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Oil price dynamics: A behavioral finance approach with heterogeneous agents

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ABSTRACT

In this paper, we develop and test a heterogeneous agent model for the oil market. The demand for oil is divided in a speculative component and a real component. Speculators are boundedly rational in forming price expectations. Expectations are formed by one of two boundedly rational rules of thumb: fundamentalist and chartist. While fundamentalists trade on mean-reversion, chartists follow the trend in prices. Speculators then choose between these rules based on past profitability. Estimation results on Brent and WTI oil reveal that both groups are active in the oil market, and that speculators often switch between the groups. The model outperforms both the random walk and VAR models in out-of-sample forecasting.

1. Introduction

For the effectiveness of economic policies in response to oil price shocks, it is crucial to know the major causes of price movements. We can distinguish price effects on both the supply and the demand side of the market. Changes in the supply of oil can cause price shocks through, for example, OPEC decisions, refining capacity, and humanitarian unrest. On the demand side we face, besides the large amount of oil that the western world is still consuming, rapidly growing countries like China and India that have been demanding an increasing number of barrels of crude oil in the past years. Yet this is not enough to explain the large and sharp price increase of 100% between mid-2007 and mid-2008. In recent years the price of London Brent Crude dropped below $20 per barrel at the end of 2001, rose to a level of almost $140 in mid-2008, and decreased to less than $40 per barrel at the end of 2008.

A possible cause of this large price volatility is the existence and behavior of speculators in the oil market. The existence of speculation in commodity markets has been gaining attention along a broad spectrum in the previous decade. Greenspan (2004) mentions that speculators holding long positions were likely to influence oil prices to move in an upward direction. In 2007 and 2008 more media adopted this view. Newspapers, magazines and news web pages[1,2,3] reported the view of financial specialists that commodity investors were driving prices of crude oil to excessively high levels by speculating on price increases. Similarly, a special report by the US Government corroborated with this conclusion (US Senate, 2006).

The academic literature has provided evidence of speculative pressure on oil prices as well. As an early example, Danielsen (1979) stresses the importance of inventory speculation in the oil price run-ups during the 1970's. Chevillon and Rifflart (2009) set up a model consisting of pure fundamental factors in order to explain the increase in oil prices from 2000–2005. They show that a significant part cannot be attributed to fundamental factors, but to speculative forces instead. Kaufmann and Ullman (2009) study the causal relation between spot and future markets after 2004 and show that speculators tend to exacerbate price changes that were initially fundamental in nature. Sornette et al. (2009) research the 2006–2008 period and find that the oil price run-up was "amplified by speculative behavior of the type found during a bubble-like expansion".

The existence and survival of speculators implies that the market is not fully efficient and thus that not all commodity traders behave rationally according to the Efficient Market Hypothesis; see Fama (1970). This theory assumes representative agents and rational expectations in financial markets. If investors were representative and rational, they would all have expected the oil price to reflect or

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[1] USA Today; "Regulators: Tough to measure oil speculation", 9/11/2008.
[2] BusinessWeek, "A Hot Hand in Oil Speculation", 11/26/2007.
[3] ABC Money, "Ahead of the bell: oil speculation", 12/11/2007.

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return to its fundamental value. However, there are large misalignments between the price and the fundamental value of crude oil (Sornette et al., 2009). Indeed, oil market efficiency is rejected by Gjølberg (1985) and Moosa and Al-Loughani (1994), whom directly assess the efficiency of the market for oil products and crude oil futures, respectively.

Now that the Efficient Market Hypothesis is losing popularity, other theories are gaining momentum. Following Simon (1957), the effect of boundedly rational expectations of traders on market prices has been studied. That is, there is only one way of behaving rationally while there is an infinite number of ways of behaving boundedly rational. De Long et al. (1990) introduce noise traders into financial markets and shed light on a number of anomalies, including the excess volatility puzzle, mean reversion of stock returns, the underpricing of closed end mutual funds, and the Mehra–Prescott equity premium puzzle.

Brock and Hommes (1997, 1998) make the distinction between naïve investors and rational investors and state that investors switch between different types of forecasting strategies based on the past performance of these strategies. The switching is a particularly interesting feature, which introduces non-linear dynamics into the model. The awareness of this heterogeneous behavior in financial markets has resulted in the introduction of a theory that includes heterogeneous investor expectations. The models that arose from this theory are known as Heterogeneous Agents Models (HAMs); see Hommes (2006) for an overview.

Within HAMs, typically two investor groups are distinguished, following on from Frankel and Froot (1986, 1987); fundamentalists and chartists. Firstly, fundamentalists base their expectations on economic theory. This group believes that the market price will revert to the intrinsic value of an asset and therefore bases expectations on the deviation of the market price from the fundamental value. Technical traders, or chartists, on the other hand, base their expectations on past price changes. They extrapolate information from previous prices, expecting trends to continue in the same direction. Taylor and Allen (1992) confirm Frankel and Froot's presumption of the existence of technical traders in foreign exchange markets with a survey. Fundamentalist behavior is assumed to have a stabilizing effect on prices, while chartists tend to have a destabilizing effect driving asset prices away from the intrinsic value of the asset.

