Short-term oriented oil price models and the financial crisis

- The need for oil price models with a short-term forecasting horizon has increased considerably in recent years, not least with the emergence of Exchange Traded Funds (ETFs) in the commodity sector, i.e. exchange-traded commodity investment funds with no fixed maturity.

- In this paper, we present three different forecasting models on a weekly basis. They permit us to make an oil price prediction with a time horizon of up to three months.

- The first two variants are so-called Vector Auto-Regressive (VAR) models and incorporate fundamental factors such as the net long positions or oil stockpiles. The third variant is a pure Futures model.

- It becomes apparent that the two fundamental models generate superior results up to mid/end-2007 and from mid-2009 on. In contrast, the Futures model is clearly superior in predicting the oil price during the financial market crisis from the end-2007 to mid-2009.

Growing need for short-term models

Because of the strong oil price increases primarily at the beginning of the century, the oil market has attracted increasing attention from various quarters, and specifically from banks. This has impacted the range of products offered (e.g. ETFs on commodities), but also the need to develop quantitative models to forecast the oil price. The latter trend was amplified further by the price slumps with the onset of the financial market crisis in 2007 and the renewed rise in the oil price from the turn of 2008/09.

Weekly and monthly models are prime candidates for those interested primarily in short-term oil price forecasts (up to at most one quarter). The academic literature differentiates here between pure financial models, which use only information from spot and futures prices, and structural models (fundamental models), which factor in the special characteristics of the oil market (specifically, the supply and demand situation and its determinants). Longo et al. (2007) provides a good overview here, including further differentiations above all of the empirical-econometric approach. In the following, we present three different weekly models from both categories for the oil price (West Texas Intermediate, WTI). Our primary interest is the performance of the models in quiet versus turbulent phases (as during the recent financial market crisis). Subsequently, we describe the models, the econometric methodology and the data used. We then discuss in detail the results and the performance of the models since mid-2007.

Econometric methodology

In principle, there are two alternatives available to explain and predict the oil price. The first is a univariate approach. This has the advantage that it is easy to model and that the results are, as a rule, easier to interpret and more plausible for the user. If, however, the primary focus is on the forecast, univariate approaches have the drawback that the exogenous variables also have to be predicted, thereby creating an additional area of uncertainty.

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Vector Auto-Regressive Models

For that reason, the scientific norm now is the use of state-of-the-art, Vector Auto-Regressive (VAR) models, in which all variables used are endogenized (with respect to oil prices see, for example, Akram, 2009; Kaufmann et al., 2004; Miller and Ratti, 2009). Because of the concrete model structure, each variable from the model context is itself forecasted within the model for arbitrary forecasting horizons. It was possible to demonstrate that an unrestricted VAR is a good approximation for every data-generating process, provided sufficient lags are factored into the variables (Canova, 1995).

A VAR takes the following form:

$$X_t = \Phi + A_1 X_{t-1} + \ldots + A_p X_{t-p} + \varepsilon_t \qquad (1)$$

where X_t represents the vector of the endogenous variables, Φ represents the matrix of the deterministic terms, specifically the constant and a linear deterministic trend, A_1 to A_p represent the symmetric coefficient matrices, p represents the selected lag length and ε_t the vector of the residuals. If the variables used are not stationary but cointegrated, it is possible to recast the VAR model into a so-called Vector Error Correction (VEC) model (for details, see Johansen, 1995). To this end (1) is modified to

$$\Delta X_t = \Phi + \Pi X_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \varepsilon_t \qquad (2)$$

$$\text{mit } \Pi = \sum_{i=1}^{p} A_i - I,\ \Gamma_i = -\sum_{j=i+1}^{p} A_j$$

In (2), X_t is the vector of the k non-stationary I(1) variables. If the matrix has Π reduced ranking (r-k), there are according to Granger's representation theorem (kxr) matrices α and ß with ranking r, with the result that $\Pi = \alpha\beta'$ and $ß'X_t \sim I(0)$; r represents here the number of cointegration relationships and each column of ß includes a cointegration vector. The α-coefficients are the so-called adjustment coefficients or error correction terms of the VEC model. Here, the number of cointegration relationships is normally determined by the trace and maximum eigenvalue statistics.

