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Macro Wine in Financial Skins: The Oil-FX Interdependence

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Macro Wine in Financial Skins: The Oil-FX Interdependence[1]

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Abstract

This paper analyses mutual causalities between crude oil price and euro / US dollar exchange rate. Instead of focusing on long-run macroeconomic linkages like the bulk of the relevant literature, the present approach takes a financial markets perspective using daily data. The fast-running simultaneous impacts are identified through heteroscedasticity by specifying multivariate EGARCH processes for the structural variances. While for the decade after 1986 no significance is found, thereafter oil price changes cause inverse reactions of the dollar price and affect its volatility. Reversely, dollar appreciation asymmetrically increases the oil price.

Keywords: Crude Oil Price, Foreign Exchange, Identification
JEL classification: C32, F31, Q43

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1 Introduction

Oil price shocks have traditionally been seen as important factors influencing the global and national macroeconomy. Empirically, the econometric literature including Darby (1982), Hamilton (1983, 1988), Bohi (1989, 1991) and Ferderer (1996) has concentrated on the transmission of changes in oil prices to aggregate output and inflation. Concerning the connection of the oil and foreign exchange markets, academic interest focused on explaining long-run persistent fluctuations of the real exchange rate by stochastic trending in the oil price (e.g. Amano and van Norden 1998).

The present paper takes a financial markets perspective, which differs from conventional macroeconomic analyses in that causalities in very short time horizons are considered. For that purpose, I employ daily instead of monthly or quarterly data of crude oil prices and the euro / US dollar rate. Nonetheless, even here spillover effects largely appear contemporaneously, since adjustment of financial markets to economic information and capitalisation of investors' expectations typically take place within one trading day. Usual Granger-causality-type tests relying on serial cross-correlation are thus unlikely to capture the transmission structure appropriately, which is instead identified by an innovative method discussed below.

The above-mentioned literature well elaborated several channels through which oil prices may affect the macroeconomy, reviewed for instance in Barsky and Kilian (2004). To just mention a few, rising[2] oil prices might lower aggregate output by transferring income to oil-exporting countries, lowering production capacity in their role as input factors, invoking (sectoral and factor) adjustment costs or delaying (irreversible) investment decisions. Inflation is logically boosted by the input price increase, with potential repercussions on output through lowering real balances and evoking counterinflationary monetary policy reactions.

Resuming the discussion on the exchange rate, both real activity slowdown and accelerating inflation, or far more according expectations in financial markets, should lead to nominal devaluation. In addition, higher import prices and deterioration of the balance of trade have a direct effect in the same direction. On a bilateral exchange rate, the overall impact thus depends on the relative oil dependency and intensity of the involved economies. For the US compared to Euroland, one might expect dollar depreciation in response to rising oil prices. Even though the literature largely places oil prices at the

[2] As long as they are symmetric, for reasons of brevity, reverse effects are not mentioned throughout the paper.

beginning of cause-and-effect chains, the current study does not assume this exogeneity; after all, oil is traded in US dollar, and changes in the value of this means of payment might clearly matter for the nominal price. Therefore, the pure observation for instance of coinciding oil price increase and dollar devaluation is not sufficient for revealing any structural economic interpretation.

Obviously, the simultaneity in potential causalities inevitably induces a classical identification problem. This is addressed employing the methodology suggested by Weber (2007a), which exploits the heteroscedasticity in financial data to identify the contemporaneous impacts without recourse to exclusion restrictions. As a conceptual enhancement, the present approach additionally takes asymmetries into account. While the following section discusses the methodology in more detail, empirical results of the application to the euro / dollar example are presented in section 3. The last section concludes.

2 Econometric Methodology

The data generating process of the n-dimensional vector y_t (here containing daily oil and FX returns) is approximated by the structural VAR with lag length q

$$Ay_t = \mu_0 + \mu_1 d_t + \sum_{j=1}^{q} B_j y_{t-j} + \varepsilon_t \; , \tag{1}$$

where the B_j represent $n \times n$ coefficient matrices of lagged effects and ε_t is an n-dimensional vector of uncorrelated structural residuals. The contemporaneous impacts are included in the matrix A with diagonal elements normalised to one. The deterministics comprise a constant and day-of-the-week dummies d_t.

