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Asymmetric Effects of Oil Prices on Highway Travel Demand in Korea

유류가격 변동에 의한 국내 고속도로 통행수요의 비대칭적 효과 분석

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Ⅰ. Introduction

Recently, crude oil prices fluctuated, and we experienced a dramatic change of oil product prices. In the first half of 2008, we underwent the economic shock due to a sharp rise in the price of crude oil and deliberated how to decrease the oil use amount. However, the worldwide economic crisis sparked by the U.S. financial crisis made crude oil prices plummet in the second half of 2008. Recently, our economy has a sign of economic recovery, and there is an indication of a rise in oil product prices.

Oil price change could affect various economic activities. Many research papers demonstrate that oil price increases have a significantly negative impact on GDP etc (Mork. 1989). Some researchers argue that oil price increases lead to inflation which lowers real income and consumption levels of economic agents (Ferderer. 1996).

Oil price changes might have a significant impact on travel demand. Our transportation system depends upon oil products such as gasoline, diesel, and liquefied petroleum gas (LPG). So we believe that road traffic volumes are closely related with oil prices. Generally, car trips and car vehicle-kilometers have a negative relationship between fuel prices (De Jong and Gunn. 2001; Graham and Glaister. 2002). That is, as fuel prices increase, the road traffic volumes measured as vehicle-kilometers decrease (Hanly et al. 2002).

Many economic documents show that oil prices have asymmetric effects on economic activity. Mork (1989) show that oil price increases have significant negative effects on GDP growth while oil price decreases do not lead to increased output growth (Ferderer. 1996). It is well known that this asymmetry is caused by irreversibility of investment decisions. If a change in oil prices induces firms to adopt new technologies, one does not expect them to instantaneously undo the investment if the oil price changes are reversed (Kuper and Soest. 2006).

So we believe that oil prices have these kind of asymmetric effects on road travel demand too. In order words, we believe oil price elasticities for road traffic volumes when oil prices are high are less than those when they are low. When oil prices are low, agents would be more likely to use their private cars instead of public transit. Meanwhile, agents would be less likely to use their private cars, when oil prices are high. The levels to change mode choice are different when oil prices are high and low. That is, the decreasing amount in using private cars when oil prices high is less than the increasing amount in using them when they are low.[1)]

We have several articles to investigate the asymmetric effects of oil prices on oil demand. Dargay and Gately (1997) examined the price-reversibility of fuel demand for road transport using price decomposition technique. They proved that consumers do not necessarily respond in the same fashion to rising and falling fuel prices. Gately and Huntington (2002) demonstrated that the oil demand of OECD countries responds much more to oil price

1) Another asymmetric effect is that the changes in the transport volume when oil prices increase are different from those when oil prices decrease. Our asymmetric elasticities are a kind of time varying elasticities. However, if time varying elasticities show asymmetric characteristic according to the periods, we can define those time varying elasticities as asymmetric elasticities.

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increases than to decreases and that ignoring this asymmetric price response would bias downward the estimated response to income change.

We have Korean research reports to show that oil prices have negative effects on the road traffic volumes. KDI and KOTI (2008) and KOTI (2010) analyze the effects of oil prices on highway travel demand using ECM and ADL models respectively. In addition, KOTI (2004, 2005) and Lee and Park (2005) used ECM model to estimate the Korean highway demand function using time series analysis. The research report of Korea Expressway Corporation (2011) also deals with the trip demand for Korean highway.

However, there is no article to examine the asymmetric effects of oil prices on the road traffic volumes. In this study, we will investigate the asymmetric effects of oil prices on the highway travel demand in Korea.[2] In order to do that, we have to divide the data, which are monthly data from January 2000 to December 2008, into two periods such as low and high oil price periods. We will estimate and compare the oil price elasticities of the high way travel demand in the low and high oil price periods as well as in the total time span. By doing so, we are going to give policy implications about energy policies for transportation.

II. Theoretical Background and Model Specification

1. Theoretical Background

We explain why oil price changes have asymmetric effects on the highway travel demand. We follow the elasticity decomposition suggested by Graham and Glaister (2002).[3] They defined the generalized costs of driving a vehicle kilometer as,

$$g = \frac{p}{s} + k \qquad \text{<1>}$$

g: generalized costs of driving a vehicle kilometer

p: fuel prices (KRW/liter), KRW means the monetary unit of Korea[4]

s: fuel efficiency (km/liter)

k: non-fuel component of generalized cost

The ratio of p to s gives a measure of fuel prices per kilometer (KRW/km), which is the cost of fuel to the driver (r).

2) We do not have any other road traffic volume data except for highways in Korea, which is collected periodically. Thus we use highway traffic volume data in this study.

3) We follow the notation and elasticity decomposition of Graham and Glaister (2002).

4) The exchange rate of KRW to USD is 1.373.84 in December 2008.

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They called it as fuel costs, which are differentiated from fuel prices. The fuel efficiency, s, is expressed as,

$$s = f(p, t, I, v) \qquad \text{<2>}$$

t: vehicle technology regarding fuel efficiency

I: income

v: vehicle speed

Graham and Glaister (2002) maintained that fuel prices would affect driving style and hence specific fuel consumption. The world economy experienced two oil price shocks in the second half of the 20th century. In response to oil price shocks, auto makers accomplished technological progress in producing energy efficient cars. Conclusively, fuel price increases made fuel efficiency of the vehicle improve. Thus, we believe that fuel prices have positive effects on fuel efficiency ($\partial s/\partial p > 0$).

