2

(b) Other parameters

This table provides the description for each parameter and its value in the numerical analysis. Sub-table (a) contains the empirically estimated parameters, and Sub-table (b) contains the parameters whose values are based on assumptions. The estimation uses S&P500 prices as the stock market parameters, prices of the WTI front-month contract as the spot market parameters, prices of the WTI second nearby maturity as the parameters relative to the front-month contracts, and the prices of the WTI sixth maturity as the parameters relative to the deferred contract for the time period of January 2013 to February 2014.

Table 1: Parameters of the numerical analysis

Second, the values of the other parameters presented in Sub-table 1b are based on assumptions. The principal assumptions are: i) the covariances between non-contemporaneous futures contracts are null ($\sigma_{[11,22]} = \sigma_{[12,22]} = 0$); ii) the covariances between the physical revenues and non-contemporaneous futures contracts are null ($\rho_{[2,11]} = \rho_{[2,12]} = 0$); iii) the covariance between the physical revenue and the front-month contract is stationary ($\rho_{[1,11]} = \rho_{[2,22]}$); and iv) the commodity risk of the investors is stationary ($\varphi_1 = \varphi_2$).

The values of the remaining parameters are based on arbitrary choices but their signs are important. The parameters $\rho_{[1,11]}$, $\rho_{[1,12]}$, and $\rho_{[2,22]}$ determine the hedging pressure on the model and are assumed to be positive in accordance with the *theory of normal backwardation*. Thus, the covariances with the front-month contract are set to one and the covariance with the deferred contract is assumed to be lower than the two others at

0.7. The parameters φ_1 and φ_2 that determine the commodity exposure of the investors are assumed to be negative as in Boons et al. [2014] because of the existence of an inflation risk for the investors.

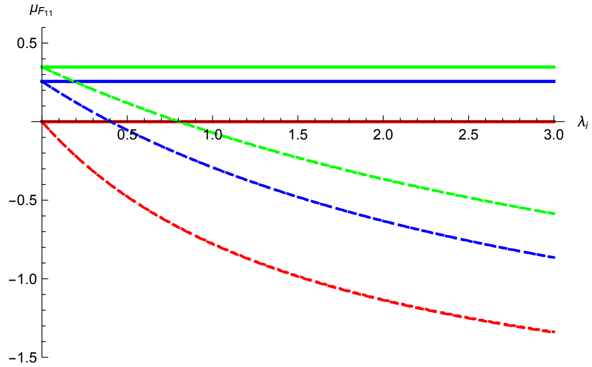
6.2 Risk premia contract by contract

Using the parameters in Section 6.1, I look at the expected returns as functions of the number of investors for different numbers of producers.

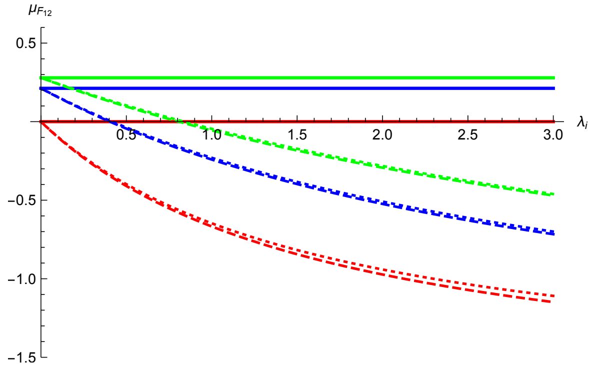
Figure 1 shows for the three futures contracts the associated risk premia pre- and post-financialization (with constrained and unconstrained investors). This figure illustrates Results 1, 2, and 3 and shows the following general results: i) In pre-financialization without producers (red solid lines), there is no risk premium. However, when there are producers (blue and green solid lines), then the risk premia are positive, increase with the elasticity of the producers, and are independent of the elasticity of the investors (λ_{in}). ii) In post-financialization (dashed and dotted lines), if there are no investors ($\lambda_{in} = 0$), then the risk premia are the same as in pre-financialization. iii) In post-financialization, without producers and with investors (dashed and dotted red lines), there are negative risk premia because of the choice of the commodity exposure. These risk premia increase in absolute value with the elasticity of the investors (λ_{in}). iv) In post-financialization, the combined effect of the producers' hedging pressure and the investors' investment pressure leads to a decrease in the absolute value of the risk premia when the elasticity of both increases. The reasoning behind this finding is because each has an opposite exposure to the commodity. Section 7.2 shows that this is also the case when producers and investors have the same exposure to the commodity.

By describing lower and most of the time negative post-financialization risk premia, Figure 1 confirms the empirical results of Hamilton and Wu [2014] regarding the level of the risk premia pre- and post-financialization. According to these authors, a positive risk premium is associated to the holding of the front-month futures contract before 2005. However, after 2005, the risk premium is lower and even sometimes negative. Moreover, my results show that when the market is characterized by a bigger investment industry (λ_{in}) than a producing industry (λ_p), then the negative risk premia reach more important levels in absolute values. In other words, the investment pressure does more than compensate for the hedging pressure.

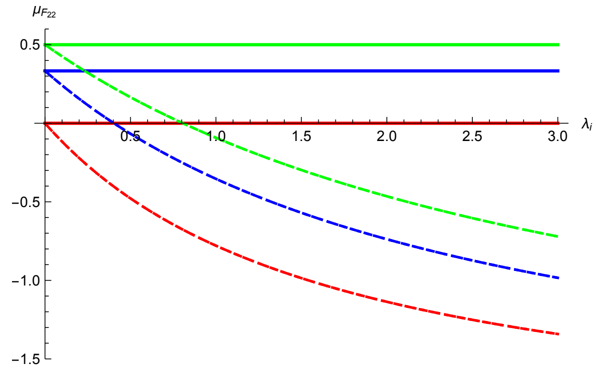
Finally, the effects of the financialization on the risk premia with constrained and unconstrained investors are very close (dashed versus dotted lines). There is only a small difference for the deferred contract. This result is driven by the important integration of the different maturities along the term structure of the prices (important covariance). This integration implies that the trading of some futures contracts of the term structure by financial investors propagates to all of the other existing contracts.



(a) $\mu_{F_{1,1}}$



(b) $\mu_{F_{1,2}}$



(c) $\mu_{F_{2,2}}$

This figure shows for each futures contract (Sub-tables) the associated risk premium before and after the financialization, as a function of the number of investors for three different numbers of producers. The red lines are for $\lambda_p = 0$, the blue lines are for $\lambda_p = 1$, and the green lines are for $\lambda_p = 2$. The thick lines are for the pre-financialization, the dashed lines are for the financialization with constrained investors, and the dotted lines are for the financialization with unconstrained investors. The charts are obtained using the estimated parameters described in Section 6.1.

