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Decision Support

# Heterogeneous beliefs, regret, and uncertainty: The role of speculation in energy price dynamics☆

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ABSTRACT

This paper proposes to investigate the impact of financialization on energy markets (oil, gas, coal, and electricity European forward prices) during both normal times and periods of extreme fluctuation by using an original behavioral and emotional approach. With this aim, we propose a new theoretical and empirical framework based on a heterogeneous agents model in which fundamentalists and chartists co-exist and are subject to regret and uncertainty. We find significant evidence that energy markets are composed of heterogeneous traders who behave differently depending on the intensity of the price fluctuations and the uncertainty context. In particular, energy prices are governed primarily by fundamental and chartist agents that are neutral to uncertainty during normal times, whereas these prices face irrational chartist investors averse to uncertainty during periods of extreme fluctuations. In this context, the recent surge in energy prices can be viewed as the consequence of irrational exuberance. Our new theoretical model is suitable for modeling energy price dynamics and outperforms both the random walk and the ARMA model in out-of-sample predictive ability.



## 1. Introduction

The recent and unprecedented surge observed in energy prices, particularly in the price of crude oil, from 2003 to 2008 has given rise to heated public and academic debates about the true nature of these shocks. Due to the potential impact of these huge movements on most economies (Edelstein & Kilian, 2007; Hamilton, 2003; Kilian, 2008, among others), the effectiveness of economic policies strongly depends on the identification of the major causes of energy price movements. Since Greenspan's (2004) intervention regarding the existence of speculators in the oil market, a popular view of the origins of the price surge has been that these movements cannot be attributed to economic fundamentals (such as changes in the conditions of supply and demand) but were caused by the increasing financialization of commodities. This financialization should, in turn, cause volatility clustering phenomena, extreme movements, higher comovements between oil, financial assets, and commodity prices, and an increased impact of financial investors' decisions (such as hedge funds and swap dealers). In the context of market deregulation where certain market players may now have the ability to exert market power, the question of the influence of financial investors on energy prices is of primary importance from both economic and political points of view. Economically, the role of speculation in energy markets raises the question of the trade-off between private and public interests because financialization is often defined as being beneficial from the private perspective without any beneficial considerations from a social planner's point of view. Politically, the debate is even more relevant because it lends credibility to the regulation of the markets for commodity derivatives in the same way that the G20 governments try to regulate financial markets by limiting speculative behavior.[1] Coupled with the concern over the energy security supply, the potential financialization of commodity markets is also of primary importance for operational and management issues in the energy industry because key players now face uncertainty rather than deterministic dynamics in the decision-making process due to extreme price movements (see Zhuang & Gabriel, 2008; Gabriel, Zhuang, & Egging, 2009; Gabrel, Murat, & Thiele, 2014).

Therefore, there has been a renewal of interest in the academic literature on this topic, although no clear-cut conclusion has emerged.

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[1] In 2010, the U.S. government initiated the Dodd–Frank Wall Street Reform and Consumer Protection Act for commodity markets to limit speculative behavior by mandating the centralized clearing of OTC standard contracts and automation of the Securities and Exchange Commission.

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Indeed, the question of the role of speculation in commodity markets is not trivial; identifying and quantifying this phenomenon is a difficult task because trader positions are relatively opaque. As we will see in Section 2, some studies have defined the phenomenon as the consequence of increased comovements between markets, whereas others consider markets composed of different shocks that affect price dynamics. These approaches mainly assume that the market is efficient in the sense that investors are rational and representative, and the oil price fully reflects all the available information. However, oil market efficiency was rejected by Gjølberg (1985) and by Moosa and Al-Loughani (1994). Moreover, according to Kirman (1992), aggregation arguments under rational behavior are insufficient to reduce markets to a single representative agent. Indeed, following Townsend (1983) and Singleton (1987), it seems reasonable to assume heterogeneous expectations, and it appears optimal for each agent to forecast the forecasts of others. Fundamentals are important, but a variety of different models may be relevant to explaining behavior in energy markets. For instance, as discussed by Gabriel et al. (2009), investors can exert both strategic and hedging behavior in the market. The purpose of this paper is to provide new theoretical elements to understand who and what drive the markets. Another important limitation in the existing literature is that it has been based on an analysis of risk as opposed to uncertainty. [2] Previous studies have supposed that agents do not allow for any uncertainty in their models, their priors, or the future evolution of prices, although allowing endogenous uncertainty could be relevant to account for some of the "anomalies" and stylized facts of markets. As discussed by Gabrel et al. (2014), uncertainty is also of primary importance in the optimization problem in energy systems given the framework of the energy industry. Indeed, the fossil market industry is subject to a number of uncertainties, such as unstable prices, fluctuations in energy production, and unpredictable demand for refined products that may be important to account for in management decisions. For the electricity market, uncertainty is even more important given the non-storability of energy produced.