The non-fuel component of generalized costs, the costs of time, is a function of income and vehicle speed.

$$k = g(I, v) \qquad \text{<3>}$$

Road traffic volume, T, is a function of vehicle stock and average distance travelled. The vehicle stock depends on the generalized costs, income, and costs of car ownership.

$$T = N(g, I, c) \cdot d(g, I) \qquad \text{<4>}$$

N: vehicle stock

d: average distance travelled

c: costs of car ownership

They took natural logarithms of all variables and differentiated them totally. They suggested the elasticities of road traffic volumes measured as vehicle-kilometers with respect to fuel prices after rearranging some equations.

$$\eta_{Tp} = \eta_{Tr}(1 - \eta_{sp}) \qquad \text{<5>}$$

η_{Tp}: elasticity of road traffic volumes (T) with respect to fuel prices (p)

η_{Tr}: elasticity of road traffic volumes (T) with respect to fuel costs (r)

η_{sp}: elasticity of fuel efficiency (s) with respect to fuel prices (p)

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In this notation, we believe the elasticities of road traffic volumes with respect to fuel costs, η_{Tr}, might be negative. We already think that the elasticities of fuel efficiency with respect to fuel prices, η_{sp}, are positive. If we assume that fuel efficiency has a linear relationship with fuel prices, the elasticities of fuel efficiency with respect to fuel prices are increasing functions with respect to fuel prices. Because the elasticities of fuel efficiency with respect to fuel prices are defined as $\partial s/\partial p \cdot p/s$. If fuel prices are high, the elasticities of fuel efficiency with respect to fuel prices are big. It makes the absolute values of the elasticity of the road traffic volumes with respect to fuel prices small.[5)]

Conversely, if fuel prices are low, the elasticities of fuel efficiency with respect to fuel prices are small. It makes the absolute values of the elasticity of the road traffic volumes with respect to fuel prices big. Fuel efficiency in response to fuel price changes makes the different elasticities of the road traffic volumes. Drivers in response to fuel price increases would be more likely to improve fuel efficiency changing their driving behavior. However, they would be less likely to improve fuel efficiency when fuel prices drop. Therefore, when fuel prices are high or low, we have asymmetric elasticities of road traffic volumes.

2. Estimation Model

We are going to estimate the model below.

$$\ln Y_t = \beta_0 + \beta_1 \ln Q_t + \beta_2 \ln GDP_t + \beta_3 \ln EXLN_t + u_t \quad <6>$$

Y: variables to represent the highway traffic volumes

Q: real oil prices per liter

GDP: real GDP

EXLN: length of highways adjusted by lane

u: error term

in: natural log

t: time (year and month)

We use the highway traffic volume as a proxy for the highway travel demand. We use the numbers of vehicles and vehicle-kilometers as a dependent variable. We include real oil price variable as a key explanatory variable. In order to find the effects of income on the highway travel demand, we add real GDP variable to the equation. The Korea Expressway Corporation is now constructing new highways and expanding existing highways. In order

5) We also assume that the elasticities of fuel efficiency with respect to fuel prices are less than one. This assumption ensures that the elasticities of road traffic volumes with respect to fuel prices are negative.

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to control this kind of supply side effects, we include the variable, EXLN, to represent the present highway lanes as an explanatory variable.[6)7)] We use logarithmic formation for all variables because the model with logarithmic formation variables follows the classical linear model assumption well and we can calculate the elasticities easily. The logarithmic formation decreases the effects of outlier on estimation results when the sample size is small.

Most of all, our data is time series data, and we have to follow the time series procedures. That is, we have to carry out unit root test and cointegration test for all variables. The unit root test is to inspect if all variables are stationary. If they are stationary, we can use ADL and ECM models. If they are not, we have to use cointegration test if they have long run relationships. We can use ADL and ECM models if they have cointegration relations (Maddala and Kim. 1998; Benerjee et al. 1993).

If all variables have unit roots and their first differences are stationary, they are denoted as I(1). In this case, we have to check out if they have long-run relationships using cointegration test. If they have long-run relationships, we will use autoregressive distributed lag model (ADL model), which was suggested by Hendry et al. (1984) and Error Correction model (ECM), which was suggested by Engle and Granger (1987).[8)]

According to Maddala and Kim (1998) and Benerjee et al. (1993), ADL (1,1;1) can be transformed into ECM.[9)]

The ADL model to estimate is

$$\ln Y_t = \beta_0 + \gamma_1 \ln Y_{t-1} + \beta_1 LNRPOR_t + \gamma_2 LNRPOR_{t-1} + \beta_2 LNRGDP_t \\ + \gamma_3 LNRGDP_{t-1} + \beta_3 LNEXLN_t + \gamma_4 LNEXLN_{t-1} + u_t \qquad \text{<7>}$$

in*Y*: natural log (Numbers of Vehicles or Vehicle-Kilometers)

LNRPOR: natural log (Real Weighted Oil Prices)

LNRGDP: natural log (Real GDP)

LNEXLN: natural log (Length of Highways Adjusted by Lane)

u: error term

t: time (year and month)

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6) We did not consider the tolls or fares of the Korean highway system in the main text, because the tolls or fares of the Korean highway system did not change occasionally and we could not define the tolls or fares correctly. In detail, the Korea Expressway Corporation changed their tolls three times from January 2000 to December 2008. In addition, there is a problem how to define the toll in every month. However, we define the tolls as revenue/number of vehicles and estimate the model upon the request of anonymous referees. The estimation result is reported in APPENDIX.

7) We can also consider the railroad variable which is a substitute transportation for highway. We generate a dummy variable which is equal to one after Korean Train Express (KTX) service was started, otherwise is zero. We can estimated the asymmetric effects of oil prices controlling the dummy variable, which is a substitute transportation for highway. The estimation results is provided at APPENDIX.

8) In order to use ADL model, all variables have to be stationary. However, although all variables are not stationary, we can use ADL model if they have long-run relationships (Maddala and Kim. 1998; Benerjee et al. 1993).

9) In ADL(m,n; p), m is the number of lags in dependent variables, n is the number of lags in explanatory variables, and p is the number of explanatory variables. See Bewley (1979) and Bardsen (1989).

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ECM to estimate is

$$dln\,Y_{t-1} = \alpha_0 + \alpha_1 dLNRPOR_{t-1} + \alpha_2 dLNRGDP_{t-1} + \alpha_3 dLNEXLN_{t-1}$$
$$+ \delta(\ln Y_{t-1} - \theta_0 - \theta_1 LNRPOR_{t-1} - \theta_2 LNRGDP_{t-1} - \theta_3 LNEXLN_{t-1}) + u_t \quad \text{<8>}$$

d: difference notation[10)]

In the ADL model and ECM, we could obtain the long-run elasticities of the highway travel demand with respect to oil prices.[11)] The long-run elasticities of the highway travel demand in ADL model and ECM are defined as $(\beta_1+r_2)\,/\,(1-r_1)$and θ_1 respectively.[12)]

Actually, we could obtain the elasticities of the highway travel demand with respect to oil prices in three periods. That is, we have to obtain the elasticities when oil prices are high or low as well as those in the total time span.

