Asymmetric Price Transmission from International Crude Oil Prices to Gasoline Prices in China: Evidence from the NARDL Model

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Abstract: In view of the researcher ascertaining the price transmission from international oil to gasoline in China, it can be acquired that the asymmetry arouses less attention from the academic fields. On that basis, the week spot closing price data of international crude oil and gasoline prices are collected, and the newly developed NARDAL model is adopted in this paper to ascertain the asymmetric price transmission (hereinafter referred to as APT). The prices are able to be asymmetrically related both in the long and short-run in virtue of the nonlinear ARDL model. To this end, the prices shall be asymmetric both from the perspective of magnitude and rate. In addition to this, the price asymmetry makes possible the quantification of how gasoline prices respond to the positive and negative impact exerted by crude oil prices through adopting the asymmetry-based dynamic multipliers of price. In accordance with the conclusion, the price transmission from international crude oil to Chinese gasoline shall be elaborate and delved into at great length from numerous new perspectives.

Keywords: international crude oil price; gasoline price; asymmetric price transmission (APT); NARDL model

1. Introduction

Anatomizing the price transmission from international crude oil to gasoline is of paramount necessity arising from the oil not only being a fundamental composition of gasoline, but also acting as a strategic material among people's normal life. Indeed, the fluctuation of these energy prices boosts the economy and solidifies the society of the country [1]. China became a net oil importer in 1993. Arising from an ever-increasing oil demand and limited domestic oil supply capacity, the foreign trade dependency on crude oil has been more than 65 percent since 2016 [2]. From the general perspective, crude oil cost is positioned as the domestically refined oil products, taking up approximately 50% of the product cost, the domestically refined oil and international crude oil are causally related, the higher of crude oil price, takes up the higher proportion of the total cost, the lower the price, the lower the proportion takes up the total cost of the product [3,4].

Price theory is attached critical significance to in neo-classical economics. Therefore, economists studying market processes are lured by the price transmission processes. However, of special interest are attracted by the processes denoted as asymmetry, i.e. for which transmission shall vary in line with whether prices are being elevated or slid [5]. Currently, the scholars generally assert the price transmission asymmetry basically follow the principle that, when international crude oil prices rise, domestic gasoline prices or other commodities shall correspondingly rise with the magnitude and rate more than those of international crude oil prices being slid. The transmission of crude oil prices to the prices of gasoline products has been ascertained by numerous studies recently. The co-integration relationship test is adopted, and the oil–gasoline price relationship is laid the particular stress on by the vast majority of these researches [6]. It has been documented that prices shall be more rapid in responding to the rising than to the sliding. This asymmetric price interaction was initially ascertained by Bacon [7] as he aimed to establish a partial adjustment model in UK retail gasoline prices through harnessing the quadratic quantity. "Rockets and feathers effects" have been confirmed by various studies to different extents [8]. Additionally, the model of asymmetric error correction model is established to anatomize the refined oil prices, and the evident asymmetric phenomena are acquired by them. An asymmetric error correction model is adopted by Johnson [9] to anatomize the reaction of gasoline retail prices in terms of the wholesale prices, and asymmetric responses are also supported in the United States. An Error Correction Model (ECM) distinguishing between positive and negative error correction terms provides an appropriate specification for testing APT [10].

Later, the standard Engle-Granger two-step estimation procedure other than Borenstein et al. [8] nonstandard specification, and the daily data other than the weekly data is adopted by Bachmeier and Griffin [6], accordingly yielding less evidence of price asymmetry. Al-Gudhea et al. [11] use co-integration model and daily data to support the same conclusion. This asymmetric price interaction is ascertained by various studies to different extents.

