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A Study on Nonlinear Dynamic Adjustment of Gasoline Prices in Korea†

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ABSTRACT : We employ a threshold vector error correction models (TVECM) to investigate the nonlinear dynamic adjustment of gasoline prices in Korea. We consider 10 regional gasoline markets including Seoul, Busan, Daegu, Incheon, Kwangju, Daejeon, Ulsan, Kangwon, Chungbuk, Jeonbuk and construct 9 price differences against Seoul. We use the bootstrap procedure suggested by Hansen (1999) and generalized by Lo and Zivot (2001) to show that three-regime TVECM is suitable for our analysis. Results indicate the gasoline price adjustment processes are nonlinear. Our estimation shows that Seoul-Daejeon, Seoul-Daegu and Seoul-Ulsan have bigger transaction costs than other market pairs and thus gasoline prices of these three regional markets are lower than that of Seoul. Gasoline prices of the other 6 regional markets are close to Seoul's price. One interesting finding is that the transaction costs are not proportional to geographical distances. This implies that transportation costs are not the main factor of the transaction costs. The transaction costs may depends on the competition intensity of gasoline markets in supply side.

Keywords : TVECM, Gasoline price, nonlinear dynamic adjustment

JEL 분류 : C3, D4, Q4

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우리나라 휘발유 가격의 비선형 동적 조정에 관한 연구†

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요 약 : 본 논문에서는 우리나라 휘발유 가격의 비선형 동적 조정 과정을 분석하였다. 이를 위하여 Threshold Vector Error Correction Model(TVECM)을 사용하였다. 구체적으로는 Hansen (1999)과 Lo and Zivot(2001)이 제안한 부트스트랩(bootstrap)기법을 적용하여 three-regime TVECM의 타당성을 확인한 후 사용하였다. 분석대상은 서울과 각 지역의 휘발유 가격 차이인데 서울-부산, 서울-대구, 서울-인천, 서울-광주, 서울-대전, 서울-울산, 서울-강원, 서울-충북, 서울-전북 등 총 9개 휘발유 가격차이 묶음을 다루었다. 추정결과 우리나라 휘발유 가격 조정과정은 비선형적인 것으로 나타났다. 또한 서울-대전, 서울-대구, 서울-울산의 거래비용이 큰 것으로 추정되었다. 거래비용은 지리적 거리에 반드시 비례하지 않는 것으로 나타났으며, 이는 수송비용이 거래비용의 주요한 요인이 아님을 의미한다. 거래비용은 공급측면의 경쟁정도에 의존할 것으로 추정된다.

주제어 : TVECM, 휘발유 가격, 비선형 동적 조정

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I. Introduction

Price series in different regions in a country are expected to be cointegrated; the price series move together in the long run because the law of one price holds among gasoline markets that are spatially separated. However, transaction costs may generate a neutral price differences band within which prices are not cointegrated. The existence of this neutral band implies arbitrage opportunities occur only when the spread in prices between two markets is larger than the transaction costs. In the presence of transaction costs, the threshold cointegration model rather than cointegration model can better explain the behavior of price adjustments in the long-run. Moreover, the existence of threshold cointegration implies that price adjustment processes are nonlinear.

The purpose of this study is to examine the existence of threshold cointegration among gasoline markets in Korea. To the best of our knowledge, this study is the first attempt to apply the threshold cointegration model to gasoline prices of stations in Korea to investigate nonlinear adjustments to the law of one price. In this study, we estimate the transaction costs between regional gasoline markets in Korea. We consider 10 regional gasoline markets including Seoul, Busan, Daegu, Incheon, Kwangju, Daejeon, Ulsan, Kangwon, Chungbuk and Jeonbuk. Since Seoul is the biggest market in Korea, we take price differences between Seoul and other regional markets so that we construct nine pairs of price differences such as Seoul-Busan, Seoul-Daegu and so on. If the law of one price prevails, these price differences tend to disappear. In reality, the existence of transaction costs prevents the price gaps from disappearing and the gaps have tendency to be the same as the transaction costs. Therefore, when the transaction costs are big enough, the price differences lie in the band of the transaction costs. Otherwise the price gaps converges to a very small magnitude.