In addition, we have to compare these elasticities using Chow test. Chow test is to examine if there is a structural change in designating time periods. That is, Chow test is to examine if elasticities or estimates are different when oil prices are high or low. The null hypothesis in Chow test is that all estimates in two different periods are identical. The alternative hypothesis is that all estimates in two different periods are statistically different. The test statistic in Chow test is

$$\frac{(SSE_R - SSE_U)/k}{SSE_U/(T-2k)} \quad \text{<9>}$$

$SSE_R$is the sum of squared residuals in the restricted regression to assume that all coefficient estimates are identical. SSE_U is the sum of squared residuals in the unrestricted regression to assume that all coefficient estimates are different. SSE_U is the sum of each sum of squared residuals when we estimate each equation separately. k is the number of regressors and is total number of observations. The Chow test statistic is F-distributed with the degree of freedom k and T-$2k$.

When the null hypothesis is rejected, we can say that the elasticities of the highway travel demand with respect to oil prices are not identical when oil prices are high or low. It means that the highway travel demand with respect to oil prices is asymmetric.

10) For example, $dlnY_{t-1} = lnY_{t-1}$.

11) We use monthly data in this study, so the term of long-run elasticities is not appropriate (Hughes et al. 2006). However, we will use long-run elasticities for convenience.

12) We follow Hughes et al. (2006) and Dargay et al. (2002) because they used ADL and ECM respectively.

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III. Data

In this study, we use monthly data from January 2000 to December 2008. We use the number of the first type vehicles to pass the Korean highway as a proxy for highway travel demand.[13] The first type vehicles classified in the Korean highway are mainly passenger cars that are influenced by oil price fluctuation. We also use the number of the vehicle-kilometers travelled (VKT) of the first type cars as a proxy for highway travel demand. To obtain the real oil price data, we are going to use monthly price data for three refined petroleum products such as gasoline, diesel, and LPG and the amounts to use gasoline, diesel, and LPG in road transport sector provided by Petronet (www.petronet.co.kr). We multiply each product price by the ratio of each product amount used to total products amount used (See Ferderer (1996) and KDI and KOTI (2008)).

Figure 1 _ Oil price trend in Korea

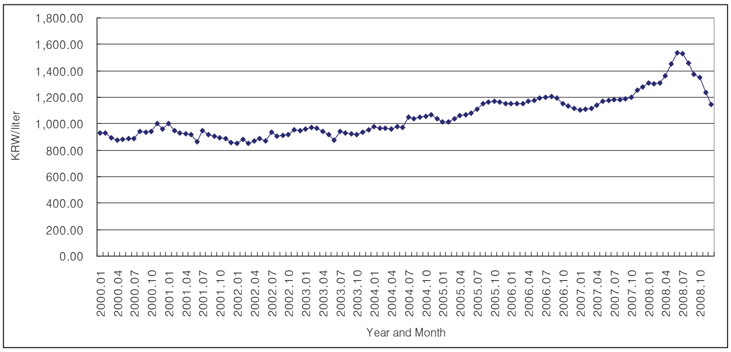
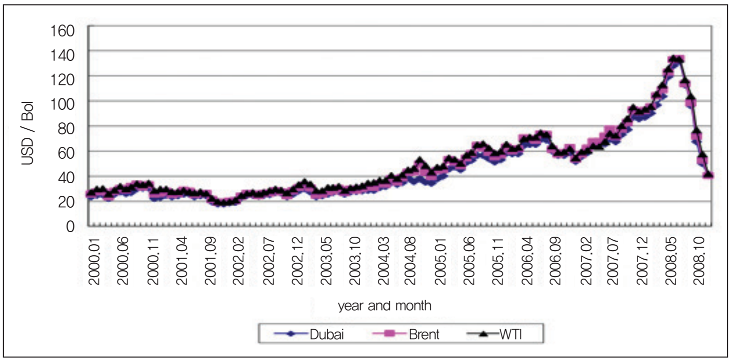


Figure 2 _ Crude oil price trend



$$WOP_{y,m} = \sum_{i=1}^{3} w^i_{y,m} \cdot OP^i_{y,m} \qquad <10>$$

$WOP_{y,m}$: weighted oil prices in month m of year y

$OP^i_{y,m}$: price of product i in month m of year y

$w^i_{y,m}$: ratio of product i amount used to total petroleum products amount used in month m of year y

i : gasoline, diesel, and LPG

y: year (2000, 2001, …, 2008)

m: months (1, 2, …, 12)

13) The Korea Expressway Corporation divides all vehicles into 5 types. The 2nd type is small sized buses and light trucks and the 3rd type is medium sized buses and trucks. The 4th type and 5th type are 3 axle trucks and 4 axle trucks respectively.

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Finally, we can obtain the real oil prices considering consumer price indices with the base year of 2005.

The economic situation could affect travel demand, so we use real GDP as a proxy for the economic situation.[14] However, GDP is announced by quarterly or yearly instead of by monthly. We have to generate monthly GDP data,

$$Monthly\ GDP_{y,m} = Quarterly\ GDP_{y,q} \times \frac{IPI_{y,m}}{IPI_{y,q}} \qquad <11>$$

IPI : Industrial Production Index

y, q and *m* : year, quarter, and month

In order to capture the supply side effect of constructing new highways and expanding existing highways, we include the variable to represent the present highway length as an explanatory variable. To construct this variable, we give the weight 0.5, 1.0, 1.5, and 2.0 to 2, 4, 6, and 8 lane roads respectively and sum each lane numbers.