Data and forecast approaches

Regime shift in 1999

The objective of the model is to explain and forecast the oil price in US dollars per barrel. As is customary, we use the respective "nearest future" contract. Its development is shown in the following chart on a weekly basis (in each case the Friday reading) since the beginning of 1993. To eliminate erratic fluctuations because of the cut-off date, we form moving 4-week averages. The rather moderate development up to the beginning of the 21st century is clearly evident; the price increases that subsequently ensued emerge clearly from the end of 2006 to the beginning of 2008 and resulted in a oil price of over USD 140 per barrel. Subsequently, the oil price fell to below USD 40 by the beginning of 2009, only to rise to levels of up to USD 80 again by the end of 2009. The graphic representation of the oil price (cf. chart next page) suggests that we have been in a new regime since 1999. Because of these developments, we decided to start the investigation period only in 1999. Overall, therefore, we have 565 observations at our disposal. We use a weekly model so as to be able to analyze forecasting horizons of one week up to three months.

Fundamental models – the role of oil inventories ...

Because of the selection of a weekly oil price, the explanatory variables should also be available at least in this frequency. As a fundamental factor in this context, the crude oil stockpiles are traditionally analyzed as "summary statistic" for the supply/demand situation (see, for example, Chevillon and Rifflart, 2009; Kaufmann et al., 2004; Ye at al., 2005; Zamani, 2004). In the following, we use the industrial stockpiles of the US, since these are the only consistent data available on a weekly basis. They constitute the bulk of the OECD stockpiles. The theoretical correlation between the stockpiles and the oil price is, however, not conclusive. A negative correlation is based on the view that rising stockpiles indicate a supply surplus, which has a dampening effect on the oil price. In contrast, strategic considerations argue for a positive correlation: The expectation of rising oil prices could, for example, prompt the industrialized countries to increase their stockpiles. Security considerations could also play a role here.

... and speculative net long positions

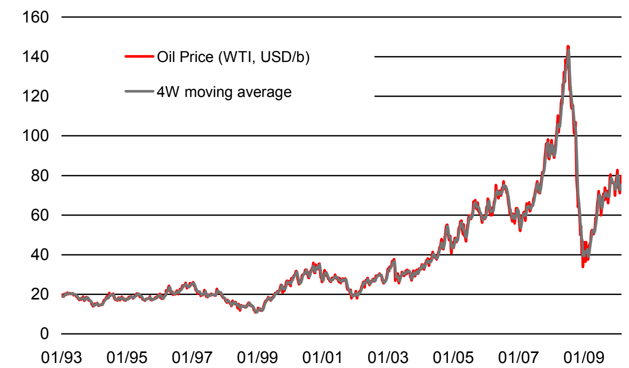
In addition to the stockpiles, we use further time series that are available on a weekly basis. First, we include the net long position of non-commercial traders (see, for example, also Merino and Ortiz, 2005). Rising net long positions suggest that the oil price will increase. However, interdependencies between the net long position and the stockpiles must also be taken into account. Under certain circumstances, changed stockpiles impact investor behavior, and vice versa. This is, for example, suggested by the positive correlation between the net long position and the stockpiles (cf. chart below). Depending on the period observed and the factored lag, the correlation coefficient between both time series was in some cases up to 50%.

Natural gas as a substitute

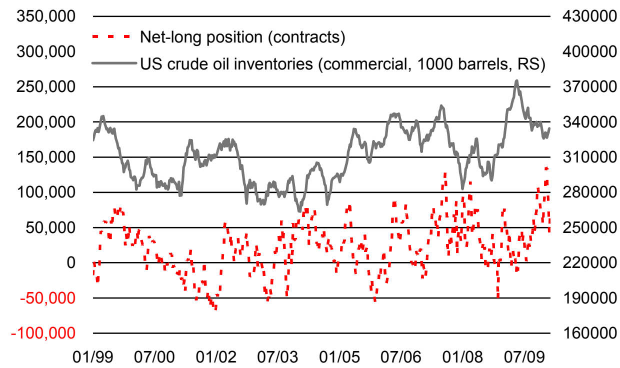
As a further variable, we factor in the Henry-Hub natural gas price in US dollars per MMBTU ("million British thermal units") and gasoline consumption in thousands of barrels per day. Since natural gas functions as a substitute for crude oil, there should be a positive correlation between the natural gas price and the oil price. Equally, rising demand for gasoline should drive up the price of crude oil. Both variables are illustrated in the chart next page. It is apparent that gasoline consumption has shifted only marginally higher since 1999, albeit with clear fluctuations from week to week. These volatilities do not appear to have changed. The natural gas price demonstrates clearer persistence, albeit with pronounced short-term fluctuations.