Figure 1: Risk premia

6.3 The term structure of risk premia

This section focuses on the study of the effect of financialization on the term structure of the risk premia. Figure 2 shows the term structure of risk premia before and after financialization. In pre-financialization (blue line), it shows the following: i) The term structure of the risk premia is downward sloping (backwardation), that is, at $t = 0$, the risk premium of the front-month contract is higher than that of the deferred contract. ii) The steepness of the term structure of the risk premia is independent of the investors. In post-financialization, it shows that: i) When the number of investors is smaller relative to the number of producers (black lines), then the term structure of the risk premia flattens. ii) When the number of investors is larger relative to the number of producers (orange lines), then the term structure of the risk premia is in contango (upward sloping term structure with negative risk premia) and steeper. iii) Because of the high level of integration of the market under consideration, the steepness of the term structure of the risk premia is roughly the same with constrained (dashed lines) and unconstrained investors (dotted lines).

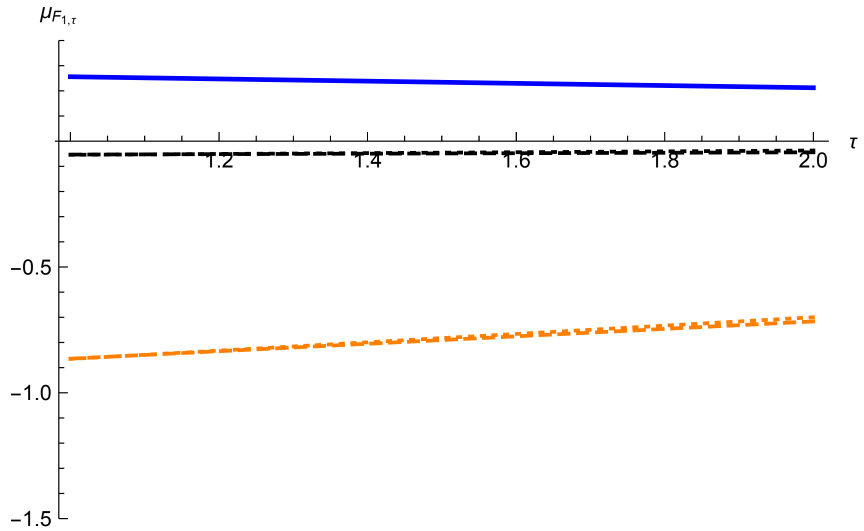
In other words, before financialization, the term structure of the risk premia is downward sloping because the front-month contract is the one most used for hedging by producers. Then, after financialization, as long as the investors remain a small group of participants in the market they help to flatten the term structure by absorbing the producers' hedging pressure. In contrast, as soon as they become more important, their investment pressure overcompensates for the producers' hedging pressure on the front month-contract. As a consequence, the term structure of the risk premia goes from backwardation to contango and becomes steeper. This result is driven by the fact that the front month futures contract is the most correlated with the physical revenue and then the one mainly used for hedging and trading.

The slope of the term structure of risk premia can be interpreted in terms of prices: $\mu_{F_{1,1}} = E_0[S_1] - F_{0,1}$ and $\mu_{F_{1,2}} = E_0[S_2] - F_{0,2}$, then:

$$\begin{aligned} \mu_{F_{1,1}} - \mu_{F_{1,2}} &= E_0[S_1] - F_{0,1} - E_0[S_2] + F_{0,2} \\ &= F_{0,2} - F_{0,1} + E_0[S_1 - S_2] \\ &= Basis - E_0[\Delta S] \end{aligned} \tag{14}$$

As explained in Section 3, the spot price S_t depends on the available quantity on the spot market which comes entirely from random production $\tilde{q}_t$. There are no inventories at play. Next, assuming that the random productions $\tilde{q}_t$ at $t = 1, 2$ have the same Gaussian distribution, then $E_0[S_1] = E_0[S_2]$ and $E_0[\Delta S] = 0$. Therefore, the term structure of the risk premia gives information on the term structure of the prices.

Under the assumptions of this section, the term structure of prices is in contango before the financialization. Then, according to the relative importance of the cross-asset investors, the term structure of prices can stay in contango and flatten or switch to backwardation with the financialization. This is because the front-month contract is the most relevant to use for trading. As a consequence, before financialization the producers sell more front-month contracts than deferred contracts and their price becomes lower.



This figure shows the term structure of risk premia before and after financialization for a given number of producers ($\lambda_p = 1$). The blue line is for the pre-financialization economy ($\lambda_{in} = 0$), the black lines are for the post-financialization economies with $\lambda_{in} = 0.5$, and the orange lines are for the post-financialization economies with $\lambda_{in} = 3$. The dashed lines are for the financialization with constrained investors, and the dotted lines are for the financialization with unconstrained investors. The charts are obtained using the estimated parameters described in Section 6.1.

Figure 2: Term structure of risk premia

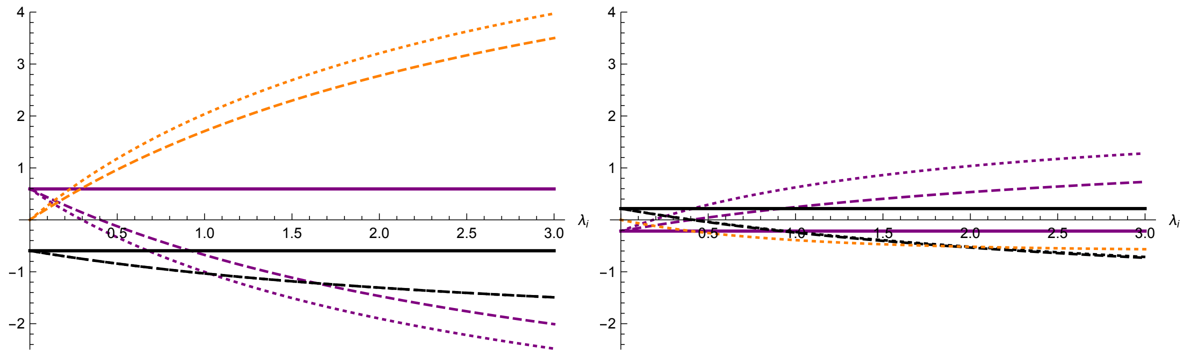
After the financialization, the cross-asset investors buy more front-month than deferred contracts and they become more expensive. This result describes only a partial effect and goes against the conclusion of Baker [2016] who states that backwardation should decrease with financialization. This contrast is because my model focuses on the effect of the hedging pressure on futures prices without taking into account any dynamic storage behavior.

Overall, my model features term structures of prices and risk premia with opposite shapes. That is, in pre-financialization, a term structure of prices in contango is associated with a term structure of risk premia in backwardation. The reverse is true post-financialization. Moreover, the model emphasizes that the financialization does affect the shape of the term structure of risk premia (and prices).