First and foremost, early works on oil price transmission asymmetry was dependent on the developed countries, whereas was placing confined attention on China under ascertainment. The pre-cointegration techniques have been adopted in more recent approaches to avoid the potential spurious regression. With regards to the Co-integration, Error Correction Model (ECM) and Threshold Vector Error Correction Model (TVECM) have been adopted in empirical studies [12] in that those models maintain the hypothesis of a linear price relationship at the long-run equilibrium. In contrast with the existing literature, this paper harnesses the latest model, viz Nonlinear Autoregressive Distributed Lag model (NARDL), and studies the effect regarding asymmetric transmission exerted by international market price on the domestic market price in China to ascertain the effect of international crude oil price on gasoline prices in China in terms of the asymmetric transmission. The NARDL model proposed by Shin et al. [13] is advantageous in the following aspects: First and foremost, the effect regarding asymmetrical transmission can be ascertained from two perspectives, both short- and long-term. Secondly, given the small samples, the method is higher in robustness. Thirdly, the model is estimated to be free from endogeneity. Fourthly, it is not required that all variables should be a sequence as single-order integer, as long as they are not sequenced as second-order single integer, and accordingly, the co-integration test and analysis can be performed. NARDL models have been adopted (among others) by Vacha and Barunik [14] to anatomize the relationship between commodity and stock prices, by Atil et al. [1] to identify APT in energy markets, by Aloui et al. [15] to identify APT in oil and natural gas markets, by Bagnai et al. [16] to anatomize the asymmetric transfer effect of crude oil prices into gasoline but in the Italian market, and by Fousekis et al. [12] to anatomize the asymmetric price transfer effect of the beef market. To the best of our knowledge, there has been no published work on APT in the relationship between international crude oil and domestic gasoline prices in China using the NARDL co-integration approach.

The rest of this paper is framed as follows. The methodology is elucidated, and the data is illuminated in Section 2. The attained results are reported in Section 3. This paper is concluded in Section 4.

2. Methodology and Data

2.1. The NARDL Model

In line with the study conducted by Pesaran et al. [17], the conventional model of Autoregressive Distributed Lag Approach (ARDL) can be denoted as follows:

$$\Delta UN_t = \alpha_0 + \rho UN_{t-1} + \theta IP_{t-1} + \sum_{j=1}^{p-1} \alpha_j \Delta UN_{t-j} + \sum_{j=0}^{q-1} \pi_j \Delta IP_{t-j} + \varepsilon_t \quad (1)$$

In this paper, UN denotes the international crude oil prices, and IP indicates the gasoline prices in China. The symbol Δ denotes the first difference, ε_t the residual term, α_0 the constant term, p and q the maximum lags. The short-and long-run relationships among price variables are enabled to be ascertained via Equation (1) The co-integration relationship between domestic gasoline prices in China and international crude oil prices is denoted as $-\theta/\rho$, being equal to the long-term delivery effect. The short-term transfer effect of international crude oil prices on China's domestic gasoline prices isπ_j. It was bespoken by Pesaran et al. [17] that the hypothesis of no co-integration can be tested either via a modified F-test, denominates it FPSS or via a Wald test, denominates it WPSS. Boundary test statistics [18] can also be adopted to confirm the null hypothesis of no co-integration via tBDM test. If the empirical values of FPSS and WPSS statistics exceed the upper bound, the relation between UN and IP turns out to abide by the long-run equilibrium. On the other side, the tBDM test also relies on the upper bound.

In a linear ARDL model, the long-term and short-term transfer effects are symmetric Shin et al. [13] proposed the NARDL model through decomposing the independent variables into the sum of positive changes and negative changes. In particular, variables can be decomposed as follows:

$$IP_t = IP_0 + IP_t^+ + IP_t^- \quad (2)$$

Where,

$$IP_t^+ = \sum_{j=1}^{t} \Delta IP_j^+ = \sum_{j=1}^{t} \max(\Delta IP_j, 0) \quad (3)$$

$$IP_t^- = \sum_{j=1}^{t} \Delta IP_j^- = \sum_{j=1}^{t} \min(\Delta IP_j, 0) \quad (4)$$

On that basis, the asymmetric long-run equilibrium relationship can be elucidated as:

$$UN_t = \beta^+ IP_t^+ + \beta^- IP_t^- + \mu_t \quad (5)$$

Where μ_t is the residual term, where β^+ and β^- are long-run parameters associated with positive and negative changes in IPt, If $\beta^+ \neq \beta^-$, then the long-term transfer effect is asymmetrical. When the asymmetries in the short- and long-run dynamics are introduced into linear ARDL model, Eq. (1) shall be amplified to attain a more general co-integration model as follows:

$$\Delta UN_t = \alpha_0 + \rho UN_{t-1} + \theta^+ IP_{t-1}^+ + \theta^- IP_{t-1}^- + \sum_{j=1}^{p-1} \alpha_j \Delta UN_{t-j} + \sum_{j=0}^{q-1} \left(\pi_j^+ \Delta IP_{t-j}^+ + \pi_j^- \Delta IP_{t-1}^- \right) + \varepsilon_t \quad (6)$$

