



## Seasonality and the valuation of commodity options

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### ABSTRACT

Price movements in many commodity markets exhibit significant seasonal patterns. However, given an observed futures price, a deterministic seasonal component at the price level is not relevant for the pricing of commodity options. In contrast, this is not true for the seasonal pattern observed in the volatility of the commodity price. Analyzing an extensive sample of soybean, corn, heating oil and natural gas options, we find that seasonality in volatility is an important aspect to consider when valuing these contracts. The inclusion of an appropriate seasonality adjustment significantly reduces pricing errors in these markets and yields more improvement in valuation accuracy than increasing the number of stochastic factors.

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## 1. Introduction

Commodity options have a long history. One of the first usages was documented by Aristotle. He reported the story about the philosopher Thales, who was able to make good predictions on the next year's olive harvest, but did not have sufficient money to make direct use of his forecasts. Therefore, Thales bought options on the usage of olive presses, which were available for small premiums early in the year. When the harvest season arrived, and the crop yield was, as expected by Thales, high, olive presses were in huge demand, and he was able to sell his usage options for a small fortune.<sup>1</sup> In contrast, modern commodity options, as we know them today, are quite recent innovations. The first commodity options traded at the Chicago Board of Trade (CBOT) were live cattle and soybean contracts, both introduced in October 1984.<sup>2</sup> As distinguished from the ancient contracts, modern commodity options are generally not written on the commodity itself, but on a futures contract. This ensures liquidity of the underlying, as most of the trading takes place in the futures and not the spot market.

When considering the pricing of commodity options contracts, the special features of these markets should be taken into account. One of the earliest, and perhaps today's most popular commodity options pricing formula among practitioners, was derived by Black (1976). Black's formula can basically be regarded as a straightforward advancement of the well-known Black and Scholes (1973) stock options pricing formula, taking into account the fact that no initial outlay is needed when entering a futures position. However, other stylized facts present in commodity markets are not considered in Black's approach. These issues have been addressed in more recent research. Gibson and Schwartz (1990), Brennan (1991), Ross (1997), and Schwartz (1997) point out that the dynamics of supply and demand result in a mean-reverting behavior of commodity prices. Schwartz (1997) tests three different model variants, incorporating mean-reversion (a one-, two-, and three-factor model), in terms of their ability to price futures contracts on crude oil, copper, and gold. All of these commodities belong to the part of the commodity universe not showing seasonality in their price dynamics.<sup>3</sup>

Seasonality can be considered as another stylized fact of many commodity markets, distinguishing them from traditional financial assets. The seasonal behavior of many commodity prices has been documented in numerous studies, e.g., Fama and French (1987), and, thus, should be considered in a valuation model. Sørensen (2002) considers the pricing of agricultural commodity futures

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<sup>1</sup> This story can be found in Aristotle's book *Politics* (published 332 BC). He refers to the strategy of Thales as a "money-spinning device". See also Williams and Hoffman (2001, Chapter 1).

<sup>2</sup> See the CME Group website: <http://www.cmegroup.com>.

<sup>3</sup> More recent advancements in pricing commodity futures contracts include, e.g., Casassus and Collin-Dufresne (2005) and Paschke and Prokopczuk (2010).

(corn, soybeans, and wheat) by adding a deterministic seasonal price component to the two-factor model of Schwartz and Smith (2000). Similarly, Lucia and Schwartz (2002) and Manoliu and Tompaidis (2002) consider the electricity and natural gas futures markets, respectively. Furthermore, Dempster et al. (2008) analyze the crack spread between heating oil and WTI crude oil. Thus, the modeling of seasonality at the price level is relatively well understood.

When it comes to commodity futures options pricing, price level seasonality is, however, of no importance. Given the corresponding futures price, the deterministic component of the price process does not enter the options valuation formula.<sup>4</sup> However, as noted by Choi and Longstaff (1985), there exists a second type of seasonality, which can have a great influence on the value of a commodity option. As the degree of price uncertainty changes through the year, the standard deviation – i.e., the volatility of a commodity futures' return – shows strong seasonal patterns. A good example is provided by most agricultural markets, where the harvesting cycles determine the supply of goods. Shortly before the harvest, the price uncertainty is higher than after the harvest when crop yields are known to the market participants resulting in a seasonal pattern in volatility in addition to the price level seasonality.

Surprisingly, the impact of seasonal volatility on commodity options valuation has attracted very little academic attention. Due to the lack of available options data, Choi and Longstaff (1985) do not conduct any empirical study. Koekkebakker and Lien (2004) study a rather small dataset of wheat options and focus on the aspect of jumps. Richter and Sørensen (2002) and Geman and Nguyen (2005) consider the soybean market and acknowledge the time-varying volatility by including a deterministic component in their models, but do not study the impact on the models' options pricing performance.