6.4 Liquidity provision by the agents

This subsection aims to study the role of each type of agent as a provider or consumer of liquidity in the futures market. The traditional view of commodity markets is that speculators provide liquidity to hedgers in exchange for a risk premium. As a consequence, as in Ekeland et al. [2016b,a] when the competition between speculators increases, then the risk premium decreases. However, financialization poses an empirical challenge to this view.

Figure 3 shows the aggregated optimal positions of the agents pre- and post-financialization for the front-month and deferred contracts at $t = 0$. Generally, trading volumes are more important for the front-month contract than for the deferred contract. This is a well-



(a) $\mu_{F_{1,1}}$ (b) $\mu_{F_{1,2}}$

This figure shows the associated aggregated optimal positions of the agents before and after the financialization for each futures contract of the first period (Sub-tables) as a function of the number of investors. The purple lines are for speculators, the black lines for producers, and the orange lines for investors. The thick lines are for the pre-financialization, the dashed lines are for the financialization with constrained investors, and the dotted lines for the financialization with unconstrained investors. The charts are obtained using the estimated parameters described in Section 6.1 and $\lambda_p = 1$.

Figure 3: Aggregated positions by category of agent

known feature of the term structure of commodity prices.

First, in the pre-financialization economy (solid lines), producers always sell front-month futures contracts (black solid line in Figure 3a). This is in agreement with their natural long exposure to the commodity. Therefore, speculators act as liquidity providers by buying futures contracts (purple solid line). In contrast, hedgers buy deferred futures contracts (black solid line in Figure 3b). By taking this position that is opposite to their hedging needs, they provide liquidity to speculators. These speculators ask for liquidity in the futures contracts in order to create optimal well-diversified portfolios. This result, in contradiction with the traditional view, has been empirically illustrated by Kang et al. [2014]. They show that hedgers provide short-term liquidity to the futures market and then to speculators.

Then, with financialization (dashed and dotted lines), investors massively buy front-month futures contracts (orange lines in Figure 3a). As a consequence, when the number of investors increases, producers sell more and more futures contracts (dashed and dotted black lines), and speculators stop buying futures contracts to sell them (dashed and dotted purple lines). This feature has been empirically illustrated by Cheng and Xiong [2014]. They show that the entry of CITs into agricultural futures markets has resulted in an important expansion in the long side of the market. And that, as a consequence, producers have expanded their short positions.

Finally, with financialization, speculators buy more and more deferred contracts (dashed and dotted purple lines in Figure 3b). Their strategy is to hedge their position in the front-month contract with the deferred contract and therefore ask for liquidity on this contract to hedgers and investors.

These results show that, both pre- and post-financialization, the traditional view of commodity futures markets as places where hedgers find liquidity is incomplete. Under some circumstances, hedgers may have to provide liquidity to speculators and investors.

This is the case because they have other trading motives than providing liquidity to hedgers.

7 Heterogeneity of commodity markets and the financialization

This section aims to emphasize that the quantitative effects of financialization are market specific. To do so, I study two specific cases by changing some of the parameters. Changing these parameters is equivalent to studying a market with different physical characteristics.

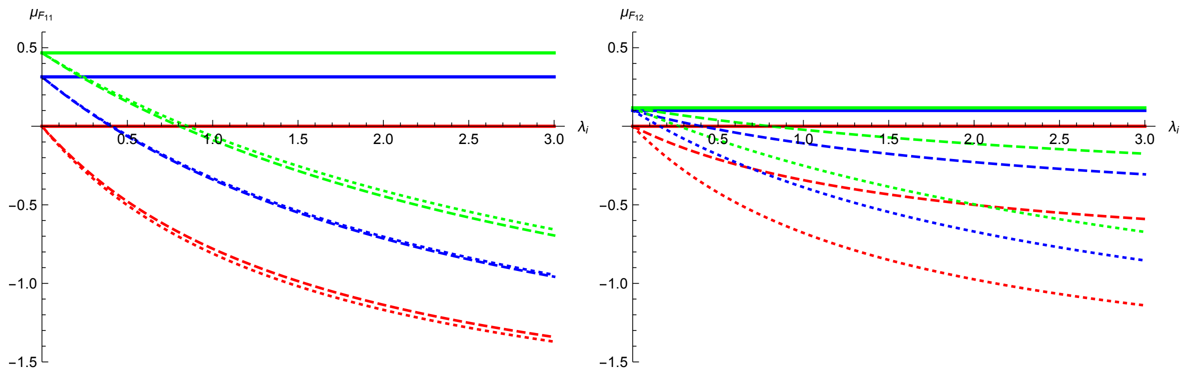
7.1 Non-integrated markets

Up to know, most of the results are identical (or at least close) when I consider constrained and unconstrained investors. This is the case because the model is calibrated with futures prices for the crude oil futures market. This market is characterized by a high level of temporal integration (an important covariance between the futures prices of different maturities). Some markets, like the electricity market tend to be less integrated (a small covariance between the futures prices of different maturities)[5]. This subsection shows that on these markets, the effect of financialization on non-traded futures contracts is different.

In the basic set of estimated parameters, the correlation between the front-month and deferred futures contracts ($\frac{\sigma_{[11,12]}}{\sqrt{\sigma_{1,1}^2}\sqrt{\sigma_{1,2}^2}}$) is approximately 0.96. For electricity futures markets, the correlation is around 0.5. Then, in order to see the effect of financialization in such a market, I set $\sigma_{[11,12]} = 0.55$. Without changing the level of variability in the market ($\sigma_{1,1}^2$ and $\sigma_{1,2}^2$), this covariance leads to a correlation equal to 0.5.

Figure 4 shows the expected returns for the front-month and deferred contracts at $t = 0$. It gives the following results: i) As for the integrated market, there is no difference in the effect of financialization on the front-month contract with constrained and unconstrained investors (dashed and dotted lines in Figure 4a). This effect is the same as the one described in the previous sections. ii) Contrary to what has been said for the integrated market, the effect on the risk premium of the deferred contract ($\mu_{F_{1,2}}$) is situation dependent. That is, the magnitude of the effect is less important with constrained (dashed lines in Figure 4b) than with unconstrained investors (dotted lines). More precisely, the risk premium in the first situation goes in the same direction (decreases and becomes negative) as in the second situation but it always stays smaller in absolute value. In general, the magnitude of the effect has two sources: an indirect propagation effect and a direct investment pressure effect. In this case the propagation effect is low because of the low integration of the different maturities, and the direct effect does not exist for the deferred contract with constrained investors.