In the literature two major empirical ways have been used to test for the existence of the law of one price. One way is to take absolute differences or fixed transaction costs (see O'Connell and Wei, 1997) and the other is to consider relative deviations or proportional transportation costs (see O'Connell and Wei, 1997, Lo and Zivot, 2001). We employ the way of taking absolute differences in this paper considering the threshold cointegration model we will utilize. This is because we try to estimate the existence and the magnitude of price differences bands among regional gasoline markets. As is stated above, cointegration is a canonical way of estimating the existence of the law of one price. Ardeni (1989) is the first paper to employ cointegration for the estimation. Later on, threshold autoregression (TAR) models or threshold vector error correction models (TVECM) have been popular.[1] Balke and Fomby (1997) suggested the bivariate threshold cointegration model and tested for the presence of the nonlinear effects for three types of TAR models; equilibrium-TAR, band-TAR and random-TAR. Lo and Zivot (2001) used a bivariate TVECM with a known cointegrating vector using log price differences of 41 goods in 28 cities in the US to investigate the existence of pair-wise threshold cointegration. Enders and Chumrusphonlert (2004) developed a threshold cointegration model to allow for asymmetric adjustments toward the long-run equilibrium. Park et al. (2007) used bivariate three-regime TVECM to examine seasonality in threshold levels in natural gas markets in the United States.

For Korean gasoline prices, Seo (2008) showed the distribution of gasoline prices across regional markets in Korea. He considered 15 provinces and metropolises and his data for these areas spanned from 1997 to 2006. Seo (2008) found that gasoline prices in Seoul, Incheon, Gyeonggi, Jeju and Kangwon were higher than the average gasoline price. In addition, the southern part of the nation including Busan, Daegu, Daejeon, Ulsan, Chungnam, Chungbuk, Jeonnam, Jeonbuk, Gyeongnam and Gyeongbuk had lower than or similar to the average gasoline price. Especially,

1) see O'Connell and Wei (1997), Balke and Fomby (1997), Tsay (1998), Goodwin and Piggott (2001), Lo and Zivot (2001), Hansen and Seo (2002), and Sephton (2003).

gasoline price in Daejeon was estimated to be the lowest in the nation. He argued that the heavy traffic volumes and higher rental costs of the northern part of the nation are the main reasons for higher gasoline prices in these areas. On the other hand the south of the nation had lower rental costs and light traffic volumes which led to an easy entry of new gasoline stations into these areas so that the regional gasoline markets in the south were more competitive than the north and thus gasoline prices were lower than those of the northern part. Seo (2008) provided distributions of gasoline prices across regional markets but he did not estimate any linear relations among the variables that could explain the distributional differences of gasoline prices across the regional markets.

Park and Lee (2012) investigated the price discovery processes of the gasoline prices in 7 major cities in Korea. They used a vector error correction model (VECM) and directed acyclic graphs (DAG) to analyze dynamic interdependences of the gasoline prices among the regional markets. The authors reported that the 7 gasoline prices are cointegrated and thus the gasoline markets tend to be integrated in the long run. Appealing to DAG analysis, they showed that Daejeon plays an important role in the flow of contemporaneous price information. Moreover, based on the variance decomposition, Ulsan in which the biggest oil refinery in Korea is located is identified as an important market in the price discovery process as the time-horizon increases.

This paper proceeds as follows. In section II econometric methods are explained and section III is devoted to the empirical results. Discussion and concluding remarks are in section IV.

II. Econometric Methods

1. Threshold vector error correction model

Let p be the price of gasoline in location i $(i=1,2)$ at time t and let $p_t=(p_{1t},p_{2t})'$. When p_t is $I(1)$ time series, the three-regime threshold vector error correction model (TVECM) representation for p_t with lag length k, threshold variable z_t and delay parameter d is given by

$$\Delta p_t=\begin{cases} A_1{}' P_{t-1}+u_t^{(1)} \text{ if } z_{t-d}<C^{(1)} \\ A_2{}' P_{t-1}+u_t^{(2)} \text{ if } C^{(1)}\le z_{t-d}\le C^{(2)} \\ A_3{}' P_{t-1}+u_t^{(3)} \text{ if } C^{(2)}<z_{t-d} \end{cases} \tag{1}$$

