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Asymmetric impact of crude price on oil product pricing in the United States: An application of multiple threshold nonlinear autoregressive distributed lag model

Debdatta Pal *, Subrata Kumar Mitra

Indian Institute of Management Raipur, Raipur, India

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ABSTRACT

By using a multiple threshold nonlinear autoregressive distributed lag model, this paper assesses the nonlinear relationship among crude oil and petroleum product prices in the United States. While the assessment of the asymmetric impact on petroleum product prices based on the upward and downward movement of crude prices is well documented in the literature, the contribution of this paper is in splitting the crude price fluctuation in multiple partial sum series, which allows for a more detailed and minute analysis of the relationship. Apart from confirmation of nonlinear influences, we also found the presence of a relatively high asymmetric impact at the lower quantiles of crude oil price changes. This implies that the benefits of sharp reductions of crude prices are, in general, not transferred to various petroleum products.

1. Introduction

The purpose of this paper is to capture the influence of crude oil price change on petroleum products and explore the presence of asymmetric relationship among them. Petroleum product includes gasoline, diesel, kerosene, and propane that serve as important energy sources across countries. Gasoline and diesel are used as main fuel for passenger and transport vehicles. As petroleum products are made from crude oil, in a free market economy, the prices of these derivative products are expected to vary with the change in the price of crude oil. However, it is found that prices of petroleum product respond faster and in larger magnitude to the increase of crude oil price, while the price of the former drops at a comparatively slower rate and in smaller magnitude in response to fall in crude oil price. The importance of the proper assessment of this asymmetric price transmission is as follows: first, it may question the very assumption of symmetric price transmission, i.e., free flow of information and may surface the manifestation of market failure. And second, the asymmetric price transmission implies that a set of transacting agents (i.e., consumers) are not benefitting out of price fall as price is being adjusted at a slower pace and lesser magnitude as expected under symmetric transmission. In contrast, the benefit of price rise is enjoyed for a longer time period by the producers. This uneven distribution of consumer and producer surplus could have important welfare effect and hence calls for appropriate policy intervention.

Bacon (1991) described this asymmetric effect as “Rockets and Feathers” resembling the price of oil derivatives accelerates like rockets as it increases at a faster and larger magnitude as the price of crude oil rises, but falls as a feather, as price reduction takes place at a much lower rate and lesser magnitude in response to decrease in the price of crude oil. This phenomenon has been further confirmed by a number of studies (see for example Borenstein et al., 1997; Bachmeier and Griffin, 2003; Chen et al., 2005; Honarvar, 2009 for the United States (U.S.) and Grasso and Manera, 2007; Meyler, 2009 for European nations) that have documented this asymmetric price interaction between gasoline and crude oil. However, empirical evidence of Berument et al. (2014) from a set of North Mediterranean nations and Karagiannis et al. (2015) from four European Union nations do not support the asymmetric pass-through of the crude oil price on petroleum product prices. Nevertheless, the majority of studies in this domain (for a detailed review, refer to Perdiguero-Garcia, 2013) focus on linear relations between the prices of crude oil and gasoline, though, exceptions can be significantly noted from the recent empirical investigations of Lamotte et al. (2013) and Atil et al. (2014) that have explored the nonlinearity between the prices of crude oil and gasoline.

Another major stream of research has focused on assessing the consequences and causes of oil price shocks. Hamilton (1983) had shown that post Second World War, nine out of ten recessions in the United States was the consequence of rising oil prices, thus suggesting a deep adverse impact on the economy. Subsequent studies of Mork (1989) and Hooker (1996) extend support to the findings of Hamilton (1983) and conclude that rising oil prices raised production cost, held pressure on inflation, as well as dampened investors' confidence and hence retarded the economic growth of U.S. Hamilton (2003) raised

* Corresponding author at: Economics and Business Environment, Indian Institute of Management Raipur, Raipur, India, 492015. Tel.: +91 771 2772139; fax: +91 771 2772116.
E-mail address: debdatta@iimraipur.ac.in (D. Pal).

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concern on the linearity assumption behind the classical production function used, in the existing literature, to capture the impact of oil price changes on real gross domestic product (GDP) growth. He argued that following linearity, if the rise of oil price brings about a recession, then the fall of oil price should invariably result in an economic boom. However, in reality, aberrations from this straightforward inverse relationship between oil price and output are more uncommon as oil price rise is quite substantial enough to be adjusted in the preceding quarters. Therefore, Hamilton (2003) proposed an approach of nonlinear modeling to capture the asymmetric pass-through of oil price change to real GDP growth. Nevertheless, there are dissent opinions countering both the exogenous supply shock as well as nonlinearity pass-through of oil price as postulated by Hamilton (1996, 2003). For instance, Kilian (2014) argues that exogenous supply shocks could explain only 25 percent of the oil price rise, while the rest 75 percent of the oil price increase could be attributed to physical oil demand shocks originated from a sudden increase in oil demand from oil importing emerging economies that traditionally used less oil, fluctuations in the global business cycle, and the speculative demand shock arising from the expectations in the physical market of crude oil. Regarding the use of nonlinear transformation, Kilian and Vigfusson (2011, 2013) had shown the symmetric nonlinear models were more robust and accurate in predicting real GDP over that of the linear models.