OIL PRICE DEVELOPMENTS

Nearest future



NET LONG POSITION AND US INDUSTRIAL STOCKPILES

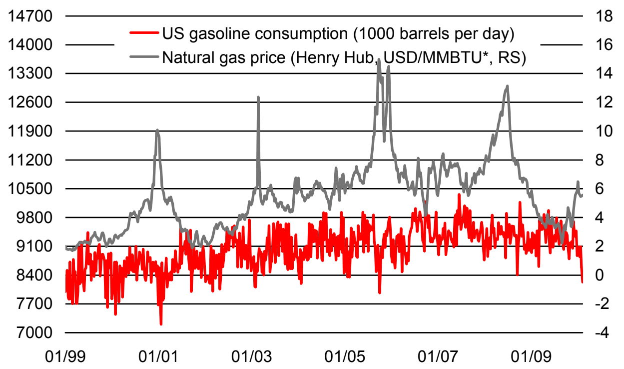


Source: Bloomberg, Thomson Datastream, UniCredit Research

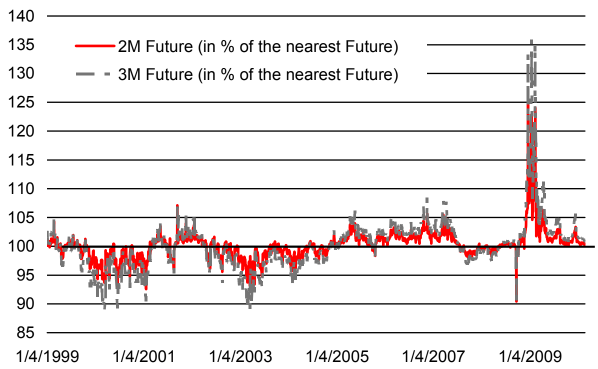
Futures model

Alongside these VAR models, we have estimated a pure financial market model, which exploits only the relationships between oil futures of various maturities and the spot price. Coppola (2008), for example, found evidence supporting a cointegration relationship between the oil spot price and the futures prices and a high explanatory power of futures prices for spot prices (see also Abosedra, 2005; Dées et al., 2008; Huang et al., 2009). If price innovations become evident initially in spot prices, market fundamental data are probably decisive for the crude oil price development. If, in contrast, the futures prices react first, speculation likely assumes an important role (Kaufmann and Ulmann, 2009). Alongside the spot price and the "nearest future" price, we also include the 2M and 3M future. They are shown in the following chart. Arbitrage processes produce the extreme parallel movement of the three time series. Furthermore, statistical tests show that they are profoundly non-stationary.

NATURAL GAS PRICE AND GASOLINE CONSUMPTION



OIL PRICE FUTURES



Source: Bloomberg, Thomson Datastream, UniCredit Research

Expectations theory as a theoretical foundation

The theoretical basis of the correlations is the expectations theory, which is based on their time series characteristic. If the various oil prices follow a stochastic trend, they must all follow the same trend irrespective of the maturity, i.e. the price differences between (arbitrarily selected) price pairs are stationary. In our case, the expectations theory states specifically that in the arbitrage equilibrium the "long-term" price – for example measured by the 3M future – must be identical to the price expected from revolving short-term transactions – for example, three consecutive transactions with a one-week maturity. With P_t as 3M future, p_t as 1M future, this then produces ("*e*" characterizes expectations variables)

