Energy Shock and Price Adjustment: National Brands vs. Private Labels of Retail Milk Products

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Abstract

This paper examines how retailers adjust prices of national brands and private labels when they are exposed to energy shocks. Empirical results from 12 U.S. fluid milk markets provide insights into the magnitude and timing of price adjustment. Asymmetric energy pass-through is validated. The pass-through rate is found to be consistently higher for national brands compared to private labels, indicating that the private labels are more insulated to energy shocks. Further results show that the speed of energy price pass-through is faster for national brands compared to private labels when the energy price increases. However, the speed is similar for the two when the energy price decrease. Overall, this paper shows that when there is a positive energy shock, the retailers adjust prices of national brands first, on average, but they are almost indifferent with the order of adjustment when there is a decrease in energy prices.

Keywords: Energy Shock, National Brand, Private Label, Price Adjustment

JEL classification: D4, L1, Q1, Q4

1. Introduction

In the last few years, U.S. food and energy prices have both experienced dramatic increases, resulting in a dual food and energy price inflation that has had a significant negative impact on consumers. Much of the previous literature sheds light on the relationship between oil prices and agricultural commodity or food prices. Generally speaking, the causal link between oil and food prices is explained by two mechanism (Reboredo, 2012). First, oil prices affect production costs directly, given that agriculture is an energy-intensive sector. For example, Hanson, Robinson and Schluter (1993) and Nazlioglu (2011) find that an increase in oil prices causes a rise in input costs and a corresponding rise in agricultural price. The strength of this effect depends on several factors, such as the relative importance of oil in the production costs and the degree of market power to pass forward increased costs. Second, on the demand side, increased oil prices have significantly raised demand for corn- and soybean-based biofuels resulting in an indirect increase in the prices of these commodities due to increased demand. Chen, Kuo and Chen (2010) and Ignaciuk and Dellink (2006) show that higher crude oil prices induced a higher derived demand for corn and soybeans and greater competition with other grains for planting areas, resulting in increased grain prices for wheat as well as for corn and soybeans. Higher grain prices increase the cost of feed used in animal agriculture such as milk production.

Yet, some studies have found no statistically significant evidence regarding an oil-food price nexus. For example, Zhang et al. (2010) find that agricultural commodity prices are neutral to oil price changes in the long run. Gilbert (2010) explains the recent upward trend in agricultural prices by distinguishing between common and market-specific factors, reporting evidence of the neutrality of market factors like oil prices and biofuel demand.

The preponderance of evidence in previous studies links oil and agricultural commodity price indexes at the aggregate farm level. However, studies linking food and energy prices at the retailer product brand level are relatively lacking even though this is the level more relevant to consumers. Moreover, in the retail food sector, how energy cost is passed through to national brands (NBs) and private labels (PLs) is of importance but is under-analyzed.

To the best of our knowledge, Volpe (2004) shed some light on the effects of crude oil on prices of NBs and PLs, but the main objective of this study is to examine the pass-through rate of food price inflation. Additionally, Loy et al. (2005) investigate the cost pass-through in differentiated product markets, and they find significant positive asymmetries in the cost pass-through processes, which vary between brands (e.g., NBs and PLs) and outlets. However, they don’t focus on magnitude and timing of energy shock pass-through.

This paper contributes to the literature by examining the dynamics of price adjustment responding to energy shocks based on the retailer and manufacturer's profit-maximization behavior. Understanding the energy shocks to NBs and PLs (including magnitude and timing) is of great importance. First, PLs, in recent years, have witnessed a sharp increase in terms of quality, sales, and total product offered. As a prominent feature in the landscape of the retail food sector with the dollar share of 18% in United States in 2014 (Nielsen, 2014), PLs are widely used as a tool by retailers to gain bargaining power in most cases via a form of vertical integration (e.g., Mills, 1995; Bontems, Monier-Dilhan and Requillart, 1999; Ward et al., 2002; Bonanno and Lopez, 2005; Bontemps, Orozco and Requillart, 2008). Second, PLs are almost uniformly cheaper than NBs (Ailawadi, Neslin, and Gedenk, 2001; Parcell and Schroeder, 2007) and are more closely related to consumers' welfare, particularly, the poor people, which is referred to as the PL welfare effects. Third, timing of the energy pass-though is certainly an important issue when policymakers try to understand and react to energy shocks (Leibtag, 2009). Finally, from the standpoint of academic research, the literature about energy pass-through to NBs and PLs is still relatively rare, in particular with regards to, the retailer and manufacturer's behavior of price adjustment.