where $P_{t-1}=[1 z_{t-1} \Delta p_{t-1} \ldots \Delta p_{t-k}]$, A_j $(j=1,2,3)$ is $(k+2)\times 2$ matrix of coefficients, $u_t^{(j)}$ $(j=1,2,3)$ is a serially uncorrelated error term with mean zero and covariance matrix $\Sigma^{(j)}(j=1,2,3)$, and $C^{(1)}$ and $C^{(2)}$ represent the critical thresholds. To reflect the law of one price, we assume $\beta'=(1,-1)$. Then, $\beta' p_{t-1}$ shows the price difference between location 1 and 2 at time $t-1$. If the law of one price prevails, $\beta' p_{t-1}$ is expected to be adjusted toward zero and in this sense, $\beta' p_{t-1}$ can be seen as the error correction term or deviation from the equilibrium. Let $z_{t-1}=\beta' p_{t-1}$. As Balke and Fomby (1997) pointed out, however, it is plausible to assume that economic agents may react to deviations from the equilibrium with a lag. With the delay parameter d, Δp_t is assumed to follow a different process based on the value of z_{t-d}. The interpretation of equation (1) is clear.

Since the values of $C^{(1)}, C^{(2)}$ and d are unknown, we have to estimate them. For the threshold values to be meaningful, the thresholds should be in between the maximum and minimum values of the data. Following Hansen (1999), we adopt the ten percent constraint which requires that at least ten percent of the observations must be contained in each regime. This constraint makes the threshold values lie within the band containing no more than the middle 80 percent of the data. Each observation belonging to this initial 80 percent band is a candidate for a threshold value. As for the delay parameter, we assume that the timing of the adjustment process takes more than one period and thus d should be greater than or equal to one.

2. Test for nonlinearity and estimation of TVECM

As Balke and Fomby (1997) suggested, two step procedures are needed. The first step is to test for no cointegration against cointegration. The second step is to test for linear cointegration against threshold cointegration if cointegration relationship exists. We will follow the two step method in this study. Before we estimate the three-regime TVECM, we should show that the model is suitable for the analysis of gasoline price. Especially we have to prove the validity of the three-regime TVECM against the vector error correction model (VECM) for our analysis, which is the testing of linear versus nonlinear model discussed in Balke and Fomby (1997). The VECM representation for p_t is given by

$$\Delta p_t = \Gamma P_{t-1} + u_t$$

where P_{t-1} is the same as above, Γ is a coefficient matrix and u_t is the error term with covariance matrix Σ. We employ the test statistic extended by Lo and Zivot (2001) for multivariate TVECM which is the sup-*LR* (likelihood ratio) statistic given by

$$\sup - LR = T(\ln(\det\hat{\Sigma}) - \ln(\det\hat{\Sigma}_3(\widehat{C^{(j)}}, \hat{d}))$$

where T is the number of observations, $\hat{\Sigma}$, $\hat{\Sigma}_3(\widehat{C^{(j)}}, \hat{d})$ $(j = 1, 2)$ denote the estimated residual covariance matrices from the linear VECM and three-regime TVECM, $\widehat{C^{(j)}}$ is the estimated threshold value, $\hat{d}$ is the estimated delay value.

Since the threshold values $C^{(1)}$ and $C^{(2)}$ are unknown under the null hypothesis of linear cointegration, we employ the bootstrap procedure suggested by Hansen (1999) and generalized by Lo and Zivot (2001) to compute p-values.

Once the three-regime TVECM is accepted, the next step is the estimation of the model. Lo and Zivot (2001) and Enders (2004) suggested what is called sequential conditional least squares method for the three-regime TVECM. We use this technique for equation (1). As in Enders (2004), it is usual to assume that variances of the error terms from each regime are equal, i.e., $var(u_t^{(1)}) = var(u_t^{(2)}) = var(u_t^{(3)})$.