(3) $$P_t = \tfrac{1}{3}\cdot(p_t + p^e_{t+1} + p^e_{t+2})$$

If p_t is subtracted on both sides, one obtains

(4) $$P_t - p_t = \tfrac{2}{3}\cdot\Delta p^e_{t+1} + \tfrac{1}{3}\cdot\Delta p^e_{t+2},$$

with $\Delta p_{t+1} = p_{t+1} - p_t$ as one-period price change. The spread $P_t - p_t$ is, therefore, a weighted mean of the changes expected in the 1M future over the next two months, whereby the price changes expected further in the future assume a smaller weight. This is illustrated by the expectations content, which according to the expectations theory lurks in the difference between a long-term and short-term "price". Above and beyond that, it is apparent from (4) that the long-term and the short-term prices follow a common trend, i.e. the spread between the 3M future and the 1M future is stationary. On the right side of (4) stand only (expected) changes of the short-term future. Since the futures follow a stochastic trend, the price difference and therefore also the right side of (4) are consequently stationary. In fact, multivariate cointegration tests show this to be the case. In our sample, the spreads we observed become greater as the maturity difference becomes longer. That also means that spot prices are, in general, lower than the future prices, which is commonly referred to as the contango effect. The marginal "convenience yields" are then probably relatively high. The so-called backwardation, spot prices above the futures prices, a standard result in the literature (e.g. French, 2005) does not, therefore, hold generally for our data set. Huang et al. (2009) also find this result for the period from September 11, 2001 to April 30, 2007, which covered the largest part of our sample. Kaufmann et al. (2008) conclude that the strong rise in the price of oil from 2005 to 2007 went hand in hand with a change in the futures markets from backwardation to contango.

General-to-specific approach

With the exception of the net long position, all variables are logarithmed. To soften the impact of individual outliers on the results and to better correlate the time series, we calculate moving 4-week averages from all variables. The lag length in the VAR models is designed to maintain forecasting quality despite frugal modeling. The respective final model includes only those variables that are required in each case on forecasting considerations. That also means that even if an additional variable or an additional lag is significant but does not bring an improvement in the forecasting, it is not included in the approach. Here, we proceed according to the so-called "general-to-specific" methodology. The forecasting period extends at most from the beginning of 1999 to October 26, 2009. Our primary interest here is how the quality of the models changed during the financial market crisis since mid/end 2007.

Forecasting

Out of sample forecasts

For out-of-sample forecasts, the respective forecasting period is shortened by one year, and the "missing" year is used as the forecasting period. The estimates and forecasts are conducted recursively, where the period used is in each case lengthened by one week. The forecasting horizons extend from one week to three months (12 weeks). The forecasting quality of our three models (VAR, VEC, Futures) is assessed using several forecasting quality yardsticks. The benchmarks used for each sample are an optimized Random Walk with/without drift and an ARIMA model. For each of these models, the oil price was estimated from the beginning of 1999 to point *t* and forecasted up to h weeks into the future based on the respective current data position (=$wti_{t+h,t}$)). The forecasting error (=$e_{t+h,t}$) is then the difference between the actual value at point t+h (=wti_{t+h}) and its forecasted value:

(5) $$e_{t+h,t} = wti_{t+h} - wti_{t+h,t}$$

The comparison of the forecasted values with the actual values produces the Root Mean Squared Error (RMSE). It is defined as

$$RMSE_h = \sqrt{\frac{1}{T}\sum_{t=1}^{T} e_{t+h,t}^2}$$

The second criterion used is the so-called Direction Hit Ratio (DHR). To this end, an indicator variable *J* is defined with the following characteristics

(6) $$\begin{aligned} &if\ \ sign\left(wti_{t+h} - wti_t\right) = sign\left(wti_{t+h,t} - wti_t\right) \Leftrightarrow J = 1 \\ &if\ \ sign\left(wti_{t+h} - wti_t\right) \neq sign\left(wti_{t+h,t} - wti_t\right) \Leftrightarrow J = 0 \end{aligned}$$

Consequently, the DHR equals

$$VZT_h = \left(\frac{1}{T}\sum_{t=1}^{T} J_t\right) \cdot 100\%$$

The higher the DHR, the greater the frequency that the direction of the oil price change is predicted correctly. For example, a direction hit ratio of 70% indicates that in 70% of cases the model correctly predicted the direction. Both forecasting quality yardsticks – RMSE and DHR – are discussed in Cheung et al. (2005). Furthermore, we assess a still rather unusual measure which we call the "Mean Weighted Hit Ratio" (MWHR). It in turn refers back to the indicator function (6); only false hits are now allocated the value "-1". MWHR is defined as follows

$$MWHR = mean\left((1,-1) \cdot |\Delta wti|\right)$$

The higher the values, the better the forecasting quality. MWHR weights the direction hit ratio with the absolute extent of the change of the oil price at the corresponding point in time. Extremely positive is factored in if major changes are predicted correctly, but extremely negative is factored in if major changes are not predicted correctly.