Previous analyses have thus evolved in a constrained world where agents are rational and where uncertainty does not exist. To deal with these limitations, we propose a new theoretical and empirical framework to investigate what drives energy price fluctuations. Our theoretical model overcomes the restrictive assumption of rationality by allowing for the possibility that heterogeneous expectations could be the cause of recent price movements. We propose to extend the traditional heterogeneous agent model (HAM) of Brock and Hommes (1997) in the same way as Kozhan and Salmon (2009) to account for uncertainty in the markets. We therefore assume that investors are faced with forming energy price expectations and consider the worst outcome within the set of different models in some interval, where the size of the interval is a subjective choice of the agents, which allows us to capture different degrees of uncertainty aversion. In traditional HAM, agents are supposed to switch between different strategies characterizing heterogeneous specifications according to a cognitive learning process. We propose to extend this rule to a more realistic one that accounts for both cognitive and emotional dimensions using a regret criterion *à la* (Bell, 1982; Loomes & Sugden, 1982). We also estimate our model empirically using nonlinear least squares (NLS) methods to investigate whether heterogeneous expectations and uncertainty exist in the markets and can lead to strong fluctuations in energy prices. The estimations are performed for both normal times and periods of extreme movements[3] to see whether the behavior of prices depends on the intensity of the markets. The theoretical model is then evaluated in terms of predictive ability and compared with a random walk (RW) and an ARMA model. To the best of our knowledge, investigating the relative impact of financialization on energy price fluctuations through behavioral and emotional aspects under uncertainty during normal and extreme situations has not previously been done. Our main results reveal that although previous studies fail to find evidence of market exuberance during the recent period, a less restrictive framework incorporating heterogeneous interactions and uncertainty aversion allows us to disentangle the existence of irrational behaviors in energy price dynamics during extreme movements.

The present paper is organized as follows. The next section provides a review of the literature on the role of speculation in energy markets as well as its managerial implications. Section 3 describes our theoretical framework, and Section 4 outlines the specification and estimation procedure of the model. Section 5 contains in-sample and out-of-sample estimation results, and Section 6 concludes the paper.

## 2. The role of speculation in energy markets: What have we learned so far?

This section reviews the literature related to the impact of speculation on energy markets, specifically oil future prices. We discuss the relative conceptualization of "commodity speculation" and how it can impact price dynamics. We identify four strands in this literature.

In this heated debate about the financialization of the oil market and, more generally, of commodity markets, the key question is how to define what we call "commodity speculation". According to Kilian and Murphy (2014), a general definition of speculation in the oil market refers to a situation of "anyone buying crude oil not for current consumption, but for future use." Following this definition, speculative investors can have two options: buying physical oil now and storing it to accumulate oil inventories or buying crude oil futures contracts. Therefore, according to Alquist and Kilian (2010) analysis, speculation in one of these markets will be necessarily reflected in speculation in other markets. In this sense, speculation would not be economically "irrational" because it seems reasonable that oil producers, considered physical traders, would stock up on crude oil to smooth the production of refined products. Speculation would be essential for the oil market to function because it provides liquidity and assists the price discovery process. However, speculation in the public debate has a negative connotation because it is often viewed as an excessive phenomenon. This excessive phenomenon would be the consequence of private interests, increasing price movements and affecting social welfare. Determining excessive speculative behavior is a difficult task because it does not necessarily come from the positions taken by traders. Commercial traders generally act as hedgers to protect their physical interests, whereas noncommercial traders are often considered speculators. However, as documented by Büyüksahin and Harris (2011), we can have situations where commercial investors take a speculative position in the sense that they take a stance on the commodity price without hedging it in the futures market.

The debate about the intrinsic nature of energy price movements has several implications. Together with the economic and political issues of extreme price fluctuations, price behaviors may have important managerial consequences in the energy industry.[4] The oil and gas industries have become increasingly heavy users of operational research to support the management of refinery operations and productions, whereas electricity companies must manage generator operations and a supply chain given the non-storability of energy

[2] In the portfolio management literature, three popular definitions of risk exist: (i) variance (Crama & Schyns, 2003; Huang, 2007; Leung, Daouk, & Chen, 2001); (ii) semivariance (Huang, 2008); and (iii) Value-at-Risk (Castellacci & Siclari, 2003).

[3] Normal times are approximated by price movements in the mean of the distribution, whereas extreme fluctuation periods are those in the quantiles.

[4] Thanks to an anonymous referee for mentioning this point.