The purpose of this paper is to examine how retailers adjust prices of NBs and PLs when they are exposed to energy shocks, via a conceptual analysis of a sequential bargaining process and an empirical analysis using data from 12 U.S. fluid milk market. Retail milk provides a good case study for examining the relation between energy and retail food prices. First, energy plays an important role in milk production as well as transportation and marketing (Brush, Masanet and Worrell, 2011). Second, given the prevalence of obesity and over-consumption of sugar-sweetened beverages (SSBs), milk is considered a lower-calorie and more nutritious substitute for SSBs (Runge, Johnson and Runge, 2011). Third, the price of milk as a staple food is closely connected with consumers' welfare and social well-being, particularly children's.

Using the sales data from Information Resources Incorporated (IRI), this study supports an asymmetric energy pass-through. Additionally, the pass-through rate is consistently higher for NBs compared to PLs, indicating PLs are more insulated to energy shocks. Further results show that the energy pass-through is faster for NBs compared to PLs when the energy price increases. However, the speed is similar for the two when the energy price decreases. Overall, these findings indicate that the retailers adjust prices of national brands first on average when there is a positive energy shock, and they are almost indifferent with the order of adjustment when the price of energy decreases. This paper contributes to the existing literature in the following aspects. First, it theoretically discusses how retailers adjust the price of NBs and PLs via a sequential bargaining process where retailer and manufacturer both seek profit-maximizations. Second, it empirically reveals on average, which prices (NBs vs. PLs) are first adjusted by retailers. The structure of this paper is of the following format: Section 2 presents the theoretical models. Section 3 contains the empirical results and the conclusion is presented in Section 4.

2. A conceptual analysis

Suppose there is a typical retailer who behaves as a category manager, i.e., maximizing the joint profits of n brands and PL products it sells. The retailer's profit maximization problem is stated as follows:

$$Max_{p_i}\, \pi^R = \sum_{i=1}^{n}(p_i - w_i - c_i)s_i M + (p_L - c_L - mc_L)s_L M, \tag{2.1}$$

where p_i is the retail price, w_i is the wholesale price, c_i is the retailer's marginal cost for brand i, s_i is market share of brand i, and M is market size (total quantity) of fluid milk sold in supermarkets. L stands for PLs. c_L is the retailer's marginal cost for PLs, and mc_L is the processing marginal cost of the PLs. Note that the wholesale price for PLs is not present because it is fully integrated.

The manufacturer's profit maximization problem is:

$$Max_{w_i}\, \pi^M = \sum_{i=1}^{n}(w_i - mc_i(\omega_i, z_i))s_i M, \tag{2.2}$$

where mc_i is marginal cost as a function of ω_i, which is brand i's cost of raw milk, and z_i denote costs of other input factors.

When there is an energy shock, the manufacturer and retailer both have incentives to adjust their offered prices, i.e., the retailer may adjust the prices (p_i, p_L) and manufacturer may adjust w_i, to maximize profits. All the possible cases are (1) the retailer adjust NBs prices first (2) the retailer adjust PLs price first, or (3) retailer sets NBs prices and PL price simultaneously. We discuss the bargaining process in each case as follows:

Case 1. First, the retailer bargains with the manufacturer with an offer for NBs' price to be p_i^*, which might be the optimal price that satisfies $\frac{\partial \pi^R}{\partial p_i} = 0$. At the same time, the manufacturer bargains with the retailer and set a price of w_i^* to maximize π^W. During the bargaining process, they reach an equilibrium at prices (p_i^*, w_i^*). Second, given p_i^* and w_i^*, the retailer sets PLs' price to be p_L^* in order to maximize its profit, i.e., $\frac{\partial \pi^M}{\partial p_L} = 0$. In this sequential game, we denote the profits of the retailer and manufacturer to be $\pi_1^R(p_L^*, p_i^*, w_i^*)$, and $\pi_1^M(p_L^*, p_i^*, w_i^*)$, respectively.