The sequential conditional least squares estimation consists of two steps. In the first step, conditional on potential candidates for $C^{(1)}, C^{(2)}$ and d the coefficient matrices A_j $(j=1,2,3)$ are estimated by multivariate least squares. The residual sum of squares of the three-regime model $S_3(C^{(1)}, C^{(2)}, d)$ is computed for possible combinations of $(C^{(1)}, C^{(2)}, d)$. Then the collection of $S_3(C^{(1)}, C^{(2)}, d)$ can be obtained. In the second step, the values of $(C^{(1)}, C^{(2)}, d)$ which minimize $S_3(C^{(1)}, C^{(2)}, d)$ are chosen from the collection and using these values, A_j $(j=1,2,3)$ are estimated again. This paper utilized Hansen's (1999) method which is a sequential procedure to estimate three-regime TVECM via the estimation of two-regime TVECM first.

III. Empirical Results

Ten price series of regular gasoline of stations in regions are used. Ten regions are Seoul (SEO), Busan (BUS), Daegu (DGU), Incheon (INC), Kwangju (KWJ), Daejeon (DJN), Ulsan (ULS), Kangwon (KWN), Chungbuk (CHB), Jeonbuk (JNB). Daily average prices of stations in these regions provided by Opinet[2] of Korea

2) www.opinet.co.kr

National Oil Corporations from 3 July 2008 to 3 July 2011. Each price series has 1096 observations. The prices are 7 days a week. The summary of statistics are presented in Table 1 and the graphs of these data are provided in Appendix.

〈Table 1〉 Summary of statistics (Unit: won per liter)

	SEO	BUS	DGU	INC	KWJ
Maximum	2027.79	1976.3	1965.65	1968.91	1954.65
Minimum	1348.92	1285.17	1284.45	1294.89	1272.22
Average	1756.58	1694.76	1686.16	1695.54	1678.98
Standard deviation	148.24	148.88	146.02	149.02	146.71

	DJN	ULS	KWN	CHB	JNB
Maximum	1979.46	1972.73	1966.13	1968.51	1965.24
Minimum	1298.1	1293.43	1284.9	1275.79	1262.44
Average	1696.06	1691.48	1692.04	1685.39	1673.52
Standard deviation	147.62	145.71	149.48	148.83	149.84

The Augmented Dickey-Fuller (ADF) test statistics show that all gasoline prices are non-stationary at both the 5% levels. The ADF tests indicate the first differences of all gasoline prices are stationary. Hence all data are integrated with order 1, i.e., $I(1)$.[3)]

To analyze the price differences among 10 markets, Seoul is used as base market to show the price differences among all 10 markets. For the cointegration test for each pair of two markets, lag length and cointegration rank were determined simultaneously using Schwarz loss measure following Wang and Bessler (2005).

3) ADF test results are not presented in this paper.

〈Table 2〉 Schwarz loss metrics on one to five lags and one and two cointegrating rank on VECM

Market pairs		1-lag	2-lags	3-lags	4-lags	5-lags
Seoul-Busan	1 rank	4.550	3.822	3.815	3.791*	3.805
	2 rank	4.560	3.833	3.825	3.801	3.816
Seoul-Daegu	1 rank	4.511	3.772	3.731	3.719	3.717*
	2 rank	4.519	3.782	3.741	3.728	3.727
Seoul-Incheon	1 rank	3.977	3.512*	3.515	3.522	3.522
	2 rank	3.989	3.524	3.527	3.533	3.533
Seoul-Kwangju	1 rank	5.917	5.272*	5.278	5.290	5.291
	2 rank	5.928	5.283	5.289	5.300	5.302
Seoul-Daejeon	1 rank	4.128	3.583	3.505	3.500	3.499*
	2 rank	4.136	3.594	3.515	3.509	3.508
Seoul-Ulsan	1 rank	4.376	3.672	3.670	3.665*	3.685
	2 rank	4.383	3.682	3.679	3.674	3.694
Seoul-Kangwon	1 rank	3.986	3.208	3.135	3.127*	3.139
	2 rank	3.994	3.218	3.145	3.136	3.148
Seoul-Chungbuk	1 rank	4.486	4.161	4.066	4.031	4.027*
	2 rank	4.495	4.171	4.076	4.040	4.036
Seoul-Jeonbuk	1 rank	5.335	4.305*	4.320	4.341	4.351
	2 rank	5.345	4.316	4.331	4.352	4.361

Note: The asterisk "*"represents minimum values of Schwarz loss metrics.