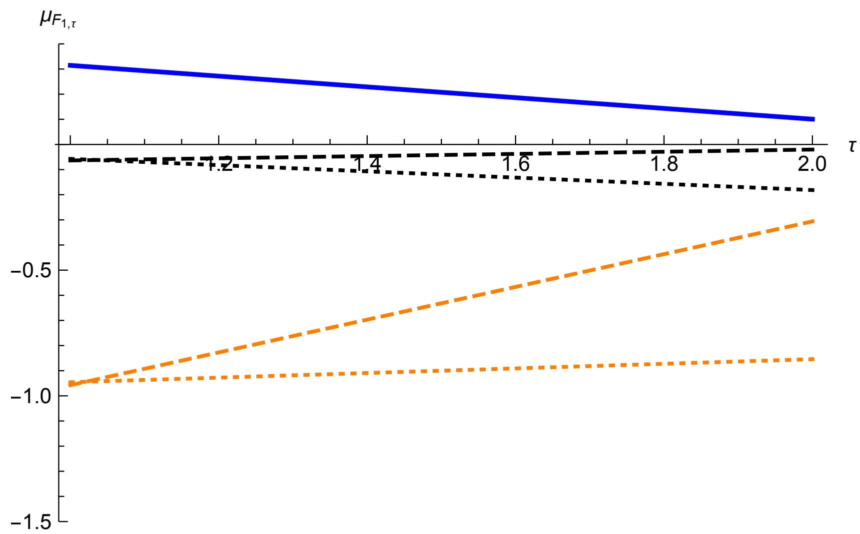
[5]See Jaeck and Lautier [2016] for an illustration of such differences in the level of integration of the term structures of futures prices between the crude oil market and electricity markets.



(a) $\mu_{F_{1,1}}$ (b) $\mu_{F_{1,2}}$

This figure shows the associated risk premia before and after the financialization for each futures contract of the first period (Sub-tables) as a function of the number of investors for three different numbers of producers. The red lines are for $\lambda_p = 0$, the blue lines are for $\lambda_p = 1$, and the green lines are for $\lambda_p = 2$. The thick lines are for the pre-financialization, the dashed lines are for the financialization with constrained investors, and the dotted lines are for the financialization with unconstrained investors. The charts are obtained by using the estimated parameters described in Section 6.1 except for the covariance between the two contemporaneous futures contracts which becomes $\sigma_{[11,12]} = 0.55$.

Figure 4: Risk premia (non-integrated market)



This figure shows the term structure of risk premia before and after financialization for a given number of producers ($\lambda_p = 1$). The blue line is for the pre-financialization economy ($\lambda_{in} = 0$), the black lines are for the post-financialization economies with $\lambda_{in} = 0.5$, and the orange lines are for the post-financialization economies with $\lambda_{in} = 3$. The dashed lines are for the financialization with constrained investors, and the dotted lines are for the financialization with unconstrained investors. The charts are obtained by using the estimated parameters described in Section 6.1 except for the covariance between the two contemporaneous futures contracts which becomes $\sigma_{[11,12]} = 0.55$.

Figure 5: Term structure of risk premia (non-integrated market)

Figure 5 represents the term structure of risk premia before (blue line) and after financialization (black and orange lines). It shows that the evolution of the shape of the term structure with unconstrained investors (dotted lines) stays roughly the same as described in Section 6.3 for the integrated market. In contrast, it changes dramatically with constrained investors (dashed lines). In the latter situation, the steepness of the term structure of the risk premia is much more important than with unconstrained investors. Indeed, the slope of the term structure can be up to three or four times in absolute value above the level with unconstrained investors. This result can be explained by the important direct investment pressure from constrained investors on the front-month contract which decreases its risk premium ($\mu_{F_{1,1}}$). Whereas the risk premium ($\mu_{F_{1,2}}$) of the deferred contract changes only through the diversification behavior of the agents. But because the market is not very integrated, the transmission of the shock (the entry of new investors) is slow.

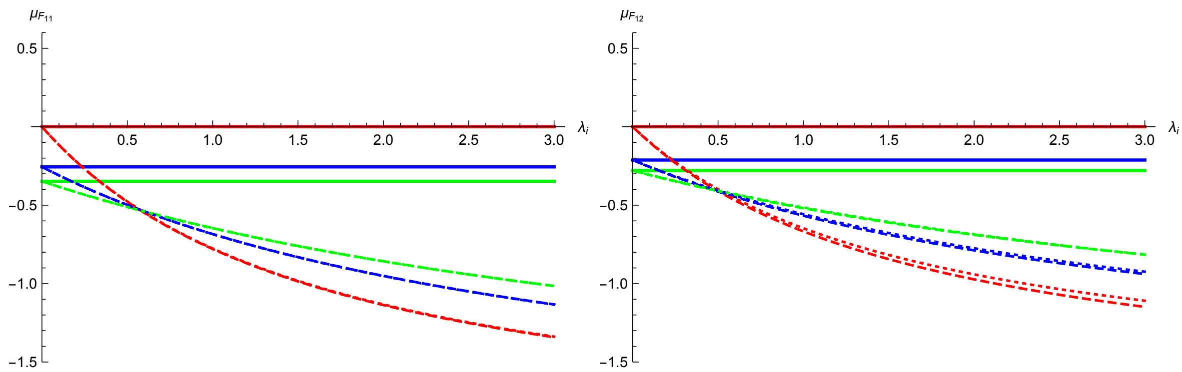
Overall, it seems that financialization reinforces the non-integration of the market when only constrained investors enter the market and does not change it when unconstrained investors enter the market.

7.2 Markets dominated by long hedgers

So far, the results are based on the assumption that commodity markets are mainly used by short hedgers as described by the *theory of normal backwardation* (Keynes [1930]). Nevertheless, as emphasized by De Roon et al. [2000], the *hedging pressure theory* states that there are substantial variations inside each commodity market and from market to market in the level and the sign of the hedging pressure. Assuming a negative covariance between the physical revenue of the producers and the futures prices ($\rho_{[1,11]} < 0$, $\rho_{[1,12]} < 0$ and $\rho_{[2,22]} < 0$), this subsection shows how a commodity market dominated by long hedgers reacts to the introduction of new (un)constrained investors.

Compared to the basic set of estimated parameters, I change the sign of the relevant parameters without changing their absolute value. Therefore, this subsection uses $\rho_{[1,11]} = -1$, $\rho_{[1,12]} = -0.7$, and $\rho_{[2,22]} = -1$.