Model (1) as it stands is not identified and therefore cannot be consistently estimated. A first step thus derives the reduced-form VAR

$$y_t = \mu_0^r + \mu_1^r d_t + \sum_{j=1}^{q} B_j^r y_{t-j} + u_t \tag{2}$$

with all coefficients obtained by premultiplying A^{-1} in (1), therefore marked by the superscript r for "reduced". Accordingly, the new residuals are given by $u_t = A^{-1}\varepsilon_t$.

Naturally, it proves impossible to recover the structural parameters from the reduced form without further constraints: In the matrix A with normalised diagonal, $n(n-1)$ simultaneous impacts have to be estimated, whereas in (2), this contemporaneous interaction is reflected by cross-correlation of the reduced-form residuals. However, the information contained in the according covariance-matrix is not sufficient for identification, because due to its symmetry, it delivers only $n(n-1)/2$ equations for simultaneous covariances. The recent literature of identification through heteroscedasticity (e.g. Rigobon 2003) addresses this problem by assuming separate time regimes with differing variances of the structural residuals ε_t. The volatility shift between the regimes would deliver two distinct reduced-form covariance-matrices, so that $n(n-1)/2$ additional covariance and n additional variance equations could be obtained from the second matrix. Since the number of free parameters only rises by n, the number of structural variances, full identification can be achieved. The approach of Weber (2007a) specifies multivariate EGARCH processes for the structural residuals, thereby basically keeping up the intuition of identification through volatility regimes: An ARCH-type model practically defines a distinct variance state for every single observation, leading to a quasi continuum of regimes. For a discussion on identification issues in this context, see as well Weber (2007b).

Formalising the model setup, first denote the conditional variances of the elements in $\varepsilon_t = Au_t$ by

$$\mathrm{Var}(\varepsilon_{jt}|\Omega_{t-1}) = h_{jt} \qquad j = 1, \ldots, n\ , \tag{3}$$

where Ω_{t-1} stands for the whole set of available information at time $t-1$. The assumption of uncorrelated structural shocks supersedes considering any *co*variances.

Then, stack the conditional variances in the vector $H_t = \begin{pmatrix} h_{1t} & \ldots & h_{nt} \end{pmatrix}'$.

At last, denote the standardised innovations by

$$\tilde{\varepsilon}_{jt} = \varepsilon_{jt}/\sqrt{h_{jt}} \qquad j = 1, \ldots, n\ . \tag{4}$$

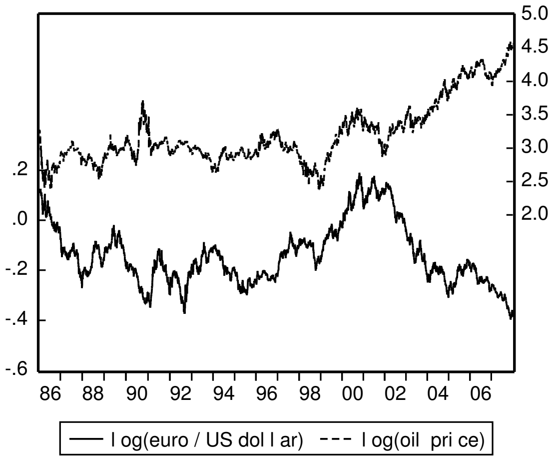
The multivariate EGARCH(1,1)-process, as suggested by Weber (2007a), is given by

$$\log H_t = C + G \log H_{t-1} + D(|\tilde{\varepsilon}_{t-1}| - \iota\sqrt{2/\pi}) + F\tilde{\varepsilon}_{t-1}\ , \tag{5}$$

where C is a n-dimensional vector of constants and G, D and F are $n \times n$ coefficient matrices. With ι denoting a column vector of n ones, the second term in parentheses simply equals the expectation of the preceding shocks in absolute value. In addition, going beyond the pure magnitude of shocks, the signed $\tilde{\varepsilon}_t$ introduce asymmetric volatility effects.