The results of Schwarz loss metric on one to five lags, and one and two cointegrating rank on VECM are shown in the Table 2. Results indicate that the Schwarz loss metric is minimized at one cointegrating rank. This implies that each of the nine market pairs have a cointegrating rank of one and the markets are pair-wise cointegrated.

We are now in a position to show the TVECM is better than the VECM for our analysis. As is well known, the VECM assumes that the error correction term adjusts to the long run equilibrium in a linear fashion. When non-linearites exist in the adjustment process, we should employ the TVECM. For a test of the null hypothesis of linearity against the alternative of a TVECM, the likelihood ratio (LR) test statistics are provided by Hansen (1999) and Lo and Zivot (2001). For this test, we use the sup-LR test statistics and bootstrap p-values and critical values are computed by a method used by Hansen and Seo (2002) and Lo and Zivot (2001). The bootstrap p-values presented in Table 3 are defined as the percentage of bootstrapped LR statistics. The bootstrap p-values imply that three-regime TVECM is better than VECM in all seven pairs at 5% level except Seoul-Daegu whose p-value is 0.09 indicating that three-regime TVECM is appropriate at 10% level for this pair.[4)]

〈Table 3〉 Test of Linearity

Market Pairs	p-value	sup-LR statistics
Seoul-Busan	0.01	261.36
Seoul-Daegu	0.09	206.67
Seoul-Incheon	0.03	200.55
Seoul-Kwangju	0.00	463.69
Seoul-Daejeon	0.03	210.21
Seoul-Ulsan	0.00	242.26
Seoul-Kangwon	0.00	238.64
Seoul-Chungbuk	0.00	345.07
Seoul-Jeonbuk	0.00	394.90

We turn to the threshold values. The threshold values $C^{(1)}$ and $C^{(2)}$ of the nine pairs are provided in Table 4. The widths of the price differences bands defined as $C^{(2)} - C^{(1)}$ in the five pairs such as Seoul-Incheon (₩1.56), Seoul-Busan (₩3.58), Seoul-Chungbuk (₩4.04), Seoul-Kwangju (₩5.01) and Seoul-Kangwon (₩6.01) are narrower than those of other market pairs. The largest width of the price difference is in Seoul-Ulsan (₩52.97). The estimated delay parameters are provided in Table 5.

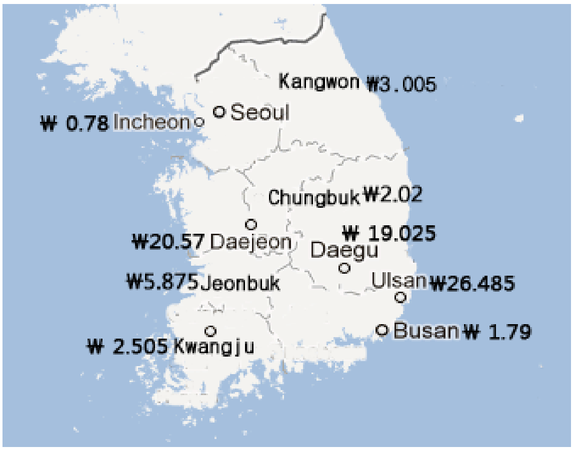
4) To analyze transaction cost, three regime TVECM seems to be more reasonable because the price difference between any two market pair can have positive or negative values.

〈Table 4〉 Threshold Values

Market Pairs	$C^{(1)}$	$C^{(2)}$	$C^{(2)}-C^{(1)}$	Half of $C^{(2)}-C^{(1)}$
Seoul-Busan	76.990	80.570	3.58	1.79
Seoul-Daegu	39.950	78.000	38.05	19.025
Seoul-Incheon	66.830	68.390	1.56	0.78
Seoul-Kwangju	92.950	97.960	5.01	2.505
Seoul-Daejeon	36.690	77.830	41.14	20.57
Seoul-Ulsan	38.730	91.700	52.97	26.485
Seoul-Kangwon	80.420	86.430	6.01	3.005
Seoul-Chungbuk	85.260	89.300	4.04	2.02
Seoul-Jeonbuk	101.49	113.24	11.75	5.875

The half of the width of $C^{(2)}-C^{(1)}$ can be seen as transaction costs in which transportation costs between two markets are included.[5] Estimated transaction costs between regional gasoline markets against Seoul range from ₩0.78 to ₩26.485 per liter.