Case 2. First, the retailer adjusted PLs price to p_L^*, which might be the optimal price that satisfies $\frac{\partial \pi^R}{\partial p_L} = 0$. Here, the retailer uses PL to increase its bargaining power and negotiates with the manufacturer. Given p_L^*, the manufacturer bargains with the retailer and adjusts its price to w_i^* in order to maximize π^W. Second, given p_L^* and w_i^*, the retailer sets the NB price p_i^* to maximize profit, i.e., $\frac{\partial \pi^R}{\partial p_i} = 0$. In this sequential game, the profit of the retailer and manufacturer are denoted as $\pi_2^R(p_L^*, p_i^*, w_i^*)$ and $\pi_2^M(p_L^*, p_i^*, w_i^*)$ respectively.

Case 3. First, the retailer negotiates with the manufacturer and respectively sets the PLs and NBs' prices simultaneously as p_L^* and p_i^*,. At the same time, the manufacturer sets the price as w_i^*. In this sequential game, the profits of the retailer and manufacturer are denoted as $\pi_3^R(p_L^*, p_i^*, w_i^*)$ and $\pi_3^M(p_L^*, p_i^*, w_i^*)$ respectively.

Note that there is no specific form of demand function and thus we cannot get an explicit solution and so, a direct comparison is not possible. However, the optimal strategy based on retailer and manufacture's profit-maximization behavior is known as follows:

If $\pi_1^R(p_L^*, p_i^*, w_i^*) > \pi_2^R(p_L^*, p_i^*, w_i^*)$, and $\pi_1^R(p_L^*, p_i^*, w_i^*) > \pi_3^R(p_L^*, p_i^*, w_i^*)$, then the retailer will set the price of NBs first and then adjust the price of PLs (i.e., Case 1).

If $\pi_2^R(p_L^*, p_i^*, w_i^*) > \pi_1^R(p_L^*, p_i^*, w_i^*)$, $\pi_2^R(p_L^*, p_i^*, w_i^*) > \pi_3^R(p_L^*, p_i^*, w_i^*)$, the retailer will set the prices of PLs first (i.e., Case 2).

If $\pi_3^R(p_L^*, p_i^*, w_i^*) > \pi_1^R(p_L^*, p_i^*, w_i^*)$, $\pi_3^R(p_L^*, p_i^*, w_i^*) > \pi_2^R(p_L^*, p_i^*, w_i^*)$, the retailer is indifferent to the order, and so prices are adjusted simultaneously (i.e., Case 3).

As the optimal profits are not observed in each case, it is impossible to conclude the order that the retailer adjusts the prices of NBs and PLs. However, it is possible to infer which case most likely happens in the market based on an empirical analysis using scanner data.

In the following section, we will investigate the price movements of NBs and PLs using energy shocks that include the magnitude and timing of energy price transmission.

3. Empirical analysis

To investigate the magnitude and times of vertical price transmission from energy price to retail milk price, a vector error correction model (VECM) is applied as

$$\boldsymbol{Y_{it}} = \boldsymbol{\varphi} + \boldsymbol{A} * \boldsymbol{ECT_{i,t-1}} + \sum_{j=1}^{k_1} \boldsymbol{\Phi(j)} * \boldsymbol{Y_{i,t-j}} + \sum_{l=1}^{k_2} \boldsymbol{\Theta(l)} \Delta \boldsymbol{p_{i,t-l}^{g}} + \boldsymbol{\varepsilon_{it}}, \tag{3.1}$$