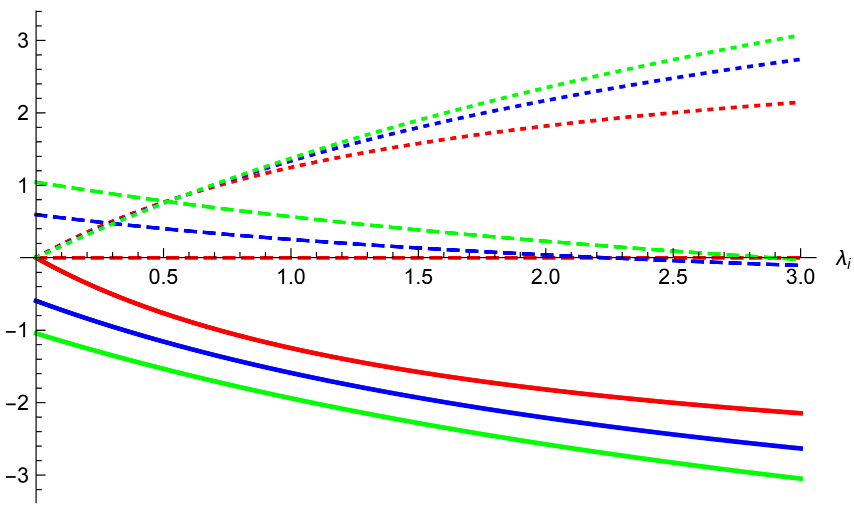
Figure 6 describes the risk premia for the front-month and deferred contracts at $t = 0$ when the futures market is dominated by long hedgers. It shows that: i) In pre-financialization (solid lines), risk premia are negative and increase in absolute value as the number of producers λ_p increases. Producers in this situation have a negative exposure to the commodity (they lose money when the price increases) and then buy the futures contract. Because of that, the futures price increases and becomes bigger than the expected spot price. ii) In post-financialization (dashed and dotted lines), the risk premia decrease in absolute value when both the number of producers (λ_p) and the number of investors (λ_{in}) increase. This combined effect of the hedging and investment pressures is more unexpected. Indeed, because the risk premia increase in absolute value in the pre-financialization with the number of producers and that without producers the risk premia increase in absolute value with the number of investors, maybe the hedging pressure and the investment pressure should have reinforced each other.



(a) $\mu_{F_{1,1}}$ (b) $\mu_{F_{1,2}}$

This figure shows the associated risk premia before and after financialization for each futures contract of the first period (Sub-tables) as a function of the number of investors for three different numbers of producers. The red lines are for $\lambda_p = 0$, the blue lines are for $\lambda_p = 1$, and the green lines are for $\lambda_p = 2$. The thick lines are for the pre-financialization, the dashed lines are for the financialization with constrained investors, and the dotted lines are for the financialization with unconstrained investors. The charts are obtained by using the estimated parameters described in Section 6.1 except for the covariances between the physical revenue of the producers and the futures prices which become $\rho_{[1,11]} = -1$, $\rho_{[1,12]} = -0.7$, and $\rho_{[2,22]} = -1$.

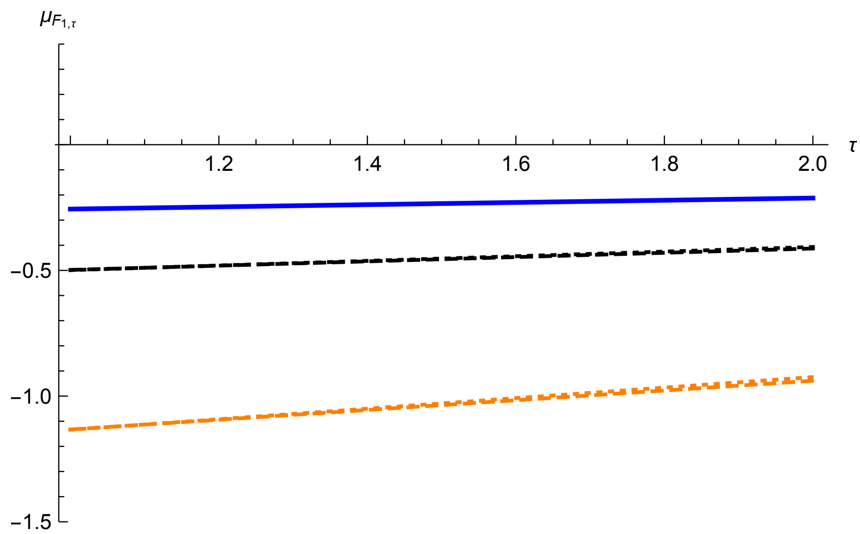
Figure 6: Risk premia (long hedgers)



This figure shows the aggregated optimal positions of the agents for the front-month futures contract at $t = 0$ with constrained investors as a function of the number of investors for three different numbers of producers. The red lines are for $\lambda_p = 0$, the blue lines are for $\lambda_p = 1$, and the green lines are for $\lambda_p = 2$. The solid lines are for the speculators, the dashed line are for the producers, and the dotted lines are for the constrained investors. The charts are obtained by using the estimated parameters described in Section 6.1 except for the covariances between the physical revenue of the producers and the futures prices which become $\rho_{[1,11]} = -1$, $\rho_{[1,12]} = -0.7$, and $\rho_{[2,22]} = -1$.

Figure 7: Positions in the front-month contract with constrained investors (long hedgers)

Figure 7 gives more insight into what happens. It shows that the unexpected combined effect of the hedging pressure and of the investment pressure is due to the hedgers. As in Kang et al. [2014], they act as liquidity providers on the futures markets. Indeed, the aggregated optimal position of the producers (dashed lines) decreases when the aggregated position of the investors (dotted lines) increases. The adjustment of the futures position of the producers is even more important when there are more producers. When the number of investors is bigger than the number of producers, the latter hold a short futures position. This is the opposite of their hedging needs.



This figure shows the term structure of risk premia before and after financialization for a given number of producers ($\lambda_p = 1$). The blue line is for the pre-financialization economy ($\lambda_{in} = 0$), the black lines are for the post-financialization economies with $\lambda_{in} = 0.5$, and the orange lines are for the post-financialization economies with $\lambda_{in} = 3$. The dashed lines are for the financialization with constrained investors, and the dotted lines are for the financialization with unconstrained investors. The charts are obtained by using the estimated parameters described in Section 6.1 except for the covariances between the physical revenue of the producers and the futures prices which become $\rho_{[1,11]} = -1$, $\rho_{[1,12]} = -0.7$, and $\rho_{[2,22]} = -1$.

Figure 8: Term structure of risk premia (long hedgers)

Figure 8 represents the term structure of risk premia before (blue line) and after financialization (black and orange lines). It shows that the term structure of the risk premia is always upward sloping (contago). Further, in post-financialization, the term structure of the risk premia is always steeper than in pre-financialization. This was not the case previously and is a consequence of the hedging and investment pressures being on the same side of the market.

In term of prices, following the same reasoning as in Section 6.3, Figure 8 shows that when the futures market is dominated by long hedgers, the term structure of prices is always in backwardation. Moreover, the financialization increases the steepness of the term structure of the prices.

8 Conclusion

I develop an equilibrium model of commodity futures markets in which traditional risk-averse agents (producers and speculators) face new cross-asset investors. Because it features a term structure of futures prices, I first extend to this framework the results regarding the functioning of commodity markets before financialization. For instance, I emphasize the role of speculators as both providers and consumers of liquidity and their role in the integration of the risk premia along the term structure. Then, I show that the financialization changes the nature of commodity markets, at least by changing their risk sharing function. Indeed, they become less segmented from the stock market, and the investment pressure from cross-asset investors becomes an important determinant of the risk premia. Moreover, my analysis shows that all of the existing maturities on a futures market are affected by the financialization, even in a context of a short-term constrained investment. This propagation effect depends on the market under consideration because it depends on the integration of the futures prices for different maturities.