In this study, we do not consider the tolls or fares of the Korea highway, because the tolls or fares of the Korea highway did not change occasionally. In detail, the Korea Expressway Corporation changed their tolls three times since 2000. If we include tolls or fares as an explanatory variable, the estimates for tolls or fares are effects not of tolls or fares but of price levels such as consumer price index (CPI). Highway traffic volumes have the characteristic of seasonality. So, we use seasonal adjustments for these variables using X11 model provided by E-Views.[15]

In order to determine if oil prices are high or low, we use 1,000 KRW/liter as a base price. Real oil prices until June 2004 were below 1,000 KRW/liter even if some months in the period were above 1,000 KRW/liter (see Figure 1). Since June 2004, real oil prices were above 1,000 KRW/liter. So we can divide the whole time span by two time spans using the price of 1,000 KRW/liter. So, we can define from January 2000 to June 2004 as low oil price periods and from July 2004 to December 2008 as high oil price periods. This kind division coincides with the patterns of the crude oil prices such as prices of Dubai, Brent, and WTI. The crude oil prices began to increase sharply, and were above 40 USD/Bbl from the second half in 2004 (see Petronet).

The numbers of vehicles and vehicle kilometers in Korean Highways are 81,929 thousands and 2,948,203 thousands in December 2008. The real oil prices and real GDP in Korea are 1,145.63 KRW/liter and 70,666.8 billion KRW in December 2008. The length of highway adjusted by lane supplied by the Korea Expressway Corporation is 3,642.5km.

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14) The base year is 2005.

15) GDP and Industrial Production Index are also adjusted seasonally.

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Table 1 _ Data summary (December 2008)

Number of Vehicles (thousand vehicle)	Number of Vehicle Kilometers (thousand VKT)	Real Oil Prices (KRW/liter)	Real GDP (billion KRW)	Length of Highways Adjusted by Lanes(km)
81,929	2,948,203	1,145.63	70,666.8	3,642.5

Notes: 1) Real terms are based upon year, 2005.
2) KRW means Korean Won, which is Korean currency.
Sources: 1) Bank of Korea (www.bok.or.kr)
2) Korea Expressway Corporation (www.ex.co.kr)
3) Korea Railroad Corporation (www.korail.com)

Ⅳ. Effects of Oil Price Changes on Highway Travel Demand

1. Unit Root and Cointegration Tests

We carry out Augmented Dickey Fuller (ADF) test to test if variables have unit roots. The null hypothesis is that variables have unit roots. However, we have to find if the variables have deterministic linear trends (intercept and time trend). So we hypothesize three cases. The first is that the variables do not have any deterministic trend and the second is that they have an intercept. The last is that they have an intercept and time trend.

$$dZ_t = \alpha + \gamma trend + \rho Z_{t-1} + \sum_{j=1}^{p} \theta_j dZ_{t-j} + u_t \quad \text{<12>}$$

Z: variables

$trend$: time trend

According to ADF test results, all variables are non-stationary, and they have unit roots. If we take first differences of all variables, they are stationary because their p-values are all zero.[16)]

We call them as integrated of order one, denoted by I(1). Since all variables have unit roots and non-stationary, we have to find if there is any long-run relationship among them. To use ADL model or ECM, it is necessary to carry out cointegration test among them.

We could use Johansen cointegration tests(Johansen. 1991; Johansen and Juselius. 1994). The null hypothesis in cointegration test is that the number of cointegration relations is n and the alternative hypothesis is that the number of cointegtration relations is greater than n.

Based upon cointegratin test results, there are one long-run relation among them-LNNVEX1SA, LNRPOR, LNRGDP, and LNEXLN and among LNVKTEX1SA, LNRPOR, LNRGDP, and LNEXLN.[17)] According to

16) The first differences of log of raw variables are the percentage changes in raw variables.

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Table 2 _ Unit root test results

Category		Level			First Difference		
		Test Statistic	P-value	Time Lag	Test Statistic	P-value	Time Lag
Number of Vehicles (LNNVEX1SA)	case 1	3.2816	0.9997	1	-13.6907	0.0000	0
	case 2	-2.8814	0.0509	1	-14.7021	0.0000	0
	case 3	-1.2080	0.9034	1	-15.3218	0.0000	0
Number of Vehicle Kilometers (LNVKTEX1SA)	case 1	1.9654	0.9880	1	-17.9538	0.0000	0
	case 2	-2.5783	0.1007	2	-18.3106	0.0000	0
	case 3	-1.5096	0.8203	2	-10.9446	0.0000	0
Real Oil Prices (LNRPOR)	case 1	0.6352	0.8520	0	-9.2873	0.0000	0
	case 2	-1.1287	0.7024	0	-9.2749	0.0000	0
	case 3	-2.9744	0.1444	2	-9.2218	0.0000	0
Real GDP (LNRGDP)	case 1	2.0275	0.9896	2	-7.9042	0.0000	1
	case 2	-1.6092	0.4743	2	-8.2529	0.0000	1
	case 3	-3.5206	0.0422	0	-8.3340	0.0000	1
Length of Highways Adjusted by Lane (LNEXLN)	case 1	2.2602	0.9942	1	-6.9271	0.0000	0
	case 2	-1.9349	0.3153	2	-7.4317	0.0000	0
	case 3	-2.2239	0.4713	1	-7.4972	0.0000	1

Notes: 1) All variables are the natural log of raw variables.
2) Number of Vehicles and Number of Vehicle-Kilometers are seasonally adjusted.

cointegration test results, we have to insert trend variable into the original model, so we add trend variable to our model as an explanatory variable.

2. Number of Vehicles

We estimate the effects of oil prices on the highway traffic volumes using ADL model and ECM using the number of vehicles as a dependent variable. We analyze our model using the whole time period from January 2000 to December 2008 and then divide our sample into two time periods and analyze each period separately. The first period is the sample from January 2000 to June 2004 when oil prices are low. The second group is from July 2004 to December 2008 when oil prices are high.

The long-run elasticities of oil prices for highway travel demand in ADL model are -0.5261 for the total time span. It means that the highway traffic volumes measured as the number of vehicles increase (decrease) by 0.5261% if oil prices drop (rise) by 1%. The p-values of $LNRPOR$ and $LNRPOR_{t-1}$ are 0.1498 and 0.1782, which are not statistically significant at 1, 5, and 10% levels. However, their t-values are marginally significant at 10%

17) We can provide the cointegration test results when requested.

