A WEEKLY STRUCTURAL VAR MODEL OF THE US CRUDE OIL MARKET

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Overview

Understanding and forecasting changes in the real price of crude oil is a challenging task. Oil price dynamics are closely tracked by authorities in charge of monetary and fiscal policies**.** Moreover, crude oil futures markets play a key role for portfolio diversification and inflation hedging (Cheng and Xiong, 2014) or for companies in the transportation and energy sectors whose assets and liabilities might be affected by oil price fluctuations (Chun et al., 2019).

In this paper, we develop a Structural Vector Autoregressive (SVAR) model of the US market for crude oil that can be used to analyse short-run price fluctuations driven by shocks hitting on the spot price of West Texas Intermediate (WTI). Our methodology for decomposing the WTI spot price into its structural drivers relies on the Bayesian approach due to Baumeister and Hamilton (2019). The peculiarity of this approach is that it allows to summarize our beliefs about the value of key structural parameters - such as oil supply and oil demand elasticities - and to contemporaneously incorporate uncertainty about such identifying assumptions. This paper has three distinguishing features. First, contrary to most analysis that rely on monthly or quarterly data (a notable exception is Venditti and Veronese (2020)) our SVAR model exploits data sampled at weekly frequency, which is particularly relevant for constructing economically meaningful scenarios. Second, we draw on the theory of competitive storage to model the forward-looking component of the real price of oil with data on WTI futures prices. Specifically, in our model the spread between the futures and spot prices of WTI crude oil proxies for the (negative of) convenience of crude oil inventories. Thus, this variable reflects the perceived relative value of inventories available in the near future (Valenti (2022)). Third, arbitrage shocks play an important role in explaining the link between physical and financial markets, consistent with the cash-and-carry arbitrage theory. In this respect, we propose an identification strategy that accounts for potential arbitrage frictions, which might determine a temporary distortion between the economic fundamentals and the WTI spot price (Ederington et al., 2020).

Method

This study relies on five variables sampled at weekly frequency to describe the main shocks driving the WTI price: *(i)* the growth rate of US domestic crude oil production (Δq_t), *(ii)* a proxy for the global business cycle based on the shipping rate index (y_t), *(iii)* the oil futures-spot spread with maturity of three months (s_t), *(iv)* the US crude oil inventory changes (Δi_t) and *(v)* the growth rate of the real price of WTI crude oil (Δp_t).
The structural form the weekly VAR model can be written as a system of five equations:

$$\begin{cases} \Delta q_t = a_{qs}^{s} s_t + a_{qp}^{s} \Delta p_t + \boldsymbol{b_1}' \boldsymbol{x_{t-1}} + v_{1,t} & (1) \\ y_t = a_{ys} s_t + a_{yp} \Delta p_t + \boldsymbol{b_2}' \boldsymbol{x_{t-1}} + v_{2,t} & (2) \\ s_t = a_{si} \Delta i_t + a_{sp} \Delta p_t + \boldsymbol{b_3}' \boldsymbol{x_{t-1}} + v_{3,t} & (3) \\ \Delta i_t = a_{is} s_t + a_{ip} \Delta p_t + \boldsymbol{b_4}' \boldsymbol{x_{t-1}} + v_{4,t} & (4) \\ \Delta q_t = a_{qy} y_t + a_{qs}^{d} s_t + \Delta i_t + a_{qp}^{d} \Delta p_t + \boldsymbol{b_5}' \boldsymbol{x_{t-1}} + v_{5,t} & (5) \end{cases}$$

where $\boldsymbol{x_{t-1}}$ is a $(k \times 1)$ vector, (with $k = 5m + 1$) containing a constant and m lags of the endogenous variables and $\boldsymbol{b_i}'$ is a row vector containing the lagged structural coefficients of a given equation. Equation (1) governs the US oil supply curve, which is contemporaneously affected by the WTI price and by the oil futures-spot spread. The parameter a_{qp}^{s} represents the short-run price elasticity of oil supply, while a_{qs}^{s} captures the feedback effects from the financial to the to physical market for crude oil. Equation (2) describes the determinants the real economic activity with the simultaneous effects of the spread and the oil price growth. Equations (3) and (4) are grounded on the theory of competitive storage. Specifically, we assume that the futures-spot spread has a contemporaneous relationship with both inventory and oil price growth. Analogously, the inventory equation is simultaneous affected by physical and financial markets, through the parameters a_{ip} and a_{is}. Finally, Equation (5) models the demand for US crude oil which is explained by all the contemporaneous variables in the system. In order to achieve the identification of the structural coefficients we follow the algorithm proposed by Baumeister and Hamilton (2019), which is based on two main steps.

The first step consists of a specification of informative prior beliefs about the structural parameters of the model.[1] The second step is designed to generate draws from the posterior distribution of the structural coefficient through the Random Walk Metropolis Hastings algorithm. We identify five structural shocks, namely a US oil supply shock ($v_{1,t}$), an aggregate demand shock ($v_{2,t}$), a financial market shock ($v_{3,t}$), a precautionary demand shock ($v_{4,t}$) and a residual demand shock ($v_{5,t}$).

Results

We provide empirical evidence that the real price of WTI oil responds to oil price shocks differently, depending on the economic motivation behind each shock. An unexpected US oil supply disruption causes a decline in the US crude oil production, an increase in the price of oil, and a reduction in the real economic activity, on impact. This shock induces a drop in the futures-spot spread and inventory changes, due to consumption smoothing. A positive aggregate demand shock yields an instantaneous increase in the real economic activity index, in the price of oil and in the US crude oil production and a reduction in the US crude oil inventory changes and futures-spot spread. A positive financial market shock capture a rise in the spread that is mainly driven by arbitrage reasons. Specifically, arbitrage activities are expected to raise the US storage, spread and price of oil, on impact. However, we remain completely agnositic on the response of inventory changes to a positive financial market shock. This allows us to identify potential abtirage frictions due to physical or financial constraints (Ederington et al., 2020). A positive precautionary demand shock causes an upward-shift in the demand for storage for speculative reasons (Kilian, 2009). This shock is responsible of an instantaneous increase in both the US crude oil inventory and production, together with reduction in the futures-spot spread, on impact. This is consistent with the view that the oil futures market is in backwardation and it supports the idea of declining spot price of oil. With this respect, oil traders use backwardation to make profits through a rolling strategy, which is easily done by selling the expiring contract and use the proceeds to buy another futures contract for delivery at a more distant date. Finally, a positive residual demand shock induces a simultaneous increase in the US oil production, accompanied by an hump-shaped response of the real price of oil and a reduction in the US crude oil inventory and futures-spot spread.

Conclusions

We study the main drivers of the WTI spot price of oil in the context of structural VAR framework. Three main conclusions emerge from this analysis. First, there is evidence that the real price of oil, futures-spot spread and the inventory changes respond to oil price shocks differently, depending on the economic motivation behind each shock. Second, weekly sampled data are expected to be very informative in identifying shocks to oil spot prices. Of particular interest is the financial market shock which is designed to capture potential arbitrage opportunities in the WTI futures market. Specifically, the size of the spread between futures and spot prices, accounting for the convenience yield, acts as a trigger for arbitrage trades, consistent with the results of Ederington et al. (2020). Finally, we expect our historical decomposition to be informative about the role of the main aggregate drivers contributing to the persistent recovery of the real price of oil after the COVID-19 outbreak.

References

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[1] Priors beliefs regarding the contemporaneous structural parameters are specified in terms of a Student t distribution and their values (magnitude and signs) are grounded on the economic theory.