3 Emprical Assessment

Daily data were obtained for the WTI crude oil price from the EIA and the euro / US dollar exchange rate (ECU before 1999) from Reuters for the sample period 1/2/1986 until 12/31/2007. Before 1986, the oil market had been characterised by strong OPEC agreement and steadily increasing prices. The log series and the continuously compounded returns can be seen in Figure 1. The oil price roughly maintained its level until 1999, except for the short Gulf war spike in 1990. The subsequent continuous rise has only been interrupted during the recession in 2001. This development coincided first with the euro depreciation directly following its introduction, and since 2002 with the ongoing dollar weakening. The return series reveal the typical financial volatility clustering.



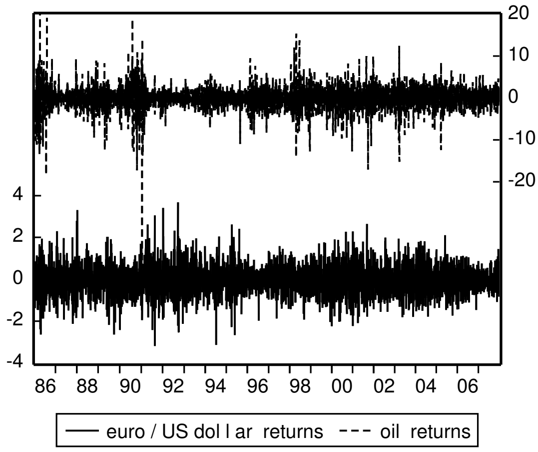


Figure 1: Euro / US dollar and crude oil log prices and returns

At first, the reduced-form model (2) for the returns is considered. Both the Hannan-Quinn and Schwarz criterion suggest a lag length of $q = 0$. Even with three lags as favoured by the Akaike criterion, no-Granger-causality hypotheses in both directions cannot be rejected by Wald tests. Therefore, I obtain the residuals $\hat{u}_t$ from (2) without any lags for use in further analysis.

Estimation of the structural EGARCH is done by Quasi Maximum Likelihood (QML) as in Weber (2007a). Numerical optimisation is performed using the BHHH algorithm (Berndt et al. 1974). With the variable names FX_t and OIL_t and QML standard errors in parentheses, the simultaneous mean equations for the full sample result as

$$\begin{aligned} \mathrm{FX}_t &= \underset{(0.005)}{-0.009}\,\mathrm{OIL}_t + \hat{\varepsilon}_{1t} \\ \mathrm{OIL}_t &= \underset{(0.066)}{0.060}\,\mathrm{FX}_t + \hat{\varepsilon}_{2t}\ . \end{aligned} \tag{6}$$

At best, the coefficient for the OIL influence might reach borderline significance, but still stays economically small. This is consistent with literature results (e.g. Mork 1989, Hooker 2002) stating distinctly weakening significance of the oil linkage with the macroeconomy going along with the first substantial price drop in 1986; presently, the empirical sample correlation only amounts to -0.3%. However, corresponding to the situation before 1986, a stronger connection could be expected to (re)appear with the significant price increases during the most recent decade. Consequently, the model is re-estimated beginning at 12/10/1998, the day of the oil price minimum (see Figure 1):[3]

$$\begin{aligned} \mathrm{FX}_t &= \underset{(0.019)}{-0.053}\ \mathrm{OIL}_t + \hat{\varepsilon}_{1t} \\ \mathrm{OIL}_t &= \underset{(0.287)}{0.551}\ \mathrm{FX}_t + \hat{\varepsilon}_{2t} \end{aligned} \tag{7}$$

Compared to (6), both spillovers are considerably larger and clearly more significant. The negative oil coefficient represents the expected dollar-depreciating effect of oil price increases (the exchange rate was defined as euro per dollar). The positive FX coefficient implies that dollar appreciation causes the oil price to rise, although the opposite should be true considering the role of the dollar as measuring unit. Solving this puzzle, dollar appreciation might be ascribed signals of positive US real activity shocks (or according expectations), thereby boosting demand for oil along with its price.[4] Before further interpretation in this line will be provided, note that the difference in magnitudes of the two coefficients should be taken with care: In terms of variance contributions, it is the oil shocks proving more important, accounting for 4% of FX variation (reverse only 2%).