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Table 3 _ Estimation results for ADL model (number of vehicles)

Variables	Total Time Span	The First Period (Low Oil Price Period)	The Second Period (High Oil Price Period)
$LNNVEX1SA_{t-1}$	0.6765**** (0.1229)	0.6942*** (0.1286)	−0.1030 (0.3212)
$LNRPOR_t$	−0.0778 (0.0536)	−0.1348 (0.1225)	0.0129 (0.0747)
$LNRPOR_{t-1}$	−0.0924 (0.0682)	−0.1478 (0.1077)	−0.2113** (0.0968)
$LNRGDP_t$	0.2355** (0.1016)	−0.1480 (0.1702)	0.3508*** (0.1251)
$LNRGDP_{t-1}$	−0.1808 (0.1323)	−0.1591 (0.2097)	0.0906 (0.0779)
$LNEXLN_t$	0.5008*** (0.1157)	0.5166*** (0.0858)	−0.2126 (0.2795)
$LNEXLN_{t-1}$	−0.2114 (0.1837)	−0.2770 (0.1298)	−0.1028 (0.2483)
trend	0.0008 (0.0006)	0.0026** (0.0011)	0.0040*** (0.0013)
constant	4.0617** (1.8518)	8.8533*** (2.9348)	18.9591*** (5.6606)
Number of Observations	107	53	54
R^2	0.9874	0.9857	0.9248
long-run elasticities	−0.5261	−0.9240	-0.1799
F-statistic	63.0498*** (0.0000)	23.7367*** (0.0000)	9.5804*** (0.0001)

Notes: 1) The numbers in parentheses are Newey-West robust standard errors.
2) ***, **, * indicate significance at 1%, 5%, 10% levels.
3) F-statistic is the statistic to test joint significance of $LNNVEX1SA_{t-1}$, $LNRPOR_t$, $LNRPOR_{t-1}$ and . The numbers in the parentheses of F-statistic are p-values.

level if we test coefficient estimates at one-sided test.

The long-run elasticities of oil prices for highway travel demand in the first period are -0.9240, but that in the second period is -0.1799. When oil prices are low, the highway traffic volumes increase by 0.9240% if oil prices drop by 1%. However, when they are high, the highway traffic volumes increase by 0.1799% if they drop by 1%. The long-run elasticities of oil prices when oil prices are low are about five times as big as one when oil prices are high. The highway traffic volumes during the periods of low oil prices are about five times as sensitive to oil prices as those during the periods of high oil prices. However, $LNRPOR_t$ and $LNRPOR_{t-1}$ in the first period and $LNNVEX1SA_{t-1}$ and $LNRPOR_t$ in the second period are not statistically significant. It weakens our inference about asymmetric characteristics of the highway traffic volumes.

We carry out F-test whether the number of vehicles in previous periods ($LNNVEX1SA_{t-1}$) and oil price variables ($LNRPOR_t$ and $LNRPOR_{t-1}$) are jointly significant or not. They are all jointly significant in all cases. Therefore, even if t-statistics are not perfectly satisfactory, we conclude that economic agents respond more actively when oil prices are low than when oil prices are high.

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Table 4 _ Estimation Results for ECM (Number of Vehicles)

Variables	Total Time Span	The First Period (Low Oil Price Period)	The Second Period (High Oil Price Period)
$dLNNVEX1SA_{t-1}$	-0.4353^{***} (0.1020)	-0.2447^{*} (0.1405)	-0.4554^{***} (0.1489)
$dLNRPOR_{t-1}$	−0.0801 (0.0754)	−0.1253 (0.1131)	0.0893 (0.1034)
$dLNRGDP_{t-1}$	−0.0322 (0.1228)	−0.3486 (0.2396)	−0.1252 (0.1364)
$dLNEXLN_{t-1}$	0.4048^{***} (0.1426)	0.2992 (0.1943)	0.2150 (0.2302)
α_0	0.0064^{***} (0.0023)	0.0105^{***} (0.0039)	0.0029 (0.0025)
δ	0.0613 (0.0626)	−0.0041 (0.0334)	-0.4337^{**} (0.2056)
$LNRPOR_{t-1}$	-0.4371^{***} (0.1229)	−0.8672 (0.6674)	-0.2483^{***} (0.0337)
$LNRGDP_{t-1}$	2.1432^{***} (0.5323)	-8.6439^{***} (1.8290)	0.8769^{***} (0.1691)
$LNEXLN_{t-1}$	1.0929^{***} (0.1406)	2.1469^{***} (0.5488)	−0.1605 (0.1102)
Trend	-0.0056^{**} (0.0022)	0.0279^{***} (0.0078)	0.0018^{**} (0.0008)
θ_0	−11.2284	101.6806	11.2453
Number of Observations	106	52	54
R^2	0.2055	0.1651	0.4891

Notes: 1) The numbers in parentheses are standard errors.
2) ***, **, * indicate significance at 1%, 5%, 10% levels.

We compare total sample with the first and second sample periods using Chow test. Chow test statistic to differentiate the first period from the second period is 3.9640, which is statistically significant. It means that the oil price elasticities in the first period and second period are different.

Except for the first group, gross domestic products have positive effects on the highway traffic volumes. Except for the second group, as the length of highways adjusted by lane increases, the highway traffic volumes also rise. However, not all t-statistics are statistically significant.

We could use not only ADL model but also ECM suggested by Engle and Granger (1987) as long as all variables have long-run relationships. The long-run elasticities of the highway travel demand with respect to oil prices are −0.4371 in the total time span. The long-run elasticities in the low and high oil price periods are −0.8672 and −0.2483 respectively. The long-run elasticities in the low oil price period are about 3.5 times as big as those in the high oil price period. The t-statistics of $LNRPOR_{t-1}$ in the total time span and the high oil price period are statistically significant at 1% level. That in the low oil price period is 1.30, which is not statistically significant, but we can say that it is marginally significant at one sided test.