We contribute to the literature by filling this gap. Two commodity pricing models, a one-factor and a two-factor model, are extended by allowing for seasonal changes of volatility throughout the calendar year. As suggested by Geman and Nguyen (2005), we model seasonal volatility by a simple sinusoidal function. The seasonal volatility models are estimated using an extensive sample of options prices for four different commodity markets. First, we consider two agricultural commodities traded at the CBOT: soybeans and corn. Soybean and corn contracts provide prominent examples of commodities with seasonality effects mainly induced from the supply side of the market. Second, we study the impact of seasonalities on two energy commodities traded at the New York Mercantile Exchange (NYMEX): heating oil and natural gas. In contrast to the agricultural commodity markets, the seasonality in these markets is mainly driven by the demand side. The options pricing models considered are calibrated on a daily basis and then tested with respect to their in- and out-of-sample pricing performance. Our results show that the pricing performance can be greatly improved by including seasonality components in the volatility. This demonstrates that considering the seasonality of

volatility is of great importance when dealing with options or option-like products in seasonally behaving commodity markets.

The remainder of this paper is organized as follows. Section 2 provides an overview of seasonality in commodity markets in general and the four markets considered in particular. In Section 3, we describe the model dynamics considered and provide futures and options valuation formulas. Section 4 presents a preliminary study regarding the pricing of futures contracts. Section 5 describes the data and the estimation procedure employed, while the main empirical results of our study are presented in Section 6. Section 7 contains concluding remarks.

## 2. Empirical evidence on seasonality in commodity markets

Hylleberg (1992) defines seasonality as “...the systematic, although not necessarily regular, intra-year movement caused by the changes of the weather, the calendar, and timing of decisions, directly or indirectly through the production and consumption decisions made by agents of the economy. These decisions are influenced by endowments, the expectations and preferences of the agents, and the production techniques available in the economy.”

Following this definition, agricultural commodity markets clearly show seasonal patterns induced by the supply side mainly due to harvesting cycles, the perishability of agricultural goods, and the effects of weather. In contrast, many energy commodity markets show seasonal patterns induced from the demand side, which are due to regular climatic changes as well as regular calendar patterns, such as holidays.<sup>5</sup> Furthermore, inventories of these commodity markets undergo a seasonal pattern. Thus, the presence of seasonality in commodity markets is also predicted by the theory of storage (Kaldor, 1939; Working, 1949; Brennan, 1958; Telser, 1958), which states that the convenience yield and, thus, the commodity price are negatively related to the level of inventory.

In this paper, we consider four commodity markets: soybeans, corn, heating oil, and natural gas. The first two are the two most important agricultural commodity markets in the world. Heating oil and natural gas, two of the biggest energy markets, are both used to meet residential and commercial heating demand. Natural gas is additionally serving as an input factor for electricity production.<sup>6</sup>

Although not the main focus of this paper, we first provide empirical evidence on seasonal patterns at the price level to draw a complete picture with respect to seasonality in the four markets considered. In order to illustrate the seasonal pattern at the price level, we consider front-month futures prices as an approximation of spot prices. We standardize each daily price observation relative to the annual average. Thereby, we obtain a price series describing the price pattern for each year considered in our sample, which spans January 1990–December 2009.<sup>7</sup> In the next step, we calculate average values of the annual patterns to derive the historical seasonal pattern of the commodities considered. Following the economic rationales outlined above, we expect soybean and corn prices to increase before the harvests in the USA (and also South America in the case of soybeans),<sup>8</sup> which take place during spring

<sup>4</sup> Intuitively, this can be seen by the fact that the deterministic price seasonality only affects the drift of the underlying. As the underlying of a commodity option is usually a futures contract, which is tradable and does not require any capital outlay, the futures price must have a zero drift under the risk-neutral measure in order to avoid arbitrage opportunities. Given an observed futures price, the price seasonality has therefore no further influence on the option price. More formally this can be seen in the model description in Section 3, Eqs. (11)–(15). One should note, however, that a predictable component in the price process might have an influence on the estimation of the model parameters. If one estimates the volatility using a historical time series of asset prices (i.e., under the physical measure), one must clearly account for seasonal price variations as changes in the mean return affect the variance. As we estimate our model implicitly using option prices (under the risk-neutral measure), this problem does not arise. See also Lo and Wang (1995) on this issue.

<sup>5</sup> In the case of electricity markets, varying demand levels induce regular intra-day and intra-week price patterns in addition to a calendar year effect as shown by Lucia and Schwartz (2002), Longstaff and Wang (2004), and Bierbrauer et al. (2007), respectively.

<sup>6</sup> Details on all four markets can be found in Geman (2005). The seasonal behavior of prices is documented by Milonas (1991), Frechette (1997), and Geman and Nguyen (2005) for agricultural markets, and Girma and Paulson (1998), Manoliu and Tompaidis (2002), Borovkova and Geman (2006), Paschke and Prokopczuk (2009), and Geman and Ohana (2009) for the energy markets considered.

<sup>7</sup> In the case of natural gas, our sample starts only with the full year of 1991 since trading of Henry Hub natural gas futures on the NYMEX commenced in April 1990.

<sup>8</sup> South America, in particular Argentina and Brazil are big markets for soybeans exported to the USA.

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