The economic implications of the financialization are: that the cost of hedging of traditional hedgers is greatly affected, that the shape of the term structure of risk premia (and of prices) changes, that speculators can face more competition from investors to earn the risk premium from the hedging pressure of the hedgers but can also have new profit opportunities when the investment pressure from investors is important, and that there is more efficient risk sharing because of the decreased fragmentation of the markets, but this may create stronger spillover effects. Regulators need to take this into account when monitoring the systemic risk of the system.

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A Appendix: Notations

Regarding the futures market:

- Position of the agent i between $t-1$ and t in a futures contract with maturity T: $f^i_{t,T}$
- Return between $t-1$ and t of a futures contract with maturity T: $R_{F_{t,T}}$
- Expected return between $t-1$ and t of a futures contract with maturity T: $\mu_{F_{t,T}}$
- Variance between $t-1$ and t of the return a futures contract with maturity T: $\sigma^2_{t,T}$
- Covariance between the returns of the two futures contracts $R_{F_{t_1,T_1}}$ and $R_{F_{t_2,T_2}}$: $\sigma_{[t_1T_1,t_2T_2]}$
- Elasticity of the agent i: $\lambda_i = \frac{N_i}{\gamma_i}$

Regarding the spot market:

- Return between $t-1$ and t of the spot commodity: $R_{s,t}$
- Variance between $t-1$ and t of the spot commodity: $\sigma^2_{s,t}$
- Commodity risk in t of an investor: φ_t

Regarding the stock market:

- Return between $t-1$ and t of a stock: R_{r_t}
- Expected return between $t-1$ and t of a stock: μ_{r_t}
- Variance between $t-1$ and t of the return a stock: $\sigma^2_{r,t}$

Regarding the link between assets:

- Covariance between the spot return between $t-1$ and t and the return of the futures contract $R_{F_{t_1,T_1}}$: $\sigma_{[s_t,F_{t_1,T_1}]}$
- Covariance between the physical revenue between $t-1$ and t and the return of the futures contract $R_{F_{t_1,T_1}}$: $\rho_{[t,t_1T_1]}$
- Covariance between the return of the stock and the return of the futures contract $R_{F_{t_1,T_1}}$: $\sigma_{[r_t,F_{t_1,T_1}]}$
- Covariance between the return of the stock and of the spot commodity between $t-1$ and t: $\sigma_{[r_t,s_t]}$

B Appendix: Optimal positions of unconstrained investors

This appendix shows the optimal positions at $t = 0$ in each asset of an unconstrained investor. They are obtained by solving the problem (1) with profit $\pi_1 = w_1 R_{r_1} + \varphi_1 R_{s,1} + f^w_{1,1} R_{F_{1,1}} + f^w_{1,2} R_{F_{1,2}}$.

$$w_1^\star = \frac{\mu_{r_1}(\sigma^2_{1,1}\sigma^2_{1,2} - \sigma^2_{[11,12]}) + \mu_{F_{1,1}}(\sigma_{[11,12]}\sigma_{[r_1,F_{1,2}]} - \sigma^2_{1,2}\sigma_{[r_1,F_{1,1}]}) + \mu_{F_{1,2}}(\sigma_{[11,12]}\sigma_{[r_1,F_{1,1}]} - \sigma^2_{1,1}\sigma_{[r_1,F_{1,2}]})}{\gamma_{in}\left(2\sigma_{[11,12]}\sigma_{[r_1,F_{1,1}]}\sigma_{[r_1,F_{1,2}]} + \sigma^2_{1,1}(\sigma^2_{1,2}\sigma^2_{r,1} - \sigma^2_{[r_1,F_{1,2}]}) - \sigma^2_{[11,12]}\sigma^2_{r,1} - \sigma^2_{1,2}\sigma^2_{[r_1,F_{1,1}]}\right)}$$
$$+ \frac{\varphi_1\left\{\sigma^2_{1,1}\sigma_{[r_1,F_{1,2}]}\sigma_{[s_1,F_{1,2}]} - \sigma_{[11,12]}(\sigma_{[r_1,F_{1,2}]}\sigma_{[s_1,F_{1,1}]} + \sigma_{[r_1,F_{1,1}]}\sigma_{[s_1,F_{1,2}]}) + \sigma^2_{[11,12]}\sigma_{[r_1,s_1]}\right.}{\left(2\sigma_{[11,12]}\sigma_{[r_1,F_{1,1}]}\sigma_{[r_1,F_{1,2}]} + \sigma^2_{1,1}(\sigma^2_{1,2}\sigma^2_{r,1} - \sigma^2_{[r_1,F_{1,2}]}) - \sigma^2_{[11,12]}\sigma^2_{r,1} - \sigma^2_{1,2}\sigma^2_{[r_1,F_{1,1}]}\right)}$$
$$\frac{\left. + \sigma^2_{1,2}(\sigma_{[r_1,F_{1,1}]}\sigma_{[s_1,F_{1,1}]} - \sigma^2_{1,1}\sigma_{[r_1,s_1]})\right\}}{\left(2\sigma_{[11,12]}\sigma_{[r_1,F_{1,1}]}\sigma_{[r_1,F_{1,2}]} + \sigma^2_{1,1}(\sigma^2_{1,2}\sigma^2_{r,1} - \sigma^2_{[r_1,F_{1,2}]}) - \sigma^2_{[11,12]}\sigma^2_{r,1} - \sigma^2_{1,2}\sigma^2_{[r_1,F_{1,1}]}\right)} \tag{15}$$

