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Revisiting asymmetric price transmission in the U.S. oil-gasoline markets: A multiple threshold error-correction analysis

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ABSTRACT

This paper revisits the asymmetric price transmission in the U.S. oil-gasoline markets by a multiple threshold error-correction model. Unlike the previous studies, the regimes and thresholds are endogenously determined by sequential model selection. A nonlinear asymmetric pattern is discovered in the short-run price transmission from crude oil to retail gasoline, via both the commodity and financial markets. For medium movements in both oil prices, increases demonstrate a significantly stronger impact on retail gasoline prices than decreases. However, asymmetry is detected for neither large nor small oil price movements. Nonlinear asymmetric transmission via the refinery markets is excluded. Nevertheless, the long-run speed towards equilibrium does not exhibit asymmetry between any paired regimes. We discuss the economic interpretations and implications of the detected nonlinear asymmetry.

1. Introduction

Downstream gasoline prices are often found to respond to increases in upstream costs more rapidly and significantly than downstream prices respond to decreases in upstream costs. This is named as the rockets and feathers theory originating from Bacon (1991), and widely studied in energy economics. To empirically test this theory, researchers have adopted different variants of cointegration and error-correction models, though a consensus has not been reached. For example, Borenstein et al. (1997) detect supportive evidence for the existence of asymmetry in the energy price transmission. On the contrary, many studies discover no strong evidence for asymmetric transmission, or unrobust results depending on the choices of weekdays, frequencies, markets, model specifications and etc.[1] Recently, Kristoufek and Lunackova (2015) introduce wave test and rescaled range ratio test to investigate possible asymmetry in the price adjustment of retail gasoline to crude oil after considering the possibility of fractional cointegration, and find no statistically significant asymmetry.

Besides the asymmetric impact of oil price on gasoline price, there have been flourishing studies on asymmetric transmission from oil price to various economic variables. Though they are not directly related to our work, they reinforce the importance of studying the asymmetric impact of oil price in recent years. To name a few, Narayan and Gupta (2015), Narayan et al. (2014) report the asymmetry in the predictability of oil price on stock prices, and find negative oil price changes a relatively more important predictor of US stock returns than positive changes. Phan et al. (2015) find that oil returns have a positive effect on stock returns of oil producers regardless of oil price increases or decreases, while imposing an asymmetric impact on stock returns for most consumer sub-sectors. Based on structural models, Kilian and Vigfusson (2011) detect roughly the same magnitude of responses of the U.S. economy to the increases and decreases of oil price. Valadkhani (2013) examines the asymmetric pricing behavior of unleaded petrol in 111 locations in Australia by considering both the size and sign of deviations from the long-run equilibrium prices, and identify that in 28 locations the asymmetric behavior does exist. Gautier and Saout (2015) assess whether thresholds triggering price increases and decreases are different and report no significant asymmetry in the transmission of wholesale price to retail prices, based on daily French micro data.

Despite the various models and diversified findings, a common strategy of the existing studies is to ad-hocly pre-specify two regimes to examine possible asymmetry, though different threshold variables and regimes have been defined. In Borenstein et al. (1997) and Bachmeier and Griffin (2003), regimes are defined as periods of rising and falling prices, with upstream price movements as the threshold variable and zero as the threshold. In some studies based on threshold cointegration, e.g., Chen et al. (2005), regimes are defined by the equilibrium prices with respect to upstream costs, and also zero threshold.

Nevertheless, the commonly applied two-regime models may have several limitations, due to arbitrarily selected regimes and thresholds. As posited in Honarvar (2009), imposing a pre-determined threshold zero misspecifies the model. Besides, asymmetric effects can sometimes be overstated or understated by coercively merging the multiple regimes, which may actually exist in the transmission process. This

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[1] See for example, Godby et al. (2000), Bachmeier and Griffin (2003), Bettendorf et al. (2003), Griffin and Schulman (2005), Ewing et al. (2006), Grasso and Manera (2007).

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Table 1
Test on stationarity and autocorrelation.

	CO_s	CO_f	GA_s	GA_f	GA_r
Ljung–Box	1013.514***	1013.890***	1007.997***	1011.195***	1013.405***
ADF (level)	−2.628*	−2.559	−2.821	−2.775	−1.790
PP (level)	−17.531**	−16.684	−17.633	−16.686	−17.385
ADF (1st diff)	−26.668***	−26.175***	−29.133***	−27.224***	−17.123***
PP (1st diff)	−889.452***	−881.124***	−1014.216***	−986.221***	−505.381***

Notes: COs, COf, GAs, GAf and GAr represent crude oil spot and futures prices, gasoline spot and futures prices, and retail gasoline prices, respectively; Statistics in this table are based on prices in dollars per gallon; the null hypothesis for ADF/PP and Ljung–Box tests is a unit root and the absence of autocorrelation, respectively.