This mixed evidence in the existing empirical literature regarding the relationship between crude oil and petroleum derivatives as well as crude oil and real output calls for further investigation. However, in this paper, we selectively explore the nonlinear pass-through of crude oil price to petroleum derivative prices in the U.S. market. We build upon our study on the recent contribution of Lamotte et al. (2013), Atil et al. (2014), and Shin et al. (2011, 2014) that have employed nonlinear autoregressive distributed lag (NARDL) model. They adopted the single-threshold method where exogenous variable is decomposed into its positive and negative components, and accordingly, the threshold for changes in the exogenous variable is set at zero. Each component captured the effect of either increase or decrease of the regressor. It was also found that prices of petroleum derivatives respond asymmetrically and in a nonlinear manner to crude oil price changes. Following Shin et al. (2011), Verheyen (2013) analyzed the effect of small and large exchange rate changes in Economic and Monetary Union (EMU) exports to the U.S. by employing NARDL model of two-threshold and reported results on the threshold set at 30th and 70th quantile of exchange rate changes. In our paper, we have extended the two-threshold NARDL methodology of Verheyen (2013) to multiple threshold NARDL model.

Instead of only analyzing the impact of upward and downward fluctuations of crude price, this study analyzes the impact on the magnitude of price changes by fixing various thresholds. This study is carried out using the following thresholds: (a) Using a single threshold where price is split into two parts—increase compared to the previous part and decrease compared to the previous part. (b) Crude oil price change is split into 5 partial sum series putting thresholds of 20th quantile, 40th quantile, 60th quantile, and 80th quantile of the weekly crude oil price series. (c) Crude oil price change is decomposed into 10 partial sum series putting thresholds at deciles. This can be generalized and easily be extended to any specific quantiles. The quantile classification of independent variable (crude oil price changes in the study) is to distinguish small to large crude oil price movements which would enable assessing an asymmetric response of petroleum products prices in a better way than only two-way classifications of increases and decreases.

The contribution of this paper is twofold. First, on the methodological front, we propose a multiple threshold NARDL model, a generalization of the two-way classification NARDL model, which would allow us decomposition of the exogenous variable in quantiles by setting multiple thresholds. Second, on the application front, the results of the multiple threshold NARDL model could capture, with more precision, the magnitude of petroleum derivative price change in response to smaller to larger change in crude price. This establishes the efficacy of the proposed multiple threshold NARDL model over the more common single-threshold NARDL model.

The limitations of the study are identified at the outset. First, while we concentrate our focus on one-way (i.e. supply side) price transmission from crude to petroleum derivative, it is worth mentioning that recent literature (for example, Kilian, 2010) has also advanced joint modeling of global crude price with the U.S. retail gasoline market to capture two-way price transmission. And second, while we understand that price transmission from crude to derivatives would have a cascading effect on a country's output and its economic wellbeing, we shall limit our discussion to the nonlinear impact of crude price change on the price of petroleum derivatives.

The rest of the paper is arranged as follows. The next section explains data followed by the description of the econometric method in Section 3. Section 4 presents results and discussion. The last section concludes.

2. Data

We used weekly time series data on the U.S. from April 19, 1996, to Jul 18, 2014. These data are published with the U.S. Energy Information Administration website. Table 1 shows the descriptive statistics for the variables used in this study. Variables include weekly New York Harbor conventional gasoline regular spot price FOB in U.S. dollars per gallon (*NYG*), weekly U.S. Gulf Coast conventional gasoline regular spot price FOB in U.S. dollars per gallon (*GCG*), weekly New York Harbor no. 2 heating oil spot price FOB in U.S. dollars per gallon (*NYH*), weekly Los Angeles, CA, ultra-low sulfur diesel spot price in U.S. dollars per gallon (*DIESEL*), weekly U.S. Gulf Coast kerosene-type jet fuel spot price FOB in U.S. dollars (*JET*), weekly Mont Belvieu TX propane spot price FOB in U.S. dollars (*PR*), weekly cushing WTI—crude oil spot price FOB in dollars per barrel (*CR*), and the volume of petroleum products in thousand barrels per day (*VOL*). All the series are positively skewed and the fourth moment shows that distributions are mesokurtic.

3. Econometric specification

3.1. ARDL model

The proposed multivariate model to capture the “Rockets and Feathers” phenomenon is as follows:

$$P = f(VOL,\ CR)$$

P refers the prices of *NYG*, *GCG*, *NYH*, *DIESEL*, *JET*, *PR*. *CR* and *VOL* refer to the crude price and the weekly volume of petroleum products in thousand barrel per day, respectively. As per economic theory, the price of a

Table 1
Descriptive statistics.

	NYG	*GCG*	*NYH*	*DIESEL*	*JET*	*PR*	*CR*	*VOL*
Mean	1.542	1.514	1.572	1.690	1.601	0.807	54.972	19504.795
Minimum	0.296	0.277	0.290	0.379	0.294	0.206	11.000	16375.000
Maximum	3.363	3.668	3.992	4.057	4.109	1.937	142.520	22156.000
Standard deviation	0.895	0.878	0.966	0.965	0.988	0.397	31.922	989.278
Kurtosis	−1.277	−1.255	−1.150	−1.186	−1.168	−0.719	−1.146	−0.547
Skewness	0.393	0.382	0.454	0.406	0.432	0.433	0.393	0.012