where $\boldsymbol{Y_{it}} = \begin{bmatrix} \Delta p_{it}^1 \\ \Delta p_{it}^2 \end{bmatrix}$, $\boldsymbol{\varphi} = \begin{bmatrix} \varphi_1 \\ \varphi_2 \end{bmatrix}$, $\boldsymbol{A} = \begin{bmatrix} \alpha_1 & 0 \\ 0 & \alpha_2 \end{bmatrix}$, $\boldsymbol{ECT_{i,t-1}} = \begin{bmatrix} p_{i,t-1}^1 - \beta_0^1 - \beta_0^1 p_{i,t-1}^g \\ p_{i,t-1}^2 - \beta_0^2 - \beta_0^2 p_{i,t-1}^g \end{bmatrix}$, $\boldsymbol{\Phi(j)} = \begin{bmatrix} \delta_{1j} & \rho_{1j} \\ \delta_{2j} & \rho_{2j} \end{bmatrix}$, $\boldsymbol{\Theta(l)} = \begin{bmatrix} \theta_{1l} \\ \theta_{2l} \end{bmatrix}$, $\boldsymbol{\varepsilon_{it}} = \begin{bmatrix} \varepsilon_{it}^1 \\ \varepsilon_{it}^2 \end{bmatrix}$.

p_{it}^1 and p_{it}^2 are the prices of NBs and PLs at market i in time t, respectively. $p_{i,t}^g$ is the commodity price of gasoline in market i at time t. φ, α, δ, ρ, and θ are parameters to be estimated. ε_{it} is white noise disturbance, where ε_{it}^1 and ε_{it}^2 are assumed to be independent since the competition between NBs and PLs are captured in the third term on the right hand side of equation (3.1). The expression $\begin{bmatrix} p_{i,t-1}^1 - \beta_0^1 - \beta_0^1 p_{i,t-1}^g \\ p_{i,t-1}^2 - \beta_0^2 - \beta_0^2 p_{i,t-1}^g \end{bmatrix}$ are often referred to as error correction term ($\boldsymbol{ECT}$), which captures deviations from the long-run equilibrium relationship between milk retail price (p_{it}^1 and p_{it}^2) and gasoline price $p_{i,t}^g$. Here the $\boldsymbol{ECT_{i,t-1}}$ equals zero when prices are in equilibrium in the long term. The parameters β and α are of great interest, which respectively, measure the magnitude of the pass-through rate from the energy price to the milk retail price in the long run and the speed at which deviations from equilibrium are corrected, i.e., the speed of the vertical price transmission. For example, if the speed of vertical price transmission is found to be larger for NBs than that for PLs, it indicates that the retailer is more likely to adjust the price of NBs first, on average.

Asymmetric price transmission is also investigated in this paper, which describes the situation in which prices that are linked by a long-run equilibrium relationship react differently depending on whether they are pushed too close together or pulled too far apart relative to that equilibrium. In this paper, asymmetry refers to the retail price responds more rapidly (or more slowly) to an increase in the energy price than it does to a decrease in the energy price. Following von Cramon-Taubadel (1998), we use a modification of the vector error correction model proposed by Granger and Lee (1989) to test for asymmetry. This modification involves segmenting the error correction term into positive and negative components, i.e., $\boldsymbol{ECT^+} = max\{0, \boldsymbol{ECT}\}$ and $\boldsymbol{ECT^-} = min\{0, \boldsymbol{ECT}\}$, and estimating the following equation system:

$$\boldsymbol{Y_{it}} = \boldsymbol{\varphi} + \boldsymbol{B} * \boldsymbol{\widetilde{ECT}_{i,t-1}} + \sum_{j=1}^{k_1} \boldsymbol{\Phi(j)} * \boldsymbol{Y_{i,t-j}} + \sum_{l=1}^{k_2} \boldsymbol{\Theta(l)} \Delta \boldsymbol{p_{i,t-l}^{g}} + \boldsymbol{\varepsilon_{it}} \tag{3.3}$$

where $\boldsymbol{B} = \begin{bmatrix} \alpha_1^+ & \alpha_1^- & 0 & 0 \\ 0 & 0 & \alpha_2^+ & \alpha_2^- \end{bmatrix}$, and $\widetilde{\boldsymbol{ECT}}'_{\boldsymbol{i,t-1}} = [ECT_{i,t-1}^{1,+}, ECT_{i,t-1}^{1,-}, ECT_{i,t-1}^{2,+}, ECT_{i,t-1}^{2,-}]$.

