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Are the macroeconomic effects of oil price shock symmetric?: A Factor-Augmented Vector Autoregressive approach

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ABSTRACT

This paper aims to examine the asymmetric effect of oil price shocks on real economic activity in the U.S. within the context of a nonlinear Factor-Augmented Vector Autoregressive (FAVAR) model. By employing simulation methods, we trace the effects of positive and negative oil price shocks on the macroeconomic variables through the Impulse Response Function (IRF). It is found that the negative impacts of higher oil prices are larger than the positive effects of lower oil prices. And the asymmetric effects are more evident when the oil price shocks are larger. The results are robust to different lag specification and choice of factors.

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1. Introduction

Over the past 20 years, markets have seen dramatic fluctuations of oil prices. And the large variability of the oil price has long been considered as a main source of macroeconomic fluctuation by many economists. According to Hamilton (2011), 10 out of 11 post world-war II recessions have followed or accompanied by a sharp rise in oil prices. Thus, the unpredictability and large fluctuation of oil price have bolstered an active line of research into the relationship between oil price and macroeconomic variables (for example, Hamilton, 2011; Herrera et al., 2011; Kilian and Vigfusson, 2012; Lee et al., 1995; Rahman and Serletis, 2011). What are the effects of the large fluctuations of oil price on the economy? Are the responses to the oil price increase and decrease symmetric?

The general consensus held in the literature is that oil price hikes have a larger adverse impact on economic development than positive effects from drops in oil prices (for example, Davis and Haltiwanger, 2001; Hamilton, 1999; Hooker, 1996, 2002; Jones and Leiby, 1996). And several studies offer important insights about the origination of such asymmetry. For example, Hamilton (1988) illustrates that adjustment costs to changing oil prices could be the source of the asymmetry. The costs of adjustment to changing oil prices retard economic activity, meanwhile falling oil price stimulates economy and rising oil price hampers economy. So rising oil price presents two obstacles to economic growth, while falling oil price witnesses the offsetting of positive and negative effects. Bohi (1989, 1991) and Bernanke et al. (1997) point out monetary policy as another possibility of the asymmetry. The contractionary monetary policy responding to the rising oil price retards the economy more in addition to the negative effects from higher oil price. Balke et al. (2002), using nonlinear dynamic relations, confirm that monetary policy and adjustment-cost could account for the asymmetry.

Although asymmetry is now fairly well accepted, a few studies recently have raised some concerns with regard to the robustness of the conclusion. For example, while Herrera et al. (2011) find strong asymmetric effect at the disaggregate level, the evidence for such effects is obscured in the aggregate data. Also, the nonlinearity effect is strongest for samples starting before 1973, while is much weaker for sample after 1973. Kilian and Vigfusson (2011) also find no evidence against the null of symmetric responses to oil price shocks for the real GDP using data for 1973:Q2–2007:Q4. Furthermore, Kilian and Vigfusson (2012) demonstrate that

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the asymmetry embodied in commonly used nonlinear transformations of the price of oil is not helpful for out-of-sample forecasting.

From the perspective of methods in the literature, there are three main methods employed. The first strand is based on dynamic correlations in the data, such as Hamilton (2003). But the approach does not allow distinction between the cause and effects, and does not shed light on the macroeconomic effects of oil price shocks. The second strand adopts the traditional approach of conducting Wald test of the coefficient of net increase of oil price (for example, Cong et al., 2008; Mordi and Adebiyi, 2010). However, these slope-based tests do not distinguish between shocks of different magnitude, which is the ultimate interest to users, and hence is limited for evaluating the degree of asymmetry. Recently, many papers quantify the asymmetric responses based on censored oil price VAR models, but Kilian and Vigfusson (2011) claim that the asymmetric models of the transmission of oil price shocks cannot be represented as censored oil price VAR models and are fundamentally misspecified whether the data-generating process is symmetric or asymmetric, and this misspecification renders the parameter estimates inconsistent and inference invalid. Therefore, the evidence for asymmetric effects should not be taken as customary as the literature established.

Compared with Kilian and Vigfusson (2011), this paper imposes a recursive ordering that treats real oil price as predetermined rather than standard identifying assumption familiar from structural VAR models. Second, to avoid Kilian and Vigfusson's criticism about the inconsistent and misleading OLS estimator, the nonlinear Hamilton oil price variable does not enter the VAR system as an endogenous variable but as an independent exogenous variable. Third, the model in this paper includes a broad class of variables reflecting the whole economy rather than focusing on oil price–output relationship.

