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Futures basis, inventory and commodity price volatility: An empirical analysis[☆]

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ABSTRACT

We employ a large dataset of physical inventory data on 21 different commodities for the period 1993–2011 to empirically analyze the behavior of commodity prices and their volatility as predicted by the theory of storage. We examine two main issues. First, we analyze the relationship between inventory and the shape of the forward curve. Low (high) inventory is associated with forward curves in backwardation (contango), as the theory of storage predicts. Second, we show that price volatility is a decreasing function of inventory for the majority of commodities in our sample. This effect is more pronounced in backwardated markets. Our findings are robust with respect to alternative inventory measures and over the recent commodity price boom.

1. Introduction

Over the past few years, the flow of funds to commodities has increased substantially, primarily through investments in exchange-traded funds (ETFs) and commodity indices.[1] This widespread interest in commodity investments is partly associated with the view of commodities as a good diversification tool, since their correlations with stocks and bonds have been low or negative (Buyuksahin et al., 2010; Gorton and Rouwenhorst, 2006). Recently, Daskalaki and Skiadopoulos (2011) point out that these diversification benefits are preserved only during the recent commodity price boom (2003–2008), but in their study vanish in an out-of-sample context. It is also a common belief that commodities provide a good hedge against inflation (Bodie, 1983; Edwards and Park, 1996). Moreover, recent evidence suggests that momentum and term-structure based strategies in commodities can generate significant profits (Fuertes et al., 2010; Miffre and Rallis, 2007).[2]

The behavior of commodity prices is strikingly different from that of stocks and bonds. For instance, such factors as seasonal supply and demand, weather conditions, and storage and transportation costs, are specific to commodities and do not affect, or at least not directly, the prices of stocks and bonds. In the light of these stylized facts, understanding the determinants of commodity prices and their volatilities is an issue of great importance.

The mainstream theory in commodity pricing, namely the theory of storage, explains the behavior of commodity prices based on economic fundamentals. Furthermore, it has major implications for the volatility of commodity prices. Since its inception, this theory has been the central topic of many theoretical and empirical papers in the economics literature. Nevertheless, most studies employ proxies for inventory, such as the sign of the futures basis (e.g., Fama and French, 1988), thus providing only indirect evidence on the effect of inventory on commodity prices and their volatilities.

In this paper, we employ real inventory data to test two of the main predictions of the theory of storage. Specifically, we show how inventory affects the slope of the forward curve (the basis) as well as the price volatility for a wide spectrum of 21 different commodities. Analyzing the relationship between inventory and the term structure of futures prices is important for various reasons. First, if inventory indeed has a significant effect on the shape of the forward curve ("contango" vs "backwardation"), then it should also affect the profitability of various term-structure based investment strategies. Additionally, the strength of this relationship will provide further evidence on whether the basis should be employed as a proxy for inventory in empirical studies.

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[1] The Financial Times characteristically reports: "… inflows into the sector reached a new high of $7.9bn in October 2010, taking total investor commodity holdings to a record $340bn."

[2] See also Fabozzi et al. (2008) for practical aspects of commodity investing.

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Furthermore, the results from our research are of substantial academic and practical interest since volatility underlies a variety of key financial decisions such as asset allocation, hedging and derivative pricing.

Our study contributes to the empirical literature on the theory of storage in several ways. Gorton et al. (2012) employ physical inventory data to document a negative non-linear relationship between inventory and the futures basis for a large cross-section of commodities. They do not examine the link between inventory and volatility as we do. Also, Geman and Ohana (2009) examine the relationship between inventory and the adjusted futures spread in the oil and natural gas markets, using end-of-month inventory data. The present paper adds to the evidence of the aforementioned studies by thoroughly analyzing the link between real inventories and the slope of the forward curve at several different maturities whereas previous research has only examined the short end of the curve. Furthermore, the sample used for our analysis includes the recent commodity price boom, which offers a great opportunity to test our hypothesis over varying market conditions (for an analysis of the recent commodity price boom, see Baffes and Haniotis, 2010).

Second, and more importantly, using our extensive inventory dataset, we document a negative relationship between inventory and commodity return volatility. We characterize the time series variability of futures returns and spreads with respect to inventory levels for each individual commodity. From this perspective, our analysis is related to Geman and Nguyen (2005), who analyze the relationship between scarcity (inverse of inventory) and return volatility in the soybean market. However, given the heterogeneous nature of commodities as an asset class (Brooks and Prokopczuk, 2011; Daskalaki et al., 2012; Erb and Harvey, 2006), it is quite intuitive to examine the inventory–volatility relationship for a broader set of commodities. For example, Fama and French (1987) find that the implications of the theory of storage are not empirically supported for certain commodities.