4. Data and estimation

Sales data of fluid milk come from the IRI, provided by the Zwick Center for Food and Resource Policy, the University of Connecticut. It records weekly sales information (e.g. dollar sales and volume sales) for thousands of milk varieties in 12 main cities (Atlanta, Boston, Chicago, Dallas, Detroit, Hartford, Los Angeles, New York City, Philadelphia, San Francisco, Seattle, and Washington, DC) during time period of 2001-2011. The average milk retail price for NBs and PLs are computed via the aggregated weekly dollar sales by the aggregated weekly volume sold, respectively. The milk weekly price is merged with gasoline commodity weekly price data, which comes from the US Energy Information Administration. Here the unit of gasoline commodity price are transformed to dollar/gallon for comparison.

Table 1 illustrates the summary statistics for the main variables, which include the mean and range for the PLs' prices and NBs' prices in 12 U.S. cities. It can be seen that the prices for PLs are consistently lower than NBs prices. In addition, the average prices in PLs are lowest in Detroit and highest in Washington D.C., and the average prices of NBs are lowest in Boston and highest in Washington D.C. Table 1 also shows us that NBs price range is smallest in Boston and largest in Dallas, while PLs price range is smallest in Boston and largest in Seattle. Without loss of generality, Figure 1 presents price trends of NBs, PLs and crude gasoline commodity in New York City where the milk prices and crude gasoline price show a very similar pattern of movement. Additionally, it seems that the price of NBs are much more volatile when compared to that of PLs.

[Please insert Table 1 about here]

[Please insert Figure 1 about here]

Following Engle and Granger (1987), we estimate the equations for an asymmetric pass-through for NBs and PLs in two steps. First, we estimate the long-run relationship and compute the residuals $\boldsymbol{ECT_{i,t-1}}$ using the NBs' price and the energy price as well as the PLs' price and energy price. In the second step, we use the residuals from the first step, and estimate the asymmetric error correction model. The model is estimated using the maximum likelihood method. Here, the lags of prices are chosen with Bayesian Information Criterion (BIC).

A smaller BIC indicates a better fit of the model.

5. Results

Table 2 presents Hadri LM test (Hadri, 2010) for existence of unit root in the price panel. The null hypothesis of Hadri test is that all panels are stationary and the alternative is some panels contain unit roots. The results of Hadri LM test show that all the panels of interest are non-stationary in levels and stationary in first difference. Additionally, we use the group-mean test and panel test to check whether the gasoline commodity price is cointegrated with NBs' price and PLs' price, respectively (Westerlund, 2007). The statistics in Table 3 indicate that the panel of prices are cointegrated no matter what test is used (group-mean test or panel test). Here a trend and a constant are included in the tests. The lag length of 2 is chosen based on the values of the AIC.

[Please insert Table 2 about here]

[Please insert Table 3 about here]

Table 4 illustrates us the results of the estimation of the symmetric and asymmetric error correction models for NBs. In order to compare the estimates some of which are quite close, we report the results with four digits after decimal point. In the symmetric case, the pass-through rate is 0.7447, which is slightly higher than that in the asymmetric case (0.6776). This results indicate that if the gasoline commodity price increases by 10 cents, the average price of NBs will increase by 7.4 cents. For the speed of vertical price transmission in the symmetric case, the speed of pass-through is 0.0487. The negative sign indicates that an increase of energy price (i.e., the ECT will be negative) will result in an increase of retail milk price. However, in the asymmetric case, the speed of vertical price transmission is much faster when ECT is negative (0.0972) compared to when ECT is positive (0.0138), implying that when there is an increase in the price of gasoline, the cost is passed through to the retail milk price faster than that when gasoline price decreases.

[Please insert Table 4 about here]

It is also possible to compute the time it takes for the NBs' price to go back to the equilibrium. If the energy commodity price increases by 1 dollar (i.e., a negative *ECT*), then it will take around 10.3 weeks for the NBs' price to adjust and to reach a new equilibrium. If the energy price decreases by one dollar (i.e., a positive ECT), then this process will take about 72.5 weeks. This finding implies that the retailer is much more active in increasing the price when there is a positive energy shock comparing to when there is a negative energy shock.

Comparing the values of BIC, the model specification with asymmetric pass-through outperforms the symmetric one, supporting the asymmetric energy cost pass-through.

