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# The asymmetric effects of oil price and monetary policy shocks: A nonlinear VAR approach

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ABSTRACT

In this paper we investigate the asymmetric effects of oil price shocks and monetary policy on macroeconomic activity, using monthly data for the United States, over the period from 1983:1 to 2008:12. In doing so, we use a logistic smooth transition vector autoregression (VAR), as detailed in Terasvirta and Anderson (1992) and Weise (1999), and make a distinction between two oil price volatility regimes (high and low), using the realized oil price volatility as a switching variable. We isolate the effects of oil price and monetary policy shocks and their asymmetry on output growth and, following Koop et al. (1996) and Weise (1999), we employ simulation methods to calculate Generalized Impulse Response Functions (GIRFs) to trace the effects of independent shocks on the conditional means of the variables. Our results suggest that in addition to the price of oil, oil price volatility has an impact on macroeconomic activity and that monetary policy is not only reinforcing the effects of oil price shocks on output, it is also contributing to the asymmetric response of output to oil price shocks.



## 1. Introduction

Recent empirical research on the relationship between oil prices and real economic activity has emphasized the importance of oil price uncertainty. For example, building on the innovative papers by Lee et al. (1995) and Lee and Ni (2002), Elder and Serletis (2009, 2010) examine the direct effects of oil price uncertainty on real economic activity in the context of a structural vector autoregression (VAR) that is modified to accommodate GARCH-in-Mean errors, as detailed in Engle and Kroner (1995) and Elder (2004). Also, Rahman and Serletis (forthcoming) investigate the asymmetric effects of uncertainty on output growth and oil price changes as well as the response of uncertainty about output growth and oil price changes to shocks. In doing so, they use U.S. data and a bivariate VAR modified to accommodate GARCH-in-Mean errors, as detailed in Engle and Kroner (1995), Grier et al. (2004), and Shields et al. (2005). All these papers present evidence that increased uncertainty about the change in the price of oil is associated with a lower average growth rate of real economic activity.

There is also a large literature that investigates whether the economic effects of oil price changes also depend on how monetary policy responds. See, for example, Herrera and Pesavento (2009) and Kilian and Lewis (2009). In this regard, in the past, when oil prices rose prior to recessions so did interest rates, and as has been argued by Bernanke et al. (1997) it was the increase in the interest rate that led to the downturn. Although this view has been challenged by Hamilton and Herrera (2004), who argue that contractionary monetary policy plays only a secondary role in generating the contractions in real output and that it is the increase in the oil price that directly leads to contractions, it is interesting to examine how the monetary policy response to oil price shocks affects the asymmetric output effects of oil price shocks. Moreover, recent work by Kilian and Vigfusson (2009) shows that the original estimates presented in Bernanke et al. (1997) in support of a feedback from monetary policy are inconsistent and were constructed in a way that exaggerates the effects of oil price shocks.

In this paper we build on the literature and investigate the asymmetric effects of oil price shocks and monetary policy on macroeconomic activity, using monthly data for the United States, over the period from 1983:1 to 2008:12. In doing so, we use a logistic smooth transition vector autoregression (VAR), as detailed in Terasvirta and Anderson (1992) and Weise (1999), and make a distinction between two oil price volatility regimes (high and low), using the realized oil price volatility as a switching variable. We isolate the effects of oil price and monetary policy shocks and their asymmetry on output growth and, following Koop et al. (1996) and Weise (1999), we employ simulation methods to calculate Generalized Impulse Response Functions (GIRFs) to trace the effects of shocks on the conditional means of the variables. Our results suggest that in addition to the price of oil, oil price volatility has a negative effect on macroeconomic activity and that monetary policy is not only reinforcing the effects of oil price shocks on

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output, it is also contributing to the asymmetric response of output to oil price shocks.

The paper is organized as follows. Section 2 presents the data and Section 3 provides a brief description of the nonlinear VAR model. Section 4 assesses the appropriateness of the econometric methodology by various linearity tests against the alternative hypothesis of the logistic smooth transition vector autoregression and presents and discusses the empirical results. The final section concludes the paper.

## 2. The data

We use monthly data for the United States from the Federal Reserve Economic Database (FRED), maintained by the Federal Reserve Bank of St. Louis, over the period from 1983 to 2008, on three variables — the industrial production index ($y_t$), the real price of oil ($oil_t$) and the federal funds rate ($r_t$). We use the spot price on West Texas Intermediate (WTI) crude oil as the nominal price of oil, and divide it by the consumer price index (CPI) to obtain the real price of oil. In addition, following Merton (1980) and Andersen et al. (2003), we use the realized oil price variance as a proxy for oil price volatility. As in Guo and Kliesen (2005), we calculate the monthly realized oil price variance, denoted $vol_t$, as the sum of the squared daily price changes in a month, as follows

$$vol_t = \sum_{d=1}^{D_t} (\Delta f_d)^2,$$

where $\Delta f_d$ is the change in the price of one-month oil futures contracts in day $d$ of month $t$; the daily one-month oil futures prices are from Reuters.