Model results I: The behavior up to the end of 2007

The models were optimized for the period up to the financial market crisis at mid/end 2007. Alongside the oil price, the only variables included (in the levels) in the two fundamental models are the natural gas price and the net long position. The net long position is included as an exogenous, not-modeled variable, since compared to the other variables it is already stationary in the levels. For the forecast, it is modeled as a univariate process. The VEC model factors in a cointegration relationship between the oil and the natural gas price. The Futures VEC model includes – pursuant to the theoretical considerations discussed in the preceding section – two cointegration relationships between the three oil prices. The two VEC models include three lags in the levels. It was not necessary to model seasonal effects in any of the models, since no pronounced and systemic seasonal patterns were observable (see here, for example, Zamani, 2004).

Fundamental models superior during quiet market phases

Tables 1-3 show the results for the three forecasting quality yardsticks (RMSE, DHR, MWHR) and the four models (VAR, VEC, Futures, Random Walk (RW)) for the 12 forecast horizons. It is apparent that the Random Walk is beaten by all three models, irrespective of the forecasting measure. With respect to futures prices, this result is also confirmed by Abosedra (2005) as well as Murat and Tokat (2009). In terms of the absolute hit ratio, measured by the RMSE, the VAR and the VEC model perform better on forecasting horizons of up to two months and better than the Futures model. The quality of the results generally declines with the forecast horizon. In the case of the DHR, the VEC fundamental model performs best irrespective of the forecast horizon. Specifically for maturities over two months, this model correctly predicts up to 80% of the oil price changes. The VAR and the Futures model produce clearly poorer results in this respect. That is also confirmed by Table 3, which shows the MWHR. The comparatively higher forecasting quality of the fundamental error correction model argues for the validity of the assumed cointegration relationship. Overall, this analysis points to the conclusion that up to the end of 2007 the two fundamental models, specifically the VEC model, produce pretty good results, and are clearly superior to the Futures model but also a Random Walk. The correlations could, however, have changed with the onset of the structural break triggered by the financial market crisis. For that reason, the focus in the following is on the performance of the various models from 2008 to the end of 2009.

TABLE 1: ROOT MEAN SQUARED ERROR (RMSE)

Forecast horizon	VAR	VEC	RW	Futures
1 week	0.9	0.9	1.9	0.9
2 weeks	2.2	2.2	3.6	2.2
3 weeks	3.7	3.7	5.2	3.7
4 weeks	5.3	5.4	6.5	5.3
5 weeks	6.5	6.7	7.6	6.6
6 weeks	7.5	7.8	8.5	7.6
7 weeks	8.2	8.5	9.1	8.4
8 weeks	8.7	9.1	9.7	9.0
9 weeks	9.1	9.5	10.3	9.5
10 weeks	9.6	9.9	10.7	10.1
11 weeks	10.2	10.3	11.2	10.7
12 weeks	10.9	10.9	11.7	11.3

TABLE 2: DIRECTION HIT RATIO (DHR)

Forecast horizon	VAR	VEC	RW	Futures
1 week	78.8	78.8	38.5	78.8
2 weeks	75.0	73.1	32.7	75.0
3 weeks	76.9	76.9	36.5	78.8
4 weeks	71.2	69.2	26.9	78.8
5 weeks	65.4	61.5	28.8	76.9
6 weeks	63.5	63.5	25.0	80.8
7 weeks	63.5	63.5	26.9	75.0
8 weeks	63.5	67.3	28.8	73.1
9 weeks	61.5	67.3	30.8	69.2
10 weeks	59.6	67.3	30.8	69.2
11 weeks	63.5	69.2	32.7	63.5
12 weeks	63.5	71.2	34.6	61.5