Chow test statistic to differentiate the first period from the second period is 3.2289, which is statistically

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Table 5 _ Estimation results for ADL model (number of vehicle – kilometers)

Variables	Total Time Span	The First Period (Low Oil Price Period)	The Second Period (High Oil Price Period)
$LNVKTEX1SA_{t-1}$	0.3366* (0.1876)	0.5875*** (0.1311)	−0.4584 (0.1727)
$LNRPOR_t$	−0.2245** (0.1008)	−0.3157** (0.1442)	0.0151 (0.1409)
$LNRPOR_{t-1}$	−0.1670 (0.1434)	−0.2426 (0.2118)	−0.3144* (0.1624)
$LNRGDP_t$	0.3162* (0.1841)	−0.4824 (0.3146)	0.3124** (0.1276)
$LNRGDP_{t-1}$	0.1961 (0.3319)	−0.0313 (0.4633)	0.5009* (0.2768)
$LNEXLN_t$	0.8171*** (0.1959)	0.6395*** (0.1495)	−0.6504 (0.5902)
$LNEXLN_{t-1}$	−0.0216 (0.3114)	−0.1770 (0.1686)	0.2772 (0.4949)
trend	−0.0008 (0.0013)	0.0033** (0.0017)	0.0043** (0.0018)
constant	5.0786 (4.0948)	14.6638*** (5.0609)	27.6850*** (6.3088)
Number of Observations	107	53	54
R^2	0.9522	0.9701	0.7537
long-run elasticities	−0.5901	−1.3534	−0.2052
F-statistic	14.4419*** (0.0000)	14.9240*** (0.0000)	4.3605*** (0.0089)

Notes: 1) The numbers in parentheses are Newey-West robust standard errors.
2) ***, **, * indicate significance at 1%, 5%, 10% levels.
3) F-statistic is the statistic to test joint significance of $LNVKTEX1SA_{t-1}$, $LNRPOR_t$, and $LNRPOR_{t-1}$. The numbers in the parentheses of F-statistic are p-values.

significant. It means that the oil price elasticities in the low and high oil price periods are different.

In the long-run, GDP has positive effects on the highway travel demand in the total time span and the high oil price period but has negative effects in the low oil price period. The length of highways adjusted by lane has positive effects on the highway travel demand in the total time span and the low oil price period but has negative effects in the high oil price period, which is not statistically significant. The time trend has positive effects on the highway travel demand if we divide the total time span into two periods while it has negative effects in the total time span.

3. Number of Vehicle – Kilometers

If we make a notice of the estimation result when a dependent variable is the number of vehicle-kilometers in ADL model, the oil price elasticities of highway traffic volumes are −0.5901 for the total time span. This estimation result shows that the highway traffic volumes measured as the number of vehicle-kilometers increase (decrease) by 0.5901% if oil prices drop (rise) by 1%.

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Table 6 _ Estimation results for ECM (number of vehicle–kilometers)

Variables	Total Time Span	The First Period (Low Oil Price Period)	The Second Period (High Oil Price Period)
$dLNNVEX1SA_{t-1}$	-0.4700^{***} (0.0962)	-0.3343^{**} (0.1421)	−0.0851 (0.1337)
$dLNRPOR_{t-1}$	−0.0978 (0.1430)	−0.2202 (0.1919)	0.2145 (0.1800)
$dLNRGDP_{t-1}$	−0.3428 (0.2339)	−0.5078 (0.4018)	-0.8049^{***} (0.2568)
$dLNEXLN_{t-1}$	0.6947^{***} (0.2630)	0.5014 (0.3170)	0.4252 (0.4427)
α_0	0.0059 (0.0043)	0.0101 (0.0064)	0.0020 (0.0046)
δ	-0.1846^{*} (0.0935)	−0.0110 (0.0398)	-1.2831^{***} (0.2216)
$LNRPOR_{t-1}$	-0.5577^{***} (0.1448)	−1.3582 (0.9639)	-0.2504^{***} (0.0576)
$LNRGDP_{t-1}$	2.7702^{***} (0.6235)	-12.2373^{***} (2.6242)	1.3020^{***} (0.2877)
$LNEXLN_{t-1}$	1.2932^{***} (0.1656)	2.9139^{***} (0.7844)	−0.1345 (0.1884)
Trend	-0.0089^{***} (0.0026)	0.0366^{***} (0.0112)	−0.0001 (0.0014)
θ_0	−15.1732	142.1074	10.0290
Number of Observations	106	52	54
R^2	0.3675	0.1787	0.7255

Notes: 1) The numbers in parentheses are standard errors.
2) ***, **, * indicate significance at 1%, 5%, 10% levels.

The long-run elasticities of oil prices for highway travel demand in the first group is −1.3534, but that in the second group is −0.2052. When oil prices are low, the highway traffic volumes increase by 1.3534% if oil prices drop by 1%. However, when they are high, the highway traffic volumes increase by 0.2052% if they drop by 1%. The long-run elasticities of oil prices when oil prices are low are about seven times as big as one when oil prices are high. The highway traffic volumes during the periods of low oil prices are about seven times as sensitive to oil prices as those during the periods of high oil prices.

We carry out F-test whether the number of vehicles in previous periods ($LNNVEX1SA_{t-1}$) and oil price variables ($LNRPOR_t$ and $LNRPOR_{t-1}$) are jointly significant or not. Tests statistics tell us that they are jointly significant in all cases. Chow test statistic to differentiate the first period from the second period is 7.2658, which is statistically significant. It means that the oil price elasticities in the first period and second period are different.

Except for the first period, gross domestic products have positive effects on the highway traffic volumes. Except for the second period, as the length of highways adjusted by lane increases, the highway traffic volumes also rise. These estimation results for gross domestic products and the length of highways adjusted by lane are also similar to those in the previous one. In the case of vehicle-kilometers as a dependent variable in ADL model,

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Table 7 _ Summary of empirical results

Category			Total Time Span	The First period	The Second period
Number of Vehicles	ADL model	Long-Run Elasticities	−0.5261	−0.9240	−0.1799
		F-Statistic	63.0498	23.7367	9.5804
		Chow Statistic	-	3.2289	
	ECM	Long-Run Elasticities	−0.4371	−0.8672	−0.2483
		t-Statistic	3.5572	1.2994	7.3586
		Chow Statistic	-	3.9640	
Number of Vehicle-Kilometers	ADL model	Long-Run Elasticities	−0.5901	−1.3534	−0.2052
		F-Statistic	14.4419	14.9240	4.3605
		Chow Statistic	-	7.2658	
	ECM	Long-Run Elasticities	−0.5577	−1.3582	−0.2504
		t-Statistic	3.8504	1.4091	4.3498
		Chow Statistic	-	6.9331	

all t-statistics are not statistically significant, which is a weak point of our analysis.