$$f^{w\star}_{1,1} = \frac{\mu_{F_{1,1}}(\sigma^2_{1,2}\sigma^2_{r,1} - \sigma^2_{[r_1,F_{1,2}]}) + \mu_{r_1}(\sigma_{[11,12]}\sigma_{[r_1,F_{1,2}]} - \sigma^2_{1,2}\sigma_{[r_1,F_{1,1}]}) + \mu_{F_{1,2}}(\sigma_{[r_1,F_{1,1}]}\sigma_{[r_1,F_{1,2}]} - \sigma_{[11,12]}\sigma^2_{r,1})}{\gamma_{in}\left(2\sigma_{[11,12]}\sigma_{[r_1,F_{1,1}]}\sigma_{[r_1,F_{1,2}]} + \sigma^2_{1,1}(\sigma^2_{1,2}\sigma^2_{r,1} - \sigma^2_{[r_1,F_{1,2}]}) - \sigma^2_{[11,12]}\sigma^2_{r,1} - \sigma^2_{1,2}\sigma^2_{[r_1,F_{1,1}]}\right)}$$
$$+ \frac{\varphi_1\left\{\sigma^2_{r,1}\sigma_{[11,12]}\sigma_{[s_1,F_{1,2}]} - \sigma_{[r_1,F_{1,2}]}(\sigma_{[r_1,F_{1,1}]}\sigma_{[s_1,F_{1,2}]} + \sigma_{[11,12]}\sigma_{[r_1,s_1]}) + \sigma^2_{[r_1,F_{1,2}]}\sigma_{[s_1,F_{1,1}]}\right.}{\left(2\sigma_{[11,12]}\sigma_{[r_1,F_{1,1}]}\sigma_{[r_1,F_{1,2}]} + \sigma^2_{1,1}(\sigma^2_{1,2}\sigma^2_{r,1} - \sigma^2_{[r_1,F_{1,2}]}) - \sigma^2_{[11,12]}\sigma^2_{r,1} - \sigma^2_{1,2}\sigma^2_{[r_1,F_{1,1}]}\right)}$$
$$\frac{\left. + \sigma^2_{1,2}(\sigma_{[r_1,F_{1,1}]}\sigma_{[r_1,s_1]} - \sigma^2_{r,1}\sigma_{[s_1,F_{1,1}]})\right\}}{\left(2\sigma_{[11,12]}\sigma_{[r_1,F_{1,1}]}\sigma_{[r_1,F_{1,2}]} + \sigma^2_{1,1}(\sigma^2_{1,2}\sigma^2_{r,1} - \sigma^2_{[r_1,F_{1,2}]}) - \sigma^2_{[11,12]}\sigma^2_{r,1} - \sigma^2_{1,2}\sigma^2_{[r_1,F_{1,1}]}\right)} \tag{16}$$

$$f^{w\star}_{1,2} = \frac{\mu_{F_{1,2}}(\sigma^2_{1,1}\sigma^2_{r,1} - \sigma^2_{[r_1,F_{1,1}]}) + \mu_{r_1}(\sigma_{[11,12]}\sigma_{[r_1,F_{1,1}]} - \sigma^2_{1,1}\sigma_{[r_1,F_{1,2}]}) + \mu_{F_{1,1}}(\sigma_{[r_1,F_{1,1}]}\sigma_{[r_1,F_{1,2}]} - \sigma_{[11,12]}\sigma^2_{r,1})}{\gamma_{in}\left(2\sigma_{[11,12]}\sigma_{[r_1,F_{1,1}]}\sigma_{[r_1,F_{1,2}]} + \sigma^2_{1,1}(\sigma^2_{1,2}\sigma^2_{r,1} - \sigma^2_{[r_1,F_{1,2}]}) - \sigma^2_{[11,12]}\sigma^2_{r,1} - \sigma^2_{1,2}\sigma^2_{[r_1,F_{1,1}]}\right)}$$
$$+ \frac{\varphi_1\left\{\sigma^2_{r,1}\sigma_{[11,12]}\sigma_{[s_1,F_{1,1}]} - \sigma_{[r_1,F_{1,1}]}(\sigma_{[r_1,F_{1,2}]}\sigma_{[s_1,F_{1,1}]} + \sigma_{[11,12]}\sigma_{[r_1,s_1]}) + \sigma^2_{[r_1,F_{1,2}]}\sigma_{[s_1,F_{1,2}]}\right.}{\left(2\sigma_{[11,12]}\sigma_{[r_1,F_{1,1}]}\sigma_{[r_1,F_{1,2}]} + \sigma^2_{1,1}(\sigma^2_{1,2}\sigma^2_{r,1} - \sigma^2_{[r_1,F_{1,2}]}) - \sigma^2_{[11,12]}\sigma^2_{r,1} - \sigma^2_{1,2}\sigma^2_{[r_1,F_{1,1}]}\right)}$$
$$\frac{\left. + \sigma^2_{1,1}(\sigma_{[r_1,F_{1,2}]}\sigma_{[r_1,s_1]} - \sigma^2_{r,1}\sigma_{[s_1,F_{1,2}]})\right\}}{\left(2\sigma_{[11,12]}\sigma_{[r_1,F_{1,1}]}\sigma_{[r_1,F_{1,2}]} + \sigma^2_{1,1}(\sigma^2_{1,2}\sigma^2_{r,1} - \sigma^2_{[r_1,F_{1,2}]}) - \sigma^2_{[11,12]}\sigma^2_{r,1} - \sigma^2_{1,2}\sigma^2_{[r_1,F_{1,1}]}\right)} \tag{17}$$

C Appendix: A model with frictionless producers

In this appendix I solve a different version of the model. In this version there is one population of long-term producers who live between $t = 0$ and $t = 2$ and can use the entire term structure to hedge their physical exposure to the commodity. This case is more general, but it supposes that producers have no trading frictions. Indeed, it induces important intertemporal diversification and hedging positions. Qualitatively, most of the results are the same as in the version of the model presented in Sections 4, 5, and 6. However, quantitatively they can differ.

In what follows I derive the optimal positions of the long-term producers. The optimal positions of the other agents are the same as in the previous version of the model. Then, I solve the model for the pre-financialization economy that is without investors. After that, I solve the model for the two types of investors (constrained and unconstrained).

C.1 Optimal position of the long-term frictionless producer

This version of the model is characterized by the existence of a long-term producer who lives at three dates and gets random productions $\tilde{q}_1$ and $\tilde{q}_2$ at $t = 1$ and $t = 2$. The producer can trade all futures contracts without constraints. The implied assumptions are that the liquidity is good enough for all the term structure or even that the producer does not face regulatory issues limiting his investment opportunities.

Because of the long-term horizon, the producer maximizes his expected utility at the final date $t = 2$ coming from the profit $\pi_2 = \pi_1 + \tilde{q}_2 R_{s,2} + R_{F_{2,2}} f^p_{2,2}$ with $\pi_1 = \tilde{q}_1 R_{s,1} + R_{F_{1,1}} f^p_{1,1} + R_{F_{1,2}} f^p_{1,2}$. I adopt a two-step backward reasoning by first solving the problem (1) for the producer at $t = 1$ over π_2 in order to find $f^{p\star}_{2,2}$ and then solve the problem (19) for the producer at $t = 0$ over π_2 to find $f^{p\star}_{1,1}$ and $f^{p\star}_{1,2}$ for the given optimal $f^{p\star}_{2,2}$.

At $t = 1$, the first step of the reasoning gives the following optimal position for the long-term producer:

$$f^{p\star}_{2,2} = \frac{\mu_{F_{2,2}}}{\gamma_p \sigma^2_{2,2}} - \frac{\rho_{[2,22]}}{\sigma^2_{2,2}} \tag{18}$$

This position is the same as the one at $t = 1$ of the long-term producer with a preferred habitat in Section 4.