In the relevant literature, for instance Hamilton (1988), Bohi (1989, 1991) and Ferderer (1996) established asymmetries in macroeconomic reactions to oil price in- and decreases. To account for these findings, both causal effects in (7) are interacted with dummies D indicating positive OIL respectively FX returns:

$$\begin{aligned} \mathrm{FX}_t &= \underset{(0.019)}{-0.040}\ \mathrm{OIL}_t - \underset{(0.012)}{0.005}\ D_{\mathrm{OIL}_t>0}\ \mathrm{OIL}_t + \hat{\varepsilon}_{1t} \\ \mathrm{OIL}_t &= \underset{(0.352)}{0.163}\ \mathrm{FX}_t + \underset{(0.181)}{0.434}\ D_{\mathrm{FX}_t>0}\ \mathrm{FX}_t + \hat{\varepsilon}_{2t} \end{aligned} \tag{8}$$

Surprisingly, it is not the oil price exerting significant asymmetric influences, but far more it reacts itself asymmetrically to exchange rate impulses. The positive dummy coefficient indicates that dollar appreciation substantially raises the oil price, while depreciation stays

[3] Moderate variations, including shifting the sample start to the distinctive local minimum at 11/15/2001, leave the results qualitatively unchanged.

[4] Note that this explanation is based on the plausible assumption that US, more than European, shocks matter for the world economy and the oil market.

relatively neutral in this respect. In this case, an implicit negative growth innovation as explained above might lower the oil price, but the loss in value of the measuring unit naturally increases it. While these conflicting influences might balance each other, the measuring unit effect may be absent in the appreciation case: Just like commercial banks normally pass down monetary policy rate changes to their clients rather in case of decreases than increases, oil suppliers might prefer to retain currency gains rather than losses. Additionally, one could think of inelasticities preventing demand from falling in view of a more expensive dollar, even though a cheaper dollar may well trigger expansion.

Besides the transmission effects analysed until now, variance spillovers might be of further interest. For the shorter sample, the multivariate EGARCH-process (5), with insignificant regressors excluded, resulted as

$$\begin{pmatrix} \log h_{1t} \\ \log h_{2t} \end{pmatrix} = \begin{pmatrix} \underset{(0.001)}{-0.002} \\ \underset{(0.090)}{0.118} \end{pmatrix} + \begin{pmatrix} \underset{(0.001)}{0.997} & 0 \\ 0 & \underset{(0.049)}{0.935} \end{pmatrix} \begin{pmatrix} \log h_{1t-1} \\ \log h_{2t-1} \end{pmatrix} + \begin{pmatrix} \underset{(0.012)}{0.026} & \underset{(0.011)}{0.027} \\ 0 & \underset{(0.067)}{0.176} \end{pmatrix} \begin{pmatrix} |\tilde{\varepsilon}_{1t-1}| \\ |\tilde{\varepsilon}_{2t-1}| \end{pmatrix} + \begin{pmatrix} 0 & \underset{(0.007)}{0.021} \\ 0 & 0 \end{pmatrix} \begin{pmatrix} \tilde{\varepsilon}_{1t-1} \\ \tilde{\varepsilon}_{2t-1} \end{pmatrix} \quad . \quad (9)$$

Besides the usual persistence, spillovers from oil price shocks to the exchange rate variance are revealed. Thereby, the estimate 0.021 for the signed $\tilde{\varepsilon}_{2t-1}$ together with the 0.027 for the absolute shock indicates that positive price innovations cause a considerable volatility impulse, whereas for negative ones the two coefficients simply offset each other. Evidently, the FX market is only susceptible to uncertainties going along with *in*creasing oil prices.

4 Concluding Summary

This paper examined financial market causalities between the daily euro / US dollar exchange rate and the crude oil price. Major findings are that

- relevant interactions are restricted to the period of rising oil prices since the late 1990s,
- increasing (decreasing) oil prices weaken (strengthen) the dollar,
- dollar appreciation asymmetrically boosts the oil price and
- positive oil price shocks asymmetrically drive FX volatility.

Importantly, while the dollar depreciating effect of rising oil prices might have been expected, the underlying study shows distinct endogenous influences on the oil price, being far from exogenous as a financial variable. An interesting approach in future research could employ macroeconomic news data and further financial variables to assess the fundamental determinants and channels of transmission.

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