If we make a notice of the estimation results in ECM, the long-run elasticities of the highway travel demand with respect to oil prices are −0.5577 in the total time span. The long-run elasticities in the low and high oil price periods of ECM are −1.3582 and −0.2504 respectively. The long-run elasticities in the low oil price period are about 5.4 times as big as those in the high oil price period. The t-statistics of in the total time span and the high oil price period are statistically significant at 1 % level. That in the low oil price period is 1.41, which is not statistically significant, but we can say that it is marginally significant at one sided test.

Chow test statistic to differentiate the first period from the second period is 6.9331, which is statistically significant. It means that the oil price elasticities in the low and high oil price periods are different.

In the long-run, GDP has positive effects on the highway travel demand in the total time span and the high oil price period but has negative effects in the low oil price period. The length of highways adjusted by lane has positive effects on the highway travel demand in the total time span and the low oil price period but has negative effects in the high oil price period, which is not statistically significant. The time trend has positive effects on the highway travel demand in the low oil price period while it has negative effects in the total time span and the high oil price period.

The long-run elasticities of different periods and Chow test statistics tell us useful implications. The highway traffic volumes respond differently when oil prices are low or high.

Ⅴ. Summary and Concluding Remarks

Oil price changes have negative effects on highway travel demand in Korea measured as the numbers of vehicles and vehicle-kilometers. The oil price elasticities when oil prices are low are greater than those when they are high. The F-statistics of the key variables in ADL model are jointly significant. In addition, Chow test results in ADL

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model show that we have to differentiate the low oil price periods from the high oil price periods. The t-statistics of oil price variables are statistically significant in the total time span and the high oil price period of ECM. Their t-statistics are marginally significant in the low oil price period of ECM. Chow test results in ECM also show that we have to differentiate the low oil price periods from the high oil price periods.

This estimation results lead us that there are asymmetric effects of oil price changes when oil prices are low or high. The agents to use private cars in the highway when oil prices are low-from January 2000 to June 2004 responded more sensitively than when oil prices are high-from July 2004 to December 2008. In other words, highway users respond differently when oil prices are high or low.

The elasticities during the total time span for the number of vehicles are about −0.53∼−0.44. KDI and KOTI (2008) reported that the oil price elasticities are about −0.43∼−0.36 and KOTI (2010) showed that the oil price elasticities are about −0.58∼−0.32. We can say that our estimation results are reasonable comparing the other Korean research reports.

Last year, we experienced a sudden rise in petroleum and diesel prices and underwent economic recess. In this situation, the excise tax rates imposed on oil products would need to be significantly larger in order to achieve a significant reduction in road traffic volumes. Because the long-run oil price elasticities of road traffic volumes when oil prices are high are less than those when they are low.

However we use aggregate data instead of disaggregate data and use macro model to find the asymmetric relationship between highway travel demand and oil prices. Therefore, our model and estimation results show a macroeconomic trend, but can not explain travel behavior of individual drivers. This is a kind limitation of our study. In addition, our estimation results do not have perfect t-statistics about the key variables. They are the limitation for our study. Maybe the reasons are that we used monthly data and that we do not have sufficiently long period data. However, we have consistent signs and magnitudes about the oil price elasticities in ADL model and ECM, which is a good point for our work.

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Appendix

We consider the railroad variable as a substitute transportation for highway. We use a dummy variable whether Korean Train Express (KTX) was started or not. From January 2000 to April 2004, the dummy variable is zero but one since then. However, it is useless to add this dummy variable to ECM because it is a kind of exogenous variable. Although it is used in ECM, we can include this dummy variable in not long term equation but short term equation. Therefore, it is not related with long run elasticities.

Instead we use this dummy variable in ADL model as an additional explanatory variable. However, we cannot get the estimation results for the second period. The period during KTX operation period is almost similar to the second period, which is the high oil price period. Thus we estimate the whole period model with the dummy variable.

According to the estimation results, the oil price elasticities of vehicles and vehicle-kilometers are −0.5183 and −0.5607, which are very close to −0.5261 and −0.5901 in <Table 3> and <Table 5>. Thus, inclusion of an alternative transportation does not affect the oil price elasticities. Our analysis is valid regardless of the inclusion of substitute transportation.

We also consider the tolls of the Korea Expressway Corporation as an explanatory variable in our model. We report the ADL model estimation result using the number of vehicles as a dependent variable. In this setup we define the tolls as toll revenues/number of vehicles in every month and get the real values of the tolls using CPI index. However, this kind of toll variables are closely related with the dependent variable because the denominator in toll variables is the dependent variable itself. Therefore, we have to use instrumental variable estimation methods to evade endogeneity problem. The instrumental variable for the toll variable is the toll variable in the previous term. That is, the instrumental variables for $TOLL_t$ and $TOLL_{t-1}$ are $TOLL_{t-1}$ and $TOLL_{t-2}$.

According to the estimation results, the oil price elasticities of vehicles in the total time span is -0.5960 and those of low and high oil price period are -1.4868 and -0.0853 respectively. The oil price elasticity of low oil price period is greater than that of high price oil period. Therefore, inclusion of toll variables do not affect the oil price elasticities. Our analysis is valid regardless of the inclusion of toll variable.