*** Indicate the rejection of the null hypothesis at 1% significance level.

** Indicate the rejection of the null hypothesis at 5% significance level.

* Indicate the rejection of the null hypothesis at 10% significance level.

can result in conflicting results. Moreover, the existing studies do not answer the following questions: Does nonlinear asymmetry exist in the price transmission process? Namely, is the asymmetric price transmission nonuniform across the distribution of the upstream price movements? Do the asymmetric transmission patterns differ among large, medium and small movements in the upstream? When the degree of asymmetry is the same for different shocks, it leads to asymmetric or symmetric (if the degree of asymmetry is zero) price transmission which has been extensively studied in the literature. However, when the degree of asymmetry varies among different shocks, this is defined as nonlinear asymmetric price transmission, which has not been fully addressed in the previous studies.[2]

This paper differs from the previous studies and addresses the above questions by a multiple threshold error-correction model. We endogenously identify the regimes existing in the price transmission process, by applying the sequential model selection approach. We choose lagged upstream movements as the threshold variable, considering that this variable is more explicitly observable to the retail customers, compared to another threshold variable as lagged error-correction terms. In order to shed light on the asymmetry at various stages of the production and distribution chain, we investigate two different price transmission channels of the U.S. markets: from crude oil to retail gasoline, and transmission via refinery markets, i.e., from crude oil to refinery gasoline, and then to retail gasoline. We also identify the potential role that future markets may play in the asymmetric price transmission, by incorporating futures prices for upstream products. According to Chen et al. (2005), futures prices rapidly disseminate information on current and future cost conditions to gasoline retailers, and most crude oil and refinery gasoline transactions are conducted through contract arrangements with pricing terms tied to either spot or future prices.

We detect a nonlinear asymmetric pattern in the short-run transmission over the distribution of upstream price movements, via both the financial and commodity markets. Specifically, for medium-size movements in the spot and futures oil prices, for example, 5 cents per gallon changes, increases demonstrate a significantly stronger impact on retail gasoline prices than decreases. For either large or small movements, for example, 10 cents or 1 cent per gallon changes, the upward and downward oil prices display symmetric transmission effects. In contrast, the nonlinear effect is veiled by the traditional threshold error-correction model, by combining multiple regimes into two regimes and setting an arbitrary threshold zero.

The rest of this paper is structured as follows. Section 2 provides the multiple threshold error-correction model and the estimation strategy. Section 3 provides the data and descriptive statistics. Section 4 presents the empirical results, robustness check and comparison with related studies. Section 5 discusses the economic interpretations. Section 6 concludes.

2. Methodology

Suppose that $\{x_t, t = 1,\ldots,n\}$ and $\{y_t, t = 1,\ldots,n\}$ are respectively the upstream and downstream energy prices. They are usually found to be $I(1)$ variables and cointegrated by the long-run equilibrium as in Engle and Granger (1987),

$$y_t = \alpha + \beta x_t + u_t \tag{1}$$

where u_t are mean-zero stationary residuals, and β is the cointegration coefficient. If Eq. (1) holds, an error-correction term (ECT) needs to be introduced to the vector autoregressive (VAR) model. The linear error-correction model (linear ECM) incorporating the short-run variations from the long-run equilibrium is then formularized as,

$$\Delta y_t = \delta ECT_{t-1} + \sum_{i=1}^{p-1} \gamma_i \Delta y_{t-i} + \sum_{j=1}^{q-1} \beta_j \Delta x_{t-j} + e_t \tag{2}$$

where p and q are the lag length, $ECT_{t-1} = \hat{u}_{t-1}$ is the ECT defined as one-period lagged residuals in Eq. (1), δ is the adjustment speed towards long-run equilibrium, and γ_i and β_j capture short-run adjustments. Specifically, β_j measures the price transmission effects from upstream to downstream.

To explore whether the transmission effects are uniform over the entire distribution of the upstream movements, following Gonzalo and Pitarakis (2002, 2006), a multiple threshold error-correction model (MTECM) with m thresholds and $m+1$ regimes is proposed as,

$$\Delta y_t = \sum_{k=1}^{m+1} \left(\delta^k ECT_{t-1} + \sum_{i=1}^{p-1} \gamma_i^k \Delta y_{t-i} + \sum_{j=1}^{q-1} \beta_j^k \Delta x_{t-j} \right) I(\lambda_{k-1} < z_{t-1} \le \lambda_k) + e_t \tag{3}$$

where $I(.)$ is the indicator function, z_{t-1} is the threshold variable and λ_k is the relevant threshold of each regime. For convenience, we denote multiple regimes as r^k $(k = 1,\ldots,m+1)$. As explained earlier, we choose the threshold variable as the lagged upstream price movements, i.e., $z_{t-1} = \Delta x_{t-1}$. MTECM covers as a special case the linear ECM (Eq. (2)) when there is a single regime, and also the traditional threshold ECM (TECM) in Eq. (4) with two regimes defined by zero. TECM and variants have been widely applied in the previous studies on asymmetric energy price transmission (Bachmeier and Griffin, 2003; Chen et al., 2005; Godby et al., 2000).

$$\begin{aligned} \Delta y_t = {} & \left(\delta^+ ECT_{t-1} + \sum_{i=1}^{p-1} \gamma_i^+ \Delta y_{t-i} + \sum_{j=1}^{q-1} \beta_j^+ \Delta x_{t-j} \right) I(z_{t-1} > 0) \\ & + \left(\delta^- ECT_{t-1} + \sum_{i=1}^{p-1} \gamma_i^- \Delta y_{t-i} + \sum_{j=1}^{q-1} \beta_j^- \Delta x_{t-j} \right) I(z_{t-1} \le 0) + e_t \end{aligned} \tag{4}$$

A natural question is how to determine the number of regimes in multiple threshold models, which has been extensively explored in

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[2] One possible case is that symmetry exists for some shocks while asymmetry exists for others. This is also defined as nonlinear asymmetric price transmission, considering that symmetry can be regarded as a special case of asymmetry when the degree of asymmetry is zero.