At $t = 0$, the long-term agent solves the following program:

$$\max_{f^p_{1,1}, f^p_{1,2}} \; E_0[\pi_2] - \frac{\gamma_p}{2} Var_0[\pi_2] \tag{19}$$

Which leads to the following optimal positions:

$$f_{1,1}^{p\star} = \frac{\mu_{F_{1,1}}\sigma_{1,2}^2 - \mu_{F_{1,2}}\sigma_{[11,12]}}{\gamma_p(\sigma_{1,1}^2\sigma_{1,2}^2 - \sigma_{[11,12]}^2)} + \frac{\sigma_{[11,12]}\left\{\rho_{[2,12]} + \rho_{[1,12]}\right\} - \sigma_{1,2}^2\left\{\rho_{[2,11]} + \rho_{[1,11]}\right\}}{(\sigma_{1,1}^2\sigma_{1,2}^2 - \sigma_{[11,12]}^2)} + \frac{\mu_{F_{2,2}}(\sigma_{[12,22]}\sigma_{[11,12]} - \sigma_{[11,22]}\sigma_{1,2}^2) + \gamma_p\rho_{[2,22]}(\sigma_{[11,22]}\sigma_{1,2}^2 - \sigma_{[12,22]}\sigma_{[11,12]})}{\gamma_p\sigma_{2,2}^2(\sigma_{1,1}^2\sigma_{1,2}^2 - \sigma_{[11,12]}^2)} \tag{20a}$$

$$f_{1,2}^{p\star} = \frac{\mu_{F_{1,2}}\sigma_{1,1}^2 - \mu_{F_{1,1}}\sigma_{[11,12]}}{\gamma_p(\sigma_{1,1}^2\sigma_{1,2}^2 - \sigma_{[11,12]}^2)} + \frac{\sigma_{[11,12]}\left\{\rho_{[2,11]} + \rho_{[1,11]}\right\} - \sigma_{1,1}^2\left\{\rho_{[2,12]} + \rho_{[1,12]}\right\}}{(\sigma_{1,1}^2\sigma_{1,2}^2 - \sigma_{[11,12]}^2)} + \frac{\mu_{F_{2,2}}(\sigma_{[11,22]}\sigma_{[11,12]} - \sigma_{[12,22]}\sigma_{1,1}^2) + \gamma_p\rho_{[2,22]}(\sigma_{[12,22]}\sigma_{1,1}^2 - \sigma_{[11,22]}\sigma_{[11,12]})}{\gamma_p\sigma_{2,2}^2(\sigma_{1,1}^2\sigma_{1,2}^2 - \sigma_{[11,12]}^2)} \tag{20b}$$

These optimal positions are different than the ones at $t = 0$ of the producer with a preferred habitat in Section 4. They describe a sophisticated hedging behavior with strong speculative and diversification parts. The important result is that without any constraint (linked for instance to liquidity issues or to the regulatory framework), the producer should create an optimal portfolio of futures contracts for hedging purposes which embeds speculative and diversification positions. More precisely, there are two kinds of diversification and hedging in these positions: at the same period and intertemporal between $t = 1$ and $t = 2$.

C.2 Pre- and post-financialization equilibria

C.2.1 Pre-financialization: clearing of the futures markets without investors

The clearing of the futures markets in the pre-financialization is the simplest case with only two types of market participants: the N_s short-term speculators and the N_p long-term producers. The clearing equations are the following:

$$\begin{aligned}
&\text{t=0, maturing in 1: } N_s f_{1,1}^{s\star} + N_p f_{1,1}^{p\star} = 0 \\
&\text{t=0, maturing in 2: } N_s f_{1,2}^{s\star} + N_p f_{1,2}^{p\star} = 0 \\
&\text{t=1, maturing in 2: } N_s\left(f_{2,2}^{s\star} - f_{1,2}^{s\star}\right) + N_p\left(f_{2,2}^{p\star} - f_{1,2}^{p\star}\right) = 0
\end{aligned}$$

Using the optimal positions of the agents from equations (2), (3), (4), (18), (20a), and (20b), the equilibrium expected returns or risk premia are:

$$\mu_{F_{1,1}}^\star = \frac{\lambda_p\gamma_p\left\{(\lambda_p+\lambda_s)\sigma_{2,2}^2\left(\rho_{[1,11]} + \rho_{[2,11]}\right) - \lambda_s\sigma_{[11,22]}\rho_{[2,22]}\right\}}{(\lambda_p+\lambda_s)^2\sigma_{2,2}^2} \tag{21a}$$

$$\mu_{F_{1,1}}^\star = \frac{\lambda_p\gamma_p\left\{(\lambda_p+\lambda_s)\sigma_{2,2}^2\left(\rho_{[1,12]} + \rho_{[2,12]}\right) - \lambda_s\sigma_{[12,22]}\rho_{[2,22]}\right\}}{(\lambda_p+\lambda_s)^2\sigma_{2,2}^2} \tag{21b}$$

$$\mu_{F_{2,2}}^\star = \frac{\lambda_p\gamma_p\rho_{[2,22]}}{(\lambda_p+\lambda_s)} \tag{21c}$$

The main results from equations (21a), (21b), and (21c) are the same as in Result 1 of the previous version of the model described in Section 5.

C.2.2 Financialization: clearing of the futures markets with investors

The clearing of the futures markets in the financialization era, with three types of market participants (the N_s short-term speculators, the N_p long-term producers, and the N_{in} investors) are given by the following equations:

With constrained investors:

$$\begin{aligned}
&\text{t=0, maturing in 1: } N_s f_{1,1}^{s\star} + N_p f_{1,1}^{p\star} + N_{in} f_{1,1}^{w\star} = 0\\
&\text{t=0, maturing in 2: } N_s f_{1,2}^{s\star} + N_p f_{1,2}^{p\star} = 0\\
&\text{t=1, maturing in 2: } N_s \left(f_{2,2}^{s\star} - f_{1,2}^{s\star}\right) + N_p \left(f_{2,2}^{p\star} - f_{1,2}^{p\star}\right) + N_{in} f_{2,2}^{w\star} = 0
\end{aligned}$$

With unconstrained investors:

$$\begin{aligned}
&\text{t=0, maturing in 1: } N_s f_{1,1}^{s\star} + N_p f_{1,1}^{p\star} + N_{in} f_{1,1}^{w\star} = 0\\
&\text{t=0, maturing in 2: } N_s f_{1,2}^{s\star} + N_p f_{1,2}^{p\star} + N_{in} f_{1,2}^{w\star} = 0\\
&\text{t=1, maturing in 2: } N_s \left(f_{2,2}^{s\star} - f_{1,2}^{s\star}\right) + N_p \left(f_{2,2}^{p\star} - f_{1,2}^{p\star}\right) + N_{in} \left(f_{2,2}^{w\star} - f_{1,2}^{w\star}\right) = 0
\end{aligned}$$

The results in the post-financialization economies obtained by using the optimal positions of the agents from equations (2), (3), (4), (10), (16), (17), (18), (20a), and (20b) are the same as in Results 2 and 3 of the previous version of the model described in Section 5.

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