APPENDIX Table 1 _ Estimation results for ADL model (KTX dummy included)

variables	number of vehicles		number of vehicle-kilometers	
	coefficient estimate	standard error	coefficient estimate	standard error
$LNVKTEX1SA_{t-1}$	0.6721***	0.1229	−	−
$LNVKTEX1SA_{t-1}$	−	−	0.2625	0.1995
$LNRPOR_t$	−0.0721	0.0568	−0.1813*	0.1050
$LNRPOR_{t-1}$	−0.0978	0.0696	−0.2322*	0.1386
$LNRGDP_t$	0.2364**	0.1034	0.3382*	0.2004
$LNRGDP_{t-1}$	−0.1896	0.1378	0.1312	0.3351
$LNEXLN_t$	0.5008***	0.1156	0.8441***	0.1827
$LNEXLN_{t-1}$	−0.2101	0.1838	0.0177	0.3187
$DUMMY_t$	0.0046	0.0068	0.0391*	0.0217
trend	0.0009	0.0007	0.0001	0.0014
constant	4.2087**	1.9339	6.7230	4.4772
Number of Observations	107		107	
R^2	0.9874		0.9543	
long-run elasticities	−0.5183		−0.5607	
F-statistic	65.0950***		14.2631***	

Notes: 1) The standard errors are Newey-West robust standard errors.
2) ***, **, * indicate significance at 1%, 5%, 10% levels.
3) F-statistic is the statistic to test joint significance of $LNNVEX1SA_{t-1}$, $LNRPOR_t$, and $LNRPOR_{t-1}$ or $LNVKTEX1SA_{t-1}$, $LNRPOR_t$, and $LNRPOR_{t-1}$.

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APPENDIX Table 2 _ Estimation results for ADL model (TOLL included)

Variables	Total Time Span	The first Period (Low Oil Price Period)	The Second Period (High Oil Price Period)
$LNNVEX1SA_{t-1}$	0.7001*** (0.1195)	0.7672*** (0.2456)	−0.3557 (0.6084)
$LNRPOR_t$	−0.0606 (0.0692)	0.1914 (0.3837)	0.1352 (0.2938)
$LNRPOR_{t-1}$	−0.1182 (0.0775)	−0.5375 (0.6426)	−0.2508** (0.1026)
$LNRGDP_t$	0.2942** (0.1194)	−0.4281 (0.8461)	0.1863 (0.3922)
$LNRGDP_{t-1}$	−0.1629 (0.1628)	−0.0630 (0.6839)	−0.0448 (0.3840)
$LNEXLN_t$	0.4401*** (0.1034)	0.4882** (0.2192)	0.0374 (0.5196)
$LNEXLN_{t-1}$	−0.2040 (0.1727)	−0.2306 (0.3084)	−0.1925 (0.3281)
$TOLL_t$	-0.1274 (0.5370)	−2.0534 (2.7220)	0.9070 (1.8222)
$TOLL_{t-1}$	−0.1049 (0.3666)	1.3740 (2.1125)	−0.1870 (0.3033)
trend	0.0002 (0.0008)	0.0009 (0.0033)	0.0070 (0.0070)
constant	5.1000*** (1.8313)	15.2140 (9.6861)	19.0452*** (4.2189)
Number of Observations	106	52	54
R^2	0.9872	0.9145	0.8566
long-run elasticities	−0.5960	−1.4868	−0.0853
F-statistic	49.2238***	3.3519**	4.1578**

Notes: 1) The numbers in parentheses are Newey-West robust standard errors.
2) ***, **, * indicate significance at 1%, 5%, 10% levels.
3) F-statistic is the statistic to test joint significance of $LNNVEX1SA_{t-1}$, $LNRPOR_t$, and $LNRPOR_{t-1}$. The numbers in the parentheses of F-statistic are p-values.

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Abstract

Asymmetric Effects of Oil Prices on Highway Travel Demand in Korea

Keywords: Oil Prices, Highway Travel Demand, Asymmetric Effects

We investigate the effects of oil price changes on highway travel demand using Korean monthly data and time series analysis. In detail, we examine if oil price elasticities for the highway travel demand when oil prices are high are less than those when they are low. In order to find this asymmetry, we use the monthly numbers of vehicles and vehicle - kilometers in the first type car from January 2000 to December 2008 provided by the Korea Expressway Corporation. We use monthly oil prices as a key explanatory variable and also control other explanatory variables such as real gross domestic product, length of highways adjusted by lane, and so on. We run unit root test for non - stationarity and cointegration test among them for long - run relationship. We estimate them using autoregressive distributed lag model and error correction model. Based upon the analysis, we can say that there are asymmetric effects of oil price changes when oil prices are low or high. The agents to use private cars in the highway when oil prices are low from January 2000 to June 2004 responded more sensitively than when oil prices are high from July 2004 to December 2008.

유류가격 변동에 의한 국내 고속도로 통행수요의 비대칭적 효과 분석

주제어: 유류가격, 고속도로 통행수요, 비대칭적 효과

본 논문에서는 유류가격 변화에 대한 우리나라 고속도로 통행량 변화를 월별 시계열 자료를 이용하여 분석하였다. 유류가격 변화에 대한 고속도로 통행량 변화의 비대칭성(asymmetry)을 가정하면 유류가격이 높을 때의 유류가격에 대한 고속도로 통행량 변화의 탄력성이 유류가격이 낮을 때에 비해 작을 것이다. 이를 분석하기 위하여 한국도로공사에서 제공한 2000년 1월부터 2008년 12월까지 1종의 월별 고속도로 통행대수 및 통행 대－km자료를 종속변수로 이용하였으며 월별 유류가격 변수를 주요 설명변수로 이용하였다. 또한 실질 국내총생산 및 차로감안 고속도로 연장변수도 다른 설명변수로 고려하였다. 이들 시계열변수에 대한 단위근 검정 및 공적분 검정을 수행하여 개별 시계열변수의 불안정성과 장기균형관계도 검정하였다. 본 논문에서는 자기회귀시차모형(autoregressive distributed lag model)과 오차수정모형(error correction model)을 이용하여 유류가격과 고속도로 통행수요와의 관계를 분석하였다. 분석 결과에 의하면 유류가격이 낮은 2000년 1월부터 2004년 6월까지의 유가변화에 대한 고속도로 통행량 탄력성이 유류가격이 높은 2004년 7월부터 2008년 12월까지의 고속도로 통행량 탄력성보다 크게 나타났다.

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