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Long- and short-run asymmetric responses of motor-vehicle travel to fuel price variations: New evidence from a nonlinear ARDL approach

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ABSTRACT

Understanding the responsiveness of travel demand to fuel price changes has an important policy implication on fuel taxation. In this paper, we employ an asymmetric nonlinear ARDL approach to investigate the short- and long-run impacts of fuel price increases and decreases and fuel price volatility on motor-vehicle travel in Korea. Using monthly data from January 2000 to December 2013, the results show that travel responds differently depending on the direction of fuel price changes. In examining the sensitivities of travel demand, the traffic volume is significantly responsive to fuel price changes when prices fall, while it is insensitive to fuel price changes when prices rise in the long-run. The fuel price volatility has a negative long-run impact on travel demand, indicating that a rise in fuel price uncertainty can induce drivers to reduce transport fuel consumption and motor-vehicle travel. The GDP and the road length are also found to be vital factors determining travel demand. In comparing the magnitude of the short- and long-run effects of fuel price changes, the short-run elasticities tend to be smaller than the long-run elasticities in absolute value.

1. Introduction

Over the last several decades, a large number of studies have examined travel demand elasticities with respect to price and income (