Where $\theta^+ = -\rho\beta^+$, $\theta^- = -\rho\beta^-$ .The positive and negative long-run coefficients can thereupon be acquired as $\beta^+ = -\theta^+/\rho$, $\beta^- = -\theta^-/\rho$. On that basis, the positive and negative short-run coefficients can be acquired as π_j^+ and π_j^-. If $\sum_{j=0}^{q-1} \pi_j^+ \neq \sum_{j=0}^{q-1} \pi_j^-$can be proved, there is an asymmetry in the short-term transfer effect of international crude oil to domestic gasoline in China.

The empirical implementation of a NARDL model involves four steps.

The first, to estimate (6) via standard OLS.

The second, to verify the existence of an asymmetric co-integration relationship between the series UN_t, IP_t^+, and IP_t^- through adopting boundary test F_{PSS} statistics, W_{PSS} statistics and t_{BDM} statistics.

The third, to test the long-term symmetry and short-term symmetry through adopting Wald test.

The fourth, given that there is asymmetry (either in the long-run or in the short-run or in both), to ascertain the dynamic multiplier effect of price through introducing the derivation of the positive and negative dynamic multipliers associated with unit changes in IP_t^+ and IP_t^- . These are acquired as

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial UN_{t+j}}{\partial IP_t^+}, \quad h=0, 1, 2,... \quad (7)$$

$$m_h^- = \sum_{j=0}^{h} \frac{\partial UN_{t+j}}{\partial IP_t^-}, \quad h=0, 1, 2,... \quad (8)$$

for IP_t^+, and IP_t^- , respectively.Here, m_h^+ can illuminate the dynamic transfer of IP_t^+ to UN_t in h period after the impact of one unit, m_h^- can illuminate the dynamic transfer of IP_t^- to UN_t in h period after the impact of one unit, m_h^+ and m_h^-adds useful information to the long-and short-run patterns of asymmetry.

2.2. Sample Data and Unit Root Test

The asymmetric price transfer effect is not an accidental phenomenon, but a universal law. However, the asymmetric transfer effect of international crude oil on gasoline price in China has not attracted the attention of academia. Our data consist of time series of week-spot closing prices for WTI crude oil and gasoline. They are attained from crawler technology and cover the period from April 1st, 2006 to July 15th, 2017. International crude oil prices week price and the price of gasoline in China (93 #) are derived from this web site (http://www.eia.gov/dnav/pet/pet_pri_spt_s1_d.htm?), RMB exchange rate data is derived from CSMAR database (http://hk.gtarsc.com/).

This article selects week data as samples from April 1st, 2006 to July 15th, 2017. Starting from April 1st, 2006, for the reason that domestically refined oil and crude oil prices have been seriously affected. In the light of the document ([2006]64) issued on March 24, 2006, and the general office of the state council on forwarding to improve the comprehensive reform plan and related opinions on the formation mechanism of crude oil prices through Development and Reform Commission and other departments (issued [2006]16). With the approval of the state council, the Chinese government has decided to increase the price of domestic refined petroleum products in an appropriate way and introduce subsidies for some vulnerable groups and public welfare sectors.

The results of international crude oil prices and domestic gasoline prices in stability test results are presented in Table 1. Both the results of the Augmented Dick – Fuller test and the Phillips-Perron test are bespoken the same results that prices along oil pertain to the first order difference. The two variables cannot reject the null hypothesis at the significance level of 10%. After the first order difference, the variables reject the null hypothesis at the significance level of 1%. The attained results bespeak that the two series are not stationary at the conventional levels, there are first-order sequences, no order of order sequences, which are appropriate for the application of the NARDL model.