The purpose of the paper is to re-evaluate the asymmetric relationship between oil price shocks and a wide range of U.S. macroeconomic variables based on a brand new nonlinear framework, i.e., nonlinear using Factor Augmented Vector Autoregression (FAVAR). As such, it would contribute more evidence on the issue. To the best of my knowledge, this is the first attempt to explore the asymmetric issue in the context of FAVAR model. FAVAR is very suitable for the topic at hand in that not only it allows us to examine the degree of the asymmetric effects to shocks of different magnitude, but also it can shed light on the transmission channels of the oil price shocks. In addition, FAVAR has several distinct advantages compared to traditional VAR. According to Bernanke et al. (2005), standard VARs rarely employ more than six to eight variables due to the concern on the degree of freedom. Thus, it is unlikely to span the information sets used by central banks, which follows hundreds of data series. Also the variables included in the VAR are not likely to precisely reflect their theoretical counterparts. For example, researchers may use GDP or industrial production index as a proxy for the "economic activity". In addition, while impulse responses for traditional VAR can be observed only for the included variables, which represent only a small fraction of variables that the researchers or policy-makers care about, FAVAR could generate impulse response function of wide range of variables in general information dataset. As such, the method will be especially essential for understanding macroeconomic effects of oil price shocks. This paper follows Bernanke et al. (2005) by considering an approach that combines the standard VAR with factor analysis (FAVAR).

To preview the results, this paper has the following findings. First, the asymmetric effects of oil price shock on macroeconomic activity are significant evident, against the conclusions obtained from Kilian and Vigfusson (2011). Rising oil price has a negative effect on output, gross saving, employee's payrolls, housing price, consumer expectation and etc., while has a positive effect on Fed Funds rate, etc. Second, the asymmetry depends on the size of the shock: the larger the shocks, the more evident the asymmetry.

The paper is organized as follows: Section 2 provides a brief description and the estimation of the nonlinear FAVAR models. Section 3 presents empirical results. Section 4 presents robustness check. Section 5 concludes.

2. Nonlinear FAVAR model

Let X_t denotes the $[N_x \times 1]$ vector of observable variables in period t, where $t = 1,\ldots,T$ is the time index. We assume that additional information can be summarized by a $[N_f \times 1]$ vector of unobserved factors, F_t, which reflects the co-movement of variables across the large data set in period t. One can regard the unobserved factors as abstract concepts such as "economic activity" and "policy stance" that cannot be comprehensively represented by one or two series but rather are reflected in a wide range of economic variables. And u_t is $[N_x \times 1]$ time t idiosyncratic component of the respective variables. In addition, let Y_t denotes the $[N_y \times 1]$ vector of perfectly observable vector of variables that have pervasive effects throughout the economy. And in this paper, real oil price is the perfectly observable factor. N_x, N_f and N_y denote the number of variables in X_t, the number of factors to be extracted from X_t and the number of perfectly observable factors respectively. The observation equation is

$$\begin{aligned} &X_t = \Lambda^f F_t + \Lambda^y Y_t + \Lambda^h Y_{H,t} + u_t \\ &u_t \sim \mathrm{N}(0, \mathrm{R}). \end{aligned} \tag{2.1}$$

Here Λ^f and Λ^y denote the factor loading matrix of the factors and the perfectly observable variables included as factors with dimension $[N_x \times N_x]$ and $[N_x \times N_y]$ respectively. The error term u_t has mean 0 and covariance R which is assumed to be diagonal. Therefore the error terms of the observable variables are mutually uncorrelated.

The FAVAR state equation represents the joint dynamics of factors and the observable variables (F_t, Y_t) following a VAR process.

The VAR equation is:

$$\begin{aligned} &\begin{bmatrix} Y_t \\ F_t \end{bmatrix} = \Phi(\mathrm{L}) \begin{bmatrix} Y_{t-1} \\ F_{t-1} \end{bmatrix} + \psi(\mathrm{L}) Y_{H,t-1} + v_t \\ &v_t \sim \mathrm{N}(0,\ \mathrm{Q}) \end{aligned} \tag{2.2}$$

where v_t is the time t reduced form shock, Q is the factor error covariance matrix and the $\Phi(\mathrm{L})$ and $\psi(\mathrm{L})$ denote the respective p-lag coefficient matrices.

In order to test the asymmetry of the system, we add an exogenous variable called Hamilton net oil price $Y_{H,t}$ into the observation equation. According to Hamilton (1996, 1999), oil price increase matters only to the extent that they exceed the maximum oil price in the recent years and oil price decrease does not matter. As such, the variable compares the oil price each quarter with the maximum value during the previous three years.

$$Y_{H,t} = \max\{0,\ Y_t - \max\{Y_{t-1}, \ldots Y_{t-12}\}\}.$$

Note that this identity is not contained in the VAR equation, because it is a nonlinear combination of the oil price variable in the VAR part. By not including the Hamilton oil price as an endogenous variable, the estimation is free of the Kilian and Vigfusson criticism of censored oil price in the VAR system leading to inconsistent estimation.

2.1. Estimation by likelihood-based Gibbs sampling

According to Bernanke et al. (2005), there are two approaches in estimating the FAVAR models. One relies on a two-step principle components approach proposed by Stock and Watson (2002) and the other is Bayesian likelihood approach. We use the second approach. As commented by Bernanke et al. (2005), it is not clear which method dominates the other. For most of papers, they use principal components approach for being computationally simple and easy to implement. In this paper we consider the joint estimation by likelihood-based Gibbs sampling techniques, which incorporates prior information about the loadings (see Mumtaz and Surico, 2007).

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