Table 5 illustrates the symmetric and asymmetric error correction models for PLs. Compared to NBs, the pass-through rate for PLs are much lower (0.4793) in the symmetric case and 0.3051 in the asymmetric case, indicating that PLs are much more insulated to energy price shock when compared to NBs. For example, in the symmetric case, the pass-through rate for NBs is 0.7447 (i.e., each10 cent oil price increase leads to a 7.4 cents increase in the price of NBs), while for PLs, it is 0.4793 (i.e., each 10 cent oil price increase leads to a 4.8 cent increase in the price of PLs). For the asymmetric case, the pass-through rate for NBs is still higher than that of PLs (i.e., 0.6776 vs. 0.3051). A possible explanation for this can be found in the marketing channel. PLs consume less energy (i.e., transportation, packaging, cooling) and thus, are less energy dependent than NBs. Similarly, we find the model specification with an asymmetric pass-through is a better fit with a smaller BIC.

[Please insert Table 5 about here]

Another finding of this study is that the speed of vertical price transmission from an energy shock to NBs is faster than that of PLs. For example, in the symmetric case, the transmission speed is 0.0487 for NBs and 0.0511 PLs. However, in the asymmetric case, when there is a positive energy shock (i.e., a negative *ECT*), the transmission speed is 0.0972 for NBs and 0.0913 for PLs. While when there is a negative energy shock (i.e., a positive *ECT*), the difference between the transmission speeds is quite small (0.0138 for NBs v.s. 0.0140 for PLs). These results indicate that when there is a positive energy shock, the retailer adjusts the price of NBs and PLs very differently. The adjustment for NBs price are much larger in magnitude and faster in speed, indicating that the retailer may gain more profits when they follow the strategy of adjusting the price of NBs first. While when there is a negative energy shock, the retailer adjusts the PLs' price a little bit faster, strictly speaking. Essentially, NBs' price goes up faster with positive energy shock and PLs' price goes down faster with negative energy shock.

6. Concluding remarks

This paper studies how retailers adjust the prices of NBs and PLs when they are exposed to energy shocks. Using a conceptual analysis of a sequential bargaining process and an empirical analysis using IRI data of 12 U.S. fluid milk market from 2001 to 2011, our empirical analysis validates an asymmetric energy pass-through.

Additionally, the pass-through rate is found to be consistently higher for national brands when compared to private labels, indicating that the private labels are more insulated to energy shocks. Further results show the speed of energy price pass-through is faster for national brands when compared to private labels in the event of an energy price increase. However, the speed is similar for the two when the price of energy decreases. Overall, this paper shows that the retailers adjust prices of national brands first when there is a positive energy shock, on average, and they are almost indifferent regarding the order of adjustment when the energy price decreases.

This study reveals the strategy chosen by the retailers when there is an energy shock. The future work can be fruitful if we observe the behavior of specific retailers and analyze it within a structural model. Additional, a dynamic model also might provide some new insights, which is also left for future research.

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Table 1 Summary statistics for price series

Market	PL price mean	PL price range		NB price mean	NB price range	
Atlanta	3.172	2.279	4.490	5.599	4.162	7.080
Boston	3.009	2.585	3.853	4.445	3.444	5.482
Chicago	2.712	1.883	3.507	4.734	3.340	5.863
Dallas	2.802	1.652	4.001	3.681	2.449	5.191
Detroit	2.593	1.707	3.632	4.510	3.291	6.277
Hartford	3.541	2.785	4.237	4.892	3.339	6.096
Los Angeles	3.001	2.425	3.782	5.884	4.761	6.809
New York	3.541	2.760	4.383	5.251	3.920	6.362
Philadelphia	3.539	2.887	4.416	5.235	3.746	6.106
San Francisco	3.263	2.645	4.209	6.002	4.577	7.877
Seattle	3.063	2.256	4.034	5.231	2.903	6.424
Washington, DC	3.612	2.835	4.554	6.588	4.437	7.560

Table 2. Unit root tests for panels of prices

Price of national brands				
Test	Trend	Lags	Statistic	P-value
Hadri LM test in levels	Yes	6	82.92	0.00
Hadri LM test in first difference	Yes	6	-3.26	1.00
Price of private labels				
Test	Trend	Lags	Statistic	P-value
Hadri LM test in levels	Yes	6	62.87	0.00
Hadri LM test in first difference	Yes	6	-1.60	0.95
Gasoline price				
Test	Trend	Lags	Value	P-value
Hadri LM test in levels	Yes	6	27.70	0.00
Hadri LM test in first difference	Yes	6	-2.94	1.00

Note: a trend is also included in the test.