Table 1. Augmented Dick-Fuller and Phillips-Perron unit root tests

Variable	Augmented Dickey-Fuller				Phillips-Perron	
	Intercept	*Intercept and trend*	*None*	*Intercept*	*Intercept and trend*	*None*
UN	-3.2622**	-3.2066*	1.0961	-3.2380**	3.2066*	-0.9943
Prob.*	0.0221	0.0948	0.2440	0.0235	0.0948	0.2828
IP	-2.2726	-2.8112	-0.5332	-2.4466	-2.8443	-0.5235
Prob.*	0.1846	0.2003	0.4809	-2.4466	0.1891	0.4850
DUN	-6.3067***	-6.5530***	6.2387***	-6.3322***	6.5410***	6.2681***
Prob.*	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DIP	-7.6456***	-7.7326***	7.6903***	-7.6241***	7.7000***	7.6643***
Prob.*	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: D is the first difference operator; *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

3. Empirical Models, and the Empirical Results

Via the least square method, the NARDL model of international crude oil price transfer is estimated, and the maximum lag p and q are set as 12. To elevate the accuracy of NARDL model estimation, in the short term, the lag term of the influence coefficient under the significance level of 1% is eliminated.

3.1. Test of Co-integration and Symmetry

The co-integration relationship between two variables, which can be confirmed through adopting border inspection F_{PSS} statistics and W_{PSS} statistic test, t_{BDM} proposed by Banerjee et al. can also be adopted to confirm the statistics of co-integration relationship. Table 2 presents the test results for asymmetric co-integration. All of these tests the F_{PSS}, the W_{PSS} and the t_{BDM} statistics reject the null hypothesis of no co-integration at any rational level of significance. It is accordingly bespoken the international crude oil prices and domestic gasoline prices are evidently related to each other regarding the co-integration. Yet whether there is an asymmetry between the co-integration relationship is required to be delved into.

Table 2. Bounds testing for asymmetric co-integration

Statistic	Price Transmission
F_{PSS}	9.589323***
W_{PSS}	28.76797***
t_{BDM}	-3.844672**

Note: *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

The test results for long- and short-run symmetry are indicated from Table 3. The Wald test strongly rejects the null hypothesis both of long-run symmetry and short-run symmetry under any rational level of significance. There is an asymmetry between transmission magnitude and transmission rate. It is also accordingly bespoken that the study of the effect of international crude oil price on the price of gasoline in China is required to reckon with the asymmetry of the transmission process.

Table 3. Long-and short-run symmetry tests

	Value	Std. Err.	Statistic
WLR	-0.0878	0.013524	42.14748***
WSR	-0.435062	0.106832	16.58444***

Note: WLR refers to the Wald test for the null of long-run symmetry defined by $-\theta^+/\rho = -\theta^-/\rho$; *** indicate statistical significance at 1% levels.

WSR refers to the Wald test for the null of the additive (weak-form) symmetry defined by

$$\sum_{j=0}^{q-1} \pi_j^+ = \sum_{j=0}^{q-1} \pi_j^-$$

3.2. Analysis of Model Estimation Results

The estimation of crude oil price transfer via the NARDL model is reported from Table 4. The estimation of the long-run coefficient β^+ equals 0.828 while that of the coefficient β^- equals 0.740, with both coefficients passing a statistical test at an evident level of 1%. Therefore, in a NARDL model, international crude oil prices on domestic gasoline prices in China long-term transfer effect coefficient is attained as 0.828, bespeaking that, regarding other conditions unchanged, the international crude oil prices shall consequently rise the domestic gasoline prices by 1% to 0.828% on average. A 1% decrease in international crude prices would lead to an average decrease of 0.740% in domestic gasoline prices. The result of Durbin-Watson statistic test is 2.287, which means there is no autocorrelation.

Table 4. NARDL estimation results

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
C	0.369927***	0.09707	3.81094	0.0002
UN(-1)	-0.055714***	0.014491	-3.844672	0.0002
IP_P(-1)	0.04612***	0.00968	4.764457	0.0000
IP_N(-1)	0.041228***	0.008316	4.957869	0.0000
DIP_N	0.074988**	0.029561	2.536753	0.0118
DIP_P(-1)	0.110482***	0.037968	2.909893	0.0039
DIP_P(-2)	0.087291**	0.035323	2.471255	0.0141
DUN(-12)	-0.170128***	0.052686	-3.229121	0.0014
DIP_N(-9)	-0.061208**	0.029209	-2.095475	0.0371
DIP_P	0.092771**	0.039113	2.371906	0.0185
DIP_N(-1)	0.077082**	0.031489	2.447936	0.0151
DIP_N(-5)	-0.065251**	0.028683	-2.274936	0.0238
L^+	0.827799***	0.109196	7.580862	0.0000
L-	0.739999***	0.106353	6.957942	0.0000
R-squared	0.352745	Adjusted R-squared		0.3239
F-statistic	12.23743	Durbin-Watson stat		2.2870