In Fig. 1 we plot the $\ln y_t$ and $\Delta \ln y_t$ series, in Fig. 2 the $\ln oil_t$ and $\Delta \ln oil_t$ series, and in Fig. 3 the $r_t$ and $\Delta r_t$ series, with shaded areas indicating NBER recessions. The realized oil price volatility series, $vol_t$, is plotted in Fig. 4. Clearly, oil price volatility increased dramatically in 1986, 1990 and 2008. The volatility increase in 1986 was the result of a sudden decline in the price of oil at that time while the increases in 1990 and 2008 were the result of the increase in the price of oil during the first Gulf war and the recent financial crisis, respectively.

A battery of unit root and stationarity tests are conducted in Table 1 for $\ln y_t$, $\ln oil_t$, $r_t$, and $vol_t$. In particular, we report augmented Dickey–Fuller (ADF) unit root test results [see Dickey and Fuller (1981)] in the first three columns of the table. Also, since unit root tests have low power against relevant stationary alternatives, we run Kwiatkowski et al. (1992) tests, known as KPSS tests, for level and trend stationarity and report the results in the last two columns of Table 1. As can be seen, the null hypothesis of a unit root cannot be rejected at conventional significance levels for the $\ln y_t$, $\ln oil_t$, and $r_t$ series; it is, however, rejected for the $vol_t$ series. Moreover, the null hypotheses of level and trend stationarity are each rejected for the $\ln y_t$, $\ln oil_t$, and $r_t$ series, but not for the $vol_t$ series.

We also test for cointegration following Johansen and Juselius (1992), in the context of the following $k$ (=4)-dimensional vector autoregression

$$\boldsymbol{y}_t = \sum_{i=1}^{k} \boldsymbol{\Phi}_i \boldsymbol{y}_{t-i} + \boldsymbol{\mu} + \boldsymbol{u}_t$$

wehre $\boldsymbol{y}_t = [\ln y_t, \ln oil_t, r_t, vol_t]$ and $\boldsymbol{u}_t$ is an independently and identically distributed $p$-dimensional vector of innovations with zero mean and covariance matrix $\boldsymbol{\Omega}$. We use the trace test statistic to test for the number of cointegrating vectors — see Johansen and Juselius (1992) for more details. We find that the null hypothesis of no cointegration is rejected at conventional significance levels. However, the usual normality and autocorrelation error-term diagnostics (for low- and high-order VARs) are inconsistent with an appropriate specification and we proceed by using a vector autoregression, instead of a vector error correction model.

## 3. Econometric methodology

We use an unrestricted reduced-form, nonlinear vector autoregression following a smooth transition autoregressive form. The nonlinearity is based on the fact that the dynamic behavior of time series depends on states or regimes of the variables. Terasvirta and Anderson (1992) used such a nonlinear model in a single equation framework, but here we follow Weise (1999) and extend it to a multi-equation setting.

By ignoring moving average terms, our logistic smooth transition vector autoregressive model is as follows

$$\Delta \boldsymbol{x}_t = \left(\boldsymbol{a}_1 + \sum_{i=1}^{p} \boldsymbol{\Gamma}_{1,i} \Delta \boldsymbol{x}_{t-i}\right) + \left(\boldsymbol{a}_2 + \sum_{i=1}^{p} \boldsymbol{\Gamma}_{2,i} \Delta \boldsymbol{x}_{t-i}\right) G(z_t; c, \gamma) + \boldsymbol{e}_t, \quad (1)$$

where $\boldsymbol{x}_t$ is a $(k \times 1)$ vector of time series and $G(z_t; c, \gamma)$ is a function which lies between zero and one, with these two extreme values

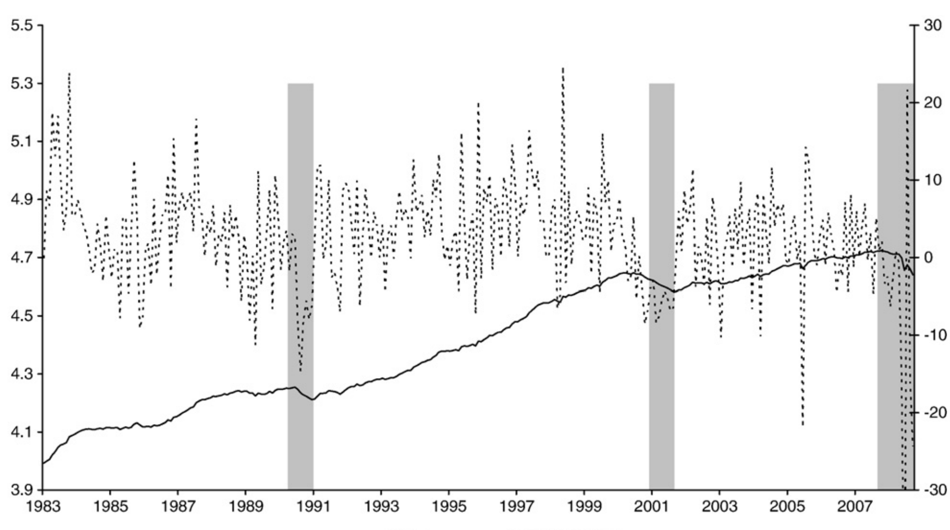


**Fig. 1.** Logged real output and the real output growth rate.