Ho: All panels are stationary

Ha: Some panels contain unit roots

Table 3. Group-mean tests and panel tests for cointegration

Price of NBs and gasoline price				
Statistics	Trend	Lags	Value	P-value
G_τ	Yes	2	-4.35	0.00
G_α	Yes	2	-51.78	0.00
P_τ	Yes	2	-19.83	0.00
P_α	Yes	2	-65.49	0.00
Price of PLs and gasoline price				
Statistics	Trend	Lags	Value	P-value
G_τ	Yes	2	-3.982	0.00
G_α	Yes	2	-41.16	0.00
P_τ	Yes	2	-15.98	0.00
P_α	Yes	2	-48.08	0.00

Note: a trend and a constant are included in the tests.
The # of lags is determined by the average AIC (1.75).
The null hypothesis is there is no cointegration.

Table 4. Results of estimation of symmetric and asymmetric error correction models for NBs

	Symmetry		Asymmetry	
Coefficient	Estimate	SE	Estimate	SE
Constant φ_1	0.2018***	0.0228	-0.0204***	0.0048
β_1	0.7447***	0.1310	0.6776***	0.0070
α_1	-0.0487***	0.0055		
α_1^+			-0.0138*	0.0076
α_1^-			-0.0972***	0.0091
BIC	-4220.53		-4264.09	

Table 5.Results of the estimation of symmetric and asymmetric error correction models for PLs

	Symmetry		Asymmetry	
Coefficient	Estimate	SE	Estimate	SE
φ_1	0.1240***	0.0143	-0.0126***	0.0030
β_1	0.4793***	0.0740	0.3051***	0.0056
α_1	-0.0511***	0.0051		
α_1^+			-0.0140*	0.0082
α_1^-			-0.0913***	0.0083
BIC	-7889.45		-7912.06	

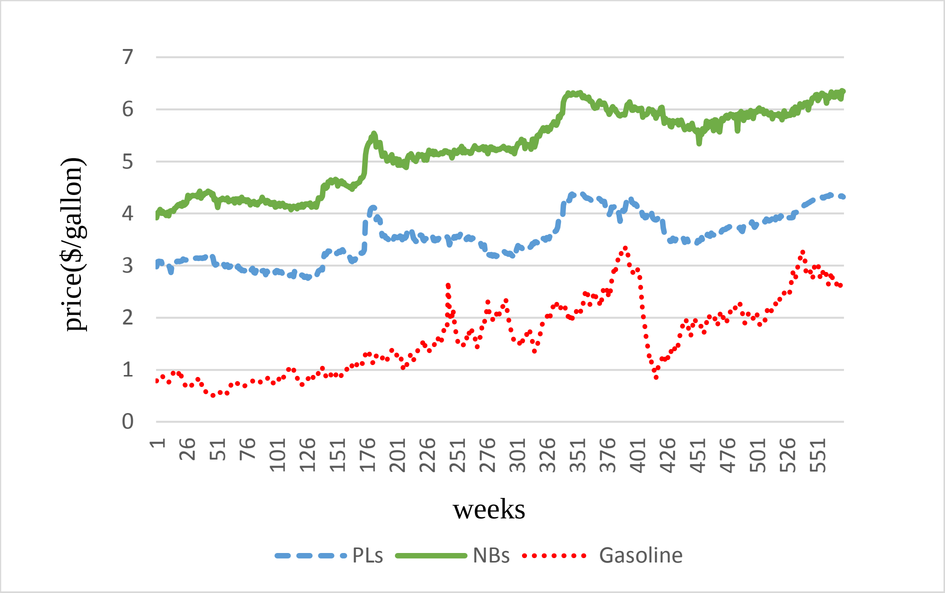

Figure 1: The price trends of PLS, NBs and Gasoline commodity in New York City.