Our analysis provides a number of interesting results. First, we find a strong positive relationship between logarithmic inventory and the slope of the forward curve, the latter approximated by the interest-adjusted basis at different maturities. In particular, lower (higher) inventory for a commodity is associated with lower (higher) basis and forward curves in "backwardation"[3] ("contango") as the theory of storage predicts. Since the interest-adjusted basis represents storage costs and convenience yields, our findings provide insights regarding the relationship between convenience yield and inventory. Our research also implicitly builds on the competing "hedging pressure" literature, which is based on the existence of a risk premium earned by investors in futures for bearing the risk of spot price changes. Recent empirical evidence has shown that there exists a link between futures basis and risk premiums (Gorton and Rouwenhorst, 2006).

Second, we find that price volatility is a decreasing function of inventory for the majority of commodities in our sample. To do this, we estimate for each commodity univariate regressions of monthly price volatility against end-of-month inventory. Monthly price volatility is measured by the standard deviation of daily nearby futures returns/adjusted basis for each month. The magnitude of the reported relationship appears to be higher for commodities that are more sensitive to fundamental supply and demand factors, which determine storage. Moreover, heterogeneity is a possible explanation for the difference in the sizes of the coefficients across individual commodities. Some commodities are more difficult to store, and some of them are seasonal or perishable, while others are not. Our evidence generally supports the implications of theoretical studies (Deaton and Laroque, 1992; Williams and Wright, 1991).

Lastly, we investigate the hypothesis that the effect of inventory varies across different states of the market. To this end, we estimate OLS regressions of commodity returns/futures basis volatility on the interest-adjusted basis, decomposing the basis into positive and negative values that indicate the state of inventories (positive basis — high inventory and vice versa). In line with the implications of the theory, our estimation results suggest that the relationship between inventory and volatility is stronger in backwardation (low inventory). Furthermore, the results for energy commodities (crude oil and natural gas) lend support for the existence of the asymmetric V-shaped relationship between inventory and volatility reported by previous studies (Kogan et al., 2009). For crude oil (natural gas), positive deviations from the long-run inventory level (positive basis) have larger (smaller) impacts than negative deviations of the same magnitude.

As mentioned in Gorton et al. (2012), there exist some problems when dealing with inventory data. These are basically associated with the definition of the appropriate measure of inventory (e.g. world vs domestic supplies) and also with the timing of information releases regarding inventory levels. Another potential pitfall concerns the difference in the quality of the corresponding data from commodity to commodity, which hampers the ability to draw universal conclusions. This is an inherent problem in any study that uses physical inventories in the analysis. Therefore, any results using inventories should be interpreted cautiously.

The remainder of the paper is organized as follows. Section 2 briefly discusses the theory of storage and the relevant literature. Section 3 presents the datasets used for the empirical analysis. Section 4 examines the relationship between inventory and the slope of the forward curve. Section 5 analyzes the relationship between scarcity and price volatility. Section 6 tests the stability of the results obtained through various robustness tests. The final section presents concluding remarks.

2. Theoretical background and relevant literature

The theory of storage, introduced in the seminal papers of Kaldor (1939), Working (1948), Brennan (1958) and Telser (1958), links the commodity spot price with the contemporaneous futures price through a no-arbitrage relationship known as the "cost-of-carry model". This theory is based on the notion of "convenience yield", which is associated with the increased utility from holding inventories during periods of scarce supply. This no-arbitrage relationship between spot and futures prices is given by:

$$F_{t,T} = S_t\left(1 + R_{t,T}\right) + w_{t,T} - y_{t,T} \quad (1)$$

where $F_{t,T}$ is the price at time t of a futures contract maturing at T, S_t is the time t spot price of the commodity, $R_{t,T}$ is the interest rate for the period from t to T, $w_{t,T}$ is the marginal cost of storage per unit of inventory from t to T, and $y_{t,T}$ is the marginal convenience yield per unit of storage.

Within the context of the theory of storage, convenience yield can be regarded as an option to sell inventory in the market when prices are high, or to keep it in storage when prices are low. Milonas and Thomadakis (1997) show that convenience yields exhibit the characteristics of a call option with a stochastic strike price, which can be priced within the framework of Black's model (Black, 1976). Evidence has also shown that convenience yield is a convex function of inventories (Brennan, 1958; French, 1986).

A high convenience yield during periods of low inventory drives spot prices to be higher than contemporaneous futures prices and

[3] Backwardation is observed when the spot price is higher than the contemporaneous futures price, or the price of the nearby futures contract is higher than the price of longer maturity contracts. Contango describes the opposite case. According to the early hedging pressure hypothesis (Hicks, 1939; Keynes, 1930), the net supply of futures contracts, namely "hedging pressure", gives rise to risk premia in futures prices (compensation for risk transferring from producers to speculators).