As stated earlier, the large price changes of crude oil can be an indication of speculative behavior in the oil market. Until now, little research has been done to investigate whether speculators influence these price swings. Due to the cyclical behavior of the oil price, it is likely that these investors have heterogeneous expectations. The chartist–fundamentalist dichotomy is therefore equally applicable to commodity markets. Smidt (1965), Canoles et al. (1998), and Draper (1985) show that besides the investors that base their expectations on economic fundamentals, there is a large group of speculators that base their expectations on past performance. He and Westerhoff (2005) introduce a model with heterogeneous agents for commodities. Following up on this, Westerhoff and Reitz (2005), Reitz and Westerhoff (2007) and Reitz and Slopek (2009) estimate a HAM for a broad range of commodities (excluding oil) and oil, respectively. Both papers find significant evidence of trader heterogeneity and switching between groups.

The aim of this paper is to develop and test a simple and stylized model for the oil market that combines both real and speculative participants. Speculators are split up between fundamentalists and chartists, and speculators are able to switch between groups by comparing recent performance. We estimate the influence of these two groups and the switching of speculators on crude oil prices. By doing so, we extend the work of Reitz and Westerhoff (2007) and Reitz and Slopek (2009) by introducing traditional, or real, market participants alongside speculators. Furthermore, instead of switching based on the distance between the market price and fundamental price like Reitz and Slopek (2009), we introduce a more realistic switching mechanism based on performance.

The model is subsequently estimated on Brent and WTI oil. The empirical results indicate that both fundamentalists and chartists are significantly affecting the oil price, while real demand and supply for oil tend to offset each other. In addition, we find evidence for switching between groups. On average the market is equally divided between fundamentalists and chartists, but there are periods in which the market is dominated by either strategy. Finally, we report that the proposed HAM is able to outperform the random walk and VAR model in terms of out-of-sample forecasting on all forecast horizons.

The structure of the paper is as follows. Section 2 gives a description of the HAM for the oil market. Section 3 contains a description of the data that has been used and the methodology. Section 4 presents the empirical results, and Section 5 contains concluding remarks and suggestions for further research.

2. Model description

This section develops the simple and stylized heterogeneous agents model that will be used to evaluate the effect of heterogeneous speculators on oil prices. The model is based on, among others, the models of Brock and Hommes (1997, 1998), Reitz and Westerhoff (2007) and Reitz and Slopek (2009). Most of the work on HAMs is focused on financial markets. However, because oil is also traded as an asset by speculators, as well as being a pure commodity, these models can also be applied to oil prices. The underlying assumption of all these models is that there are different types of agents with heterogeneous expectations active in the market.

2.1. Speculators

The group of speculators is divided between fundamentalists and chartists. The demand for oil for fundamentalists is based on the difference between the price at time t and the expected price at time $t+1$.

$$D_t^F = a^F\left[E_t^F(P_{t+1}) - P_t\right] \tag{1}$$

in which P_t is the log-price in period t (measured in months), a^F represents a positive reaction parameter and E the expectations operator. Fundamentalist demand will increase as they expect the future price to be higher than the current price and vice versa.

Traders with a fundamentalist approach include the fundamental value of the asset in their price expectations. The fundamental value is the long-run intrinsic value of oil, and therefore they expect the price of the asset to revert to that long-run value. This means that fundamentalists expect prices of overvalued assets to decrease, and prices of undervalued assets to increase, until the price of the asset reflects the fundamental value. The expected price can therefore be given by

$$E_t^F(P_{t+1}) = P_t + b_1^F(P_t - F_t)^+ + b_2^F(P_t - F_t)^- \tag{2}$$

in which F_t is the log-fundamental price in period t. The equation shows that the price movement expected by fundamentalists is caused by the deviation of the price from the fundamental value. A distinction is made between situations of overvaluation and undervaluation; $(P_t - F_t)^+ = (P_t - F_t)$ if $(P_t - F_t) \geq 0$ and zero otherwise. Similarly, $(P_t - F_t)^- = (P_t - F_t)$ if $(P_t - F_t) < 0$ and zero otherwise. Fundamentalists' reaction to an overvaluation (undervaluation) is captured by $b_1^F \in [-1,0]$ ($b_2^F \in [-1,0]$) and expected to be negative, since fundamentalists will expect the oil price to decrease (increase) if the current price is above (below) the fundamental value. Whenever b_1^F equals b_2^F, there is a symmetric response to undervaluation and overvaluation. The distinction introduces more flexibility in the behavior of fundamentalists and can be motivated by a number of