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An information diffusion-based model of oil futures price

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ABSTRACT

Inspired by the increasing evidence of financialization/speculation in commodity pricing, this paper constitutes a first attempt to build an information diffusion-based asset pricing framework for the oil futures market. With gradual information dissemination, slowly decaying uncertainty about the asset's future fundamentals generates persistent conditional volatility and a drift in asset return. Volatility-based proxies for information flows are proposed to examine empirically the asset pricing implications. The results confirm a significant intertemporal relationship between return on the price of oil futures, information diffusion and volatility components. An important implication of our study is that the slow diffusion of information generates predictability in price dynamics. A forecasting model is then constructed and tested in relation to our theory. It is found that the lagged series of the pricing factors possess significant predicting power for returns.

1. Introduction

Oil price fluctuations, although primarily determined by changes in demand and supply, can be exacerbated by speculation (Kaufmann, 2011; Kaufmann and Ullman, 2009). Evidences of this can be seen from the behavior of oil prices during 2006–2008 (Sornette et al., 2009). Many studies attribute oil price speculation to the fast development of investment vehicles and financialization in commodity futures market especially since 2004. For example, Irwin and Sanders (2011) reported that the rapid growth of financial instruments in recent years has facilitated the development of commodity markets. Tang and Xiong (2010) found that the correlations of commodity future returns with stocks, the US dollar and crude oil returns increased significantly after 2004, and that the increase was greater for commodities included in major investment indices such as the S&P-GSCI and DJ-UBS. Kaufmann and Ullman (2009) also found evidence of a shift in the price difference between oil futures prices and spot prices after 2004.

Since speculative expectations play an increasingly important role in the formation of real oil prices (Kaufmann, 2011; Kaufmann and Ullman, 2009; Sornette et al., 2009; Tang and Xiong, 2010), it is not surprising that oil prices often deviate away from levels justified by the supply/demand balance. Kaufmann (2011) identified statistical and predictive failures generated through an econometric model of oil prices based on market fundamentals, and uncovered repeated and extended break-downs in the cointegrating relationship between spot and far month oil future prices after 2004 that could not be justified by the law of one price.

The increasing tendency towards financialization in oil markets and the failure of modeling oil price dynamics through market fundamentals raises an important question: can oil price fluctuation be captured from the perspective of financial economics, particularly the risk-return relationship? Related theoretical and empirical studies are rare. Some economists have proposed market microstructure models containing heterogeneous speculators who are not fully rational (Ellen and Zwinkels, 2010; Reitz and Slopek, 2009). However these studies were not able to explicitly establish the risk-return relationship. A recent break-through has been supplied by Cifarelli and Paladino (2010), who built and examined a behavioral ICAPM with feedback trading. This paper pursues a similar objective to Cifarelli and Paladino (2010), which is to build a theoretically reasonable and empirically testable model of the risk-return relationship of oil price dynamics. Rather than focusing on feedback trading, this paper proposes an information diffusion-based asset pricing explanation and establishes an intertemporal relationship between return and volatility.

The paper is structured as follows. In Section 2, the asset pricing model with information diffusion is outlined and the intertemporal risk-return relationship is established. In Section 3, the monthly performance of our model is tested. In Section 4, its ability to be used for

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forecasting is investigated. Section 5 concludes, outlining the main contribution of the paper and some future research agendas.

2. The asset pricing model

2.1. Model setup

In this section, an asset pricing model based on an information diffusion mechanism is presented. Our focus on information diffusion is primarily motivated by Hong and Stein (1999), who developed a model of slow information diffusion to describe price continuation/drift phenomena in stock markets. There is also substantive evidence of price continuation/drift in oil markets. Demirer and Kutan (2010) documented short term post event drift in daily oil prices. Askari and Krichene (2008) found a very large drift component in daily oil price diffusion processes during the 2002–2006 upturn. These findings are consistent with the information diffusion model of Hong and Stein (1999), through which investors gradually receive/digest information about future asset payoffs from which a drift in price returns results.[1] Oil price continuation/drift phenomena can also result from persistent uncertainty about demand and supply fundamentals. Wang et al. (2010) examined the dynamics of crude oil volatility, and suggested that the effects of some exogenous shocks on oil markets could last for a long time. Similarly, Kilian's (2009) empirical investigation revealed that shocks in precautionary demand are an important source of persistent volatility. These shocks in precautionary demand reflect shifts in the market's assessment of uncertainty about future oil supply shortages.