Note: *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

3.3. Analysis of Dynamic Multiplier Effect

When the long-run price transmission elasticity of positive shocks exceeds that of negative ones, the result is an increase in the margin between two prices and an increase in the ratio of the two prices. The dynamic multipliers of price allow us to trace out the evolution of a price at a given level with a shock to a price at another level, providing a picture of the path to the new equilibrium in this way. The dynamic multipliers for the price transmission from the international crude oil on the domestic gasoline are illustrated in Fig. 1. The behaviours of the dynamic multiplier of price conforms to the short-run and long-run asymmetry. The transmission of asymmetric crude oil is also exhibited from Fig. 1, whereas it takes a lot of time to converge to the long-run multipliers over time and practically.

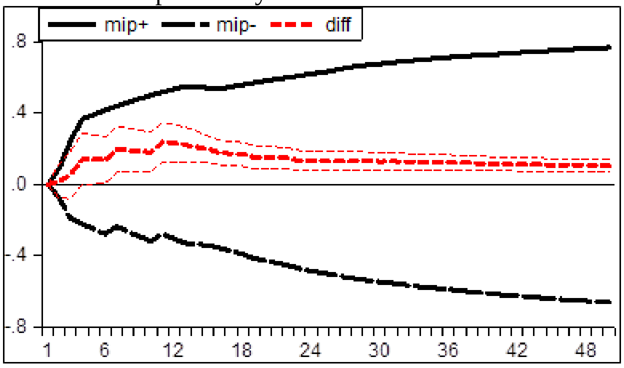

Figure 1. Dynamic multipliers of international crude oil prices to domestic gasoline level.

Note: "+" represents price increase, "-" represents price decline; diff is the difference between dynamic multipliers of price increases and dynamic multipliers of price declines.

4. Conclusions

In this paper, the effect regarding asymmetric transmission exerted by international crude oil prices on the gasoline prices in China is ascertained via NARDL model, and the asymmetrical phenomena of refined oil prices are attained. The results show that the international price has the asymmetry of the rate and the magnitude in the transmission to domestic price. International crude oil prices rise 1 percent, domestic gasoline prices in China rise 0.828 percent, while international oil prices fall 1 percent and domestic gasoline prices fall 0.74 percent. As a large developing country with a huge population, the strategy of oil resources and public goods confirm the asymmetric phenomenon of crude oil prices and refined oil prices. The existence of oligopoly and government pricing mechanism in the oil industry have contributed to this asymmetry.

In line with the conclusions of this study, it can be enlightened from three aspects. First and foremost, there is an evident transfer effect between the international crude oil price and domestic gasoline prices. From the perspective of internationalization, to achieve the domestic gasoline prices remaining at a rational interval operation, the international crude oil price change must be particularly stressed, and the ability of protection from external shocks shall be progressively strengthened. Secondly, private enterprises should be allowed and encouraged to enter the oil industry, and the private enterprises should be encouraged to open up some areas to encourage competition and progressively reform the large oil companies in China. Thirdly, to solidify our energy security, optimize the ability to reckon with the international oil price fluctuations, reliable strategic oil reserve system should be established. The international crude oil prices are long-run and short-run asymmetrical with domestic gasoline prices, and accordingly a stable domestic gasoline prices must be developed and implemented to avoid the limitations of policy making.

The shortcomings and improvements remain in this paper though the latest NARDL model is adopted to ascertain the effect regarding asymmetric transmission exerted by international crude oil price on gasoline prices in China. When it comes to data, some important information in price fluctuations might not be uncovered by the two-week data, and in the upcoming researches the weekly data or even the daily data for higher frequency analysis can be trialled. Speaking of the research methods, NARDL model is essentially a threshold, and the threshold is set to zero, threshold settings can be tried to improve. For instance, in line with the model estimation effect, the threshold value is set to endogenous. On the research content, this paper measures the effect regarding asymmetric transmission exerted by international crude oil prices on the gasoline prices in China, the influence factors, and the problems of price fluctuations in the value chain conduction can be delved into.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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