〈Figure 1〉 Transaction Costs between Seoul and other cities or regions



5) The widths of the price differences bands defined as $C^{(2)}-C^{(1)}$ in any market pair implies that the price difference between two markets can have maximum value of $C^{(2)}$ or minimum value of $C^{(1)}$ from base price. That's why the half of the width of $C^{(2)}-C^{(1)}$ can be seen as transaction costs.

In the four market pairs such as Seoul-Incheon, Seoul-Busan, Seoul-Chungbuk, and Seoul-Kwangju are the estimated transaction costs approximately under ₩2.5 per liter. The estimated transaction costs in Seoul-Kangwon and Seoul-Jeonbuk are ₩3.005, ₩5.875 per liter, respectively. The estimated transaction costs in the pairs of Seoul-Daegu, Seoul-Daejeon and Seoul-Ulsan are larger than those in other pairs. Seoul-Daegu's estimated transaction cost is ₩19.025 per liter. The transaction cost in Seoul-Ulsan is ₩26.485 which is the largest one.

〈Table 5〉 The number of observations in each regime and delay parameter

Market Pairs	No. of Obs in Regime 1	No. of Obs in Regime 2	No. of Obs in Regime 3	Delay parameter
Seoul-Busan	935	67	85	1
Seoul-Daegu	78	648	361	6
Seoul-Incheon	816	70	201	3
Seoul-Kwangju	912	64	111	2
Seoul-Daejeon	86	897	104	4
Seoul-Ulsan	72	961	54	7
Seoul-Kangwon	946	64	77	8
Seoul-Chungbuk	904	64	119	2
Seoul-Jeonbuk	970	63	54	4

Note : Regime 1 indicates the regime below the lower threshold value. Regime 2 represents the middle regime between the lower and upper threshold values. Regime 3 indicates the regime above the upper threshold value.

Table 5 provides the number of observations in each regime. In most pairs, except Seoul-Daegu, Seoul-Daejeon and Seoul-Ulsan, Regime 1 takes more than 80% of total observations. This means that price differences of each pair of gasoline markets are small and thus the gasoline price of regional markets are close to that of Seoul. On the other hand, Seoul-Daegu, Seoul-Daejeon and Seoul-Ulsan show that Regime 2 is more typical than the other two regimes. Therefore, gasoline prices in these three cities are not similar to that of Seoul. This implies that prices in these three markets lower than Seoul's gasoline price which is the highest price of all markets.

IV. Discussion and concluding remarks

We analyzed the dynamic adjustment processes of gasoline prices among 10 regional gasoline markets in Korea. All the price series were tuned out to be $I(1)$ series. We used the sup-*LR* test and bootstrap p-values to find out that the TVECM is more suitable than the VECM for our analysis. This implies that the dynamic adjustment processes are non-linear.

To measure transaction costs, we consider the price differences between Seoul and other cities or regions so that we have 9 market pairs and 9 price-difference series. We applied the TVECM to the 9 price-difference data to estimate the transaction costs among the markets. Table 4 shows the estimated transaction costs. The highest transaction cost (₩26.5) is realized between Seoul and Ulsan while the lowest (₩0.78) is estimated for Seoul-Incheon. It is interesting that the transaction costs are not proportional to the geographical distances. For instances, distances between Seoul and Kwangju and between Seoul and Jeonbuk are larger than that of Seoul and Daejeon but the transaction costs of Seoul-Kwangju (₩2.5) and of Seoul-Jeonbuk (₩5.9) are lower than that of Seoul-Daejeon (₩20.57).