TABLE 3: MEAN-WEIGHTED HIT RATIO (MWHR)

Forecast horizon	VAR	VEC	RW	Futures
1 week	1.3	1.3	-0.4	1.3
2 weeks	2.3	2.4	-0.9	2.4
3 weeks	3.0	3.0	-1.5	3.4
4 weeks	3.1	2.8	-2.2	3.9
5 weeks	3.0	2.4	-2.9	4.0
6 weeks	3.4	2.4	-3.6	4.2
7 weeks	3.2	2.2	-4.0	4.1
8 weeks	3.3	2.6	-4.4	4.1
9 weeks	3.1	3.6	-4.6	4.7
10 weeks	2.7	3.8	-4.9	4.5
11 weeks	3.2	4.7	-5.2	4.3
12 weeks	2.3	5.0	-5.5	4.1

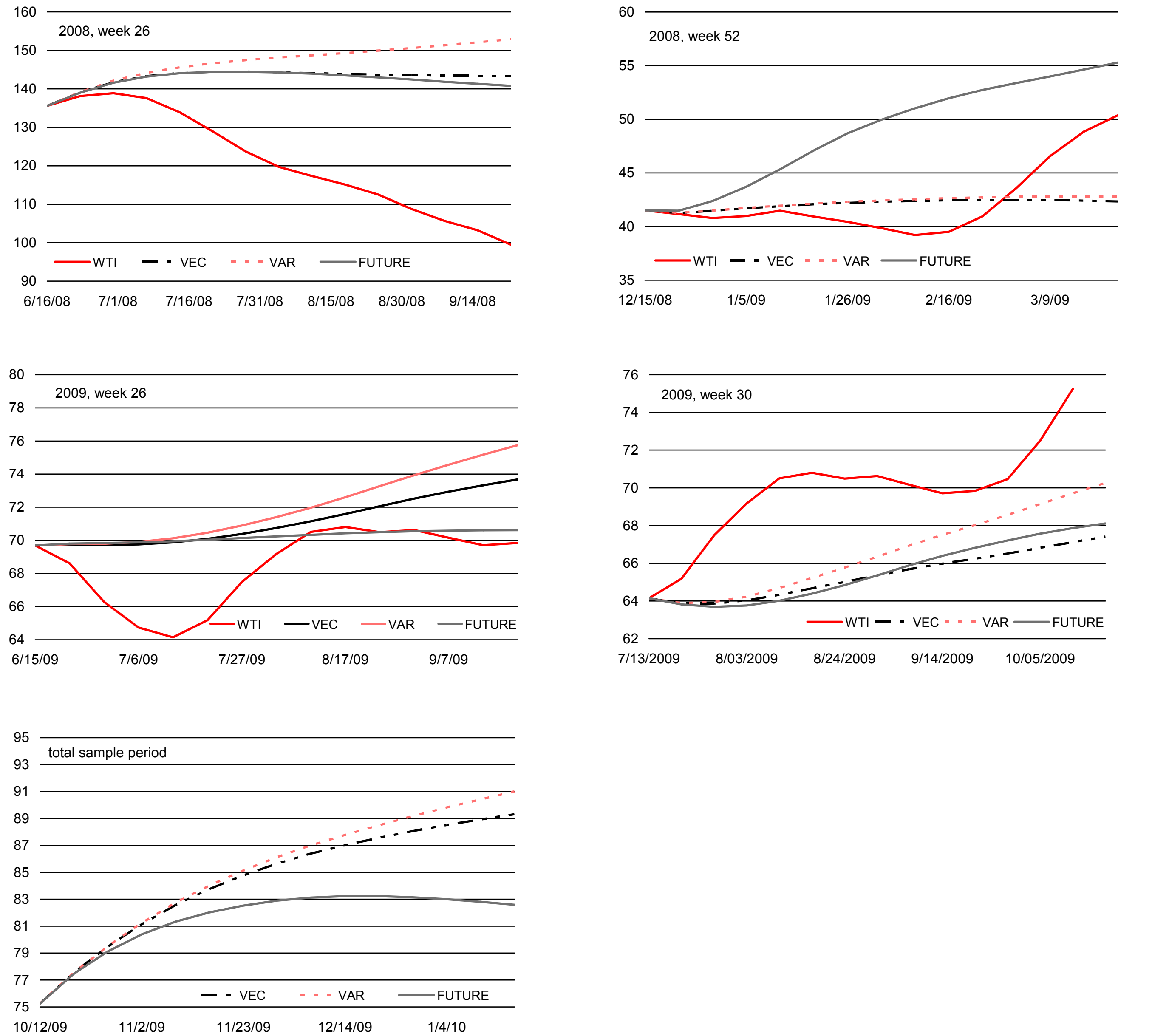
Source: UniCredit Research

Model results II: Behavior during the financial market crisis

Futures model superior during turbulent market phases

The following charts (next page) compare the forecast produced by our three models for a 3-month period with the actual development of the oil price for selected periods from mid-2008. The main focus of interest is the turning points (mid-2008, beginning of 2009). The process is once again recursive, and the period observed is extended successively to the current edge (end of October 2009). It is clear that the Futures model clearly dominates up to mid-2009, but that from the second half of 2009 the two fundamental models again come out on top. Even though the sharp pullback by the oil price in 2008 (sample up to week 26, 2008) is shown only weakly by the futures, the VAR and VEC model would, however, still have signaled rising prices. The renewed rise from February 2009 is, however, signaled early on by the Futures model (sample up to week 52, 2008). While this ranking persists until mid-2009 (sample up to week 26, 2009), the superiority of the two fundamental models is evident again after the gradual calming of the situation on financial markets (sample up to week 30, 2009). If the period observed is extended up to the end of October (sample: total period observed), the Futures model would predict only marginally rising oil prices until the end of January 2010, while the two other models suggest prices rising to over USD 90.

MODEL FORECASTS DURING THE FINANCIAL CRISIS



Note: Above the corresponding figures is the end of the respective period observed. Shown are the 4-week moving averages.
Source: Bloomberg, Thomson Datastream, UniCredit Research

Overall, these observations permit the conclusion that during strong upheavals on markets, characterized by extreme shocks, preference should be given to the Futures model over the two other models. In quiet phases, in contrast, the fundamental VAR and VEC models are more reliable. The models also appear to be still valid; the financial market crisis probably did not trigger any basic changes or instabilities. Only the short-term performance was affected.