Several modifications are made to the assumptions on information diffusion employed in Hong and Stein (1999). Our main departure is that we allow conditional volatility to vary as time approaches the terminal date. The original model focused on the impact of a linear information diffusion process on the mean of the underlying asset's final value, regardless of the dynamics of the conditional uncertainty about the future asset payoff. However, as Kilian (2009) observed, precautionary demand shocks, which arise from the conditional variance of oil fundamentals, are an important source of persistent oil price fluctuation. Thus we consider a finite investment horizon and allow the conditional mean and volatility to vary as time approaches the terminal date. This terminal date is defined as the point in time when the true state of the underlying asset is released to investors and all uncertainty is eliminated. Moreover, instead of dwelling on complex momentum trading strategies, our model focuses on the risk-return relationship and replaces the notion of momentum traders with liquidity traders.

The basic model setup is shown below:

First, the asset is issued at time 0 and pays a liquidating payoff at a later time T. The ultimate value of the liquidating payoff at the end of period T can be written as $D_T = \bar{D} + d_T$, where $d_T \sim \text{normal}\,(0, \sigma^2)$, $\bar{D}$ is a constant term and the unconditional mean of D_T.

Second, and similar to Subrahmanyam (1991), two types of investors are specified: newswatchers with private information and discretionary liquidity traders who trade stochastically without information. The newswatchers generally hold long positions and act as market makers who determine asset price dynamics. The archetypical newswatchers can be thought of as commodity index investors. The long position of newswatchers is presumably provided by discretionary liquidity traders. The net positions of newswatchers and discretionary liquidity traders offset each other, since oil future contract is an asset with net zero supply.

Third, there are z newswatchers who each have an identical constant absolute risk aversion (CARA) utility function $-e^{-\beta(N_{it}(D_T - P(t)))}$, where N_{it} is the number of shares held by newswatchers i at time t. β is the coefficient of absolute risk aversion, and $P(t)$ is the asset price at time t. Q_t is the net supply provided by discretionary liquidity traders. It is assumed that $Q_t = \bar{Q}(1 + q_t)$, where q_t is random shock with zero mean and finite variance σ_q^2. The interest rate is normalized to 0, as in Hong and Stein's (1999) model.

Fourth, all z newswatchers trade to maximize their expected utility at time T. At every time t, they formulate their asset demands based on the static-optimization notion that they buy and hold until the liquidating payoff at time T.

Fifth, and similar to Hong and Stein (1999), the liquidating payoff d_T can be decomposed into z i.i.d. (independently and identically distributed) subinnovations, each with the same variance $\frac{\sigma^2}{z}$: $d_T = d_T^1 + d_T^2 + \ldots + d_T^z$, and diffuses symmetrically to the newswatchers.[2] In this setting, the reduction of uncertainty, captured by variance, would be proportional to the amount of information flow. For more details see Appendix A. Hong and Stein (1999) assumed that the information flows at a constant rate. We relax their assumption to a more flexible one: at time t, $f(t)$ proportion of the subinnovations have been cumulatively revealed to the investment population; and the residual information random variable is normally distributed with variance $[1 - f(t)]\sigma^2$ (see Appendix A).

2.2. The price and volatility function

Each newswatcher i chooses his optimal holdings by maximizing the utility function

$$\max_{N_{it}} E_{it}\left\{-e^{-\beta(N_{it}(D_T - P(t)))}\right\},$$

which implies:

$$N_{it} = \frac{E_{it}(D_T - P(t))}{\beta \operatorname{var}_{it}(D_T)}. \tag{1}$$

For a terminal payoff d_T, the assumption that information about d_T leaks in advance and diffuses symmetrically across the newswatchers implies that at time t the pricing function is:

$$P(t) = \bar{D} + f(t)d_T - \beta[1 - f(t)]\sigma^2(1 + q_t)\frac{\bar{Q}}{z}, \tag{2}$$

where $\frac{\bar{Q}}{z}$ is the average holding of newswatchers. See Appendix B for the detail of the proof. Interestingly, there are two sources of risks in this model: conditional expectation of the terminal payoff uncertainty represented by $[1 - f(t)]\sigma^2$ and liquidity related risk q_t. Thus Eq. (2) can be rewritten as:

$$P(t) = \{\bar{D} + f(t)d_T\} - \left\{\beta[1 - f(t)]\sigma^2\frac{\bar{Q}}{z}\right\} - \left\{\beta[1 - f(t)]\sigma^2 q_t \frac{\bar{Q}}{z}\right\}. \tag{3}$$

Note that $\bar{D} > \beta\sigma^2\frac{\bar{Q} + q_0}{z}$ is required to ensure a positive price at the time 0.

[1] Price continuation may also arise from positive feedback trading. Positive feedback trading plays a complementary role in that it exacerbates price fluctuation, and is mainly a result of slow information diffusion (Hong and Stein, 1999). However, for simplicity, our model does not incorporate positive feedback trading. Instead, the model produces momentum due to slow information diffusion. Empirical test will show that information diffusion may cover the effect of positive feedback trading.

[2] It is beyond the scope of this paper to address the mechanisms underlying information diffusion. Readers may like to refer to relevant literature. For example, information diffusion through social networks has been investigated by Ivković and Weisbenner (2005).