Our estimation implies that transportation cost is not the main factor of the transaction costs. As Park and Lee (2012) suggested, it is plausible that the locations of oil refineries, oil pipelines, and the terminals may influence the transaction costs. Major oil refineries are located in Yeosu (GS), Ulsan (SK), Onsan (S-Oil), Incheon (SK) and Daesan (Hyundai). The oil pipeline distributes the refined oil from the oil refineries to the terminals which reserve the oil before it transports to consumers. South North Pipeline (SNP) and Trans Korea pipeline (TKP) are two major oil pipelines in Korea. SNP has two lines: one runs from

Onsan to Gwacheon and the other from Yeosu to Pangyo. TNP connects Pangyo to Pyongtaek and Waegwan to Daegu. There are two minor oil pipelines: Hoseo Pipeline (from Daesan to Cheonan) and Kyungin Pipeline (from Incheon to Goyang, to Gimpo Airport and to Incheon International Airport).[6] Four terminals are in Goyang, Pangyo, Cheonan and Deajeon. Considering the locations of the three factors, we can conclude that transportation costs are not the main reason for the differences of the transaction costs. Seoul-Daejeon, Seoul-Daegu and Seoul-Ulsan have such a big transaction costs that their price adjustment processes take Regime 2 as their typical regime which we see in Table 5. The other 6 pairs have small transaction costs so that their gasoline price adjustment processes follow Regime 1.

Seo (2008) found that Daejeon and Daegu had a very competitive gasoline markets and Ulsan's gasoline price was lower than the average price. Notice that the lower transaction costs implies gasoline price of a regional market is closer to Seoul's gasoline price and Seoul has the highest gasoline price. Our estimations show that for Jeonbuk and Kwangju, Regime 1 is their typical regime and thus their prices are very close to that of Seoul. This estimation, however, contradicts the results of Seo (2008) in which gasoline price in Jeonbuk were lower than the average price. However, Seo's (2008) data spanned from 1997 to 2006 while ours from 2008 to 2011, which might explain the discrepancies. On the other hand, the high transaction costs of Daejeon, Daegu and Ulsan are the same results of Seo (2008). As Seo (2008) explained, these metropolises do not have a heavy traffic volumes and high rental costs. Therefore, we may suggest new gasoline stations can easily enter the market which enables the metropolises to have very competitive gasoline markets. The lower gasoline prices may result from the high competitive gasoline markets in supply side.

6) For the oil pipeline in Korea, see Park and Lee (2012).

Transaction costs can be influenced by other factors such as competition density in market, selling cost of gas station, and so on. However, our paper mainly depends on aspect of transportation cost in analyzing the differences of transaction cost between markets. This is a limitation of our paper and what future studies need. It seems that the interdependency between gasoline stations in the same market is an important issue for Korean gasoline markets. In addition, the empirical estimation for the intensity of the competition between gasoline markets is an essential topic as well. These themes should be explored in the future study.

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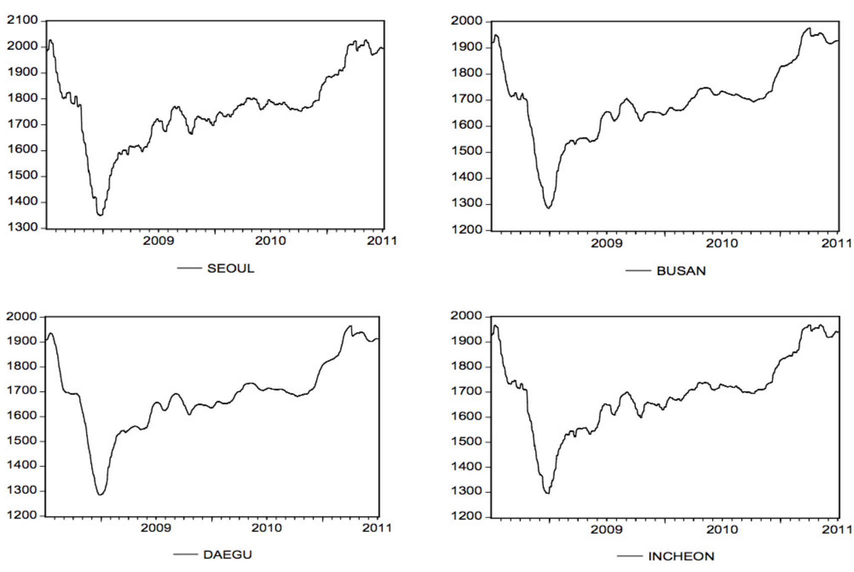
Appendix

〈Figure A〉 Daily average gasoline prices in stations of ten regions (Continued)



〈Figure A〉 Daily average gasoline prices in stations of ten regions (Continued)