Summary and outlook

Don't put all your eggs in one basket

In this analysis, we have presented three different forecasting models for the oil price. Model selection was based on a purely forecast-oriented approach. Accordingly, VAR models formed the methodological-econometric basis. On the one hand, we factored in fundamental determinants on a weekly basis, such as the net long position and the natural gas price. This was, on the other hand, compared with a pure financial market model based on futures prices. It was evident that a VAR or VEC model with fundamental variables produces good forecasting results in quiet market phases and is clearly superior to a Random Walk model and also to the Futures model. In turbulent market phases, such as triggered by the financial market crisis, investors should however tend to rely on the Futures model. It is, therefore, advantageous overall to monitor both variants and focus on a specific model depending on the market situation.

It was astonishing that the stockpiles had no significant influence and were not included in the ultimately preferred fundamental models. This could have to do with the weekly data used, but also with the fact that only US industrial stockpiles are available on a weekly basis and that we also included the net long position. In the literature, a significant influence of the stockpiles is found if these assumptions are sacrificed (see, for example, the overview in Longo et al., 2007, chapter 2.2). Some authors do, however, note that it is not the stockpiles per se but their position relative to a normal level that is the decisive variable (Ye et al., 2005; Zamani, 2004). The influence of the stockpiles could also depend on whether the market is in a phase of rising or falling prices (Ye et al, 2005). Geman and Ohana (2009) also find that the information in futures prices is a good proxy for stockpiles. The stockpiles would, therefore, be implicitly included in the Futures model.

It will require further research to determine whether the correlations discovered here are also to be found in models with monthly or quarterly frequency. Above and beyond that, it is interesting to investigate to what extent models with low data frequency are more stable in turbulent market phases, and whether they are also suitable as valid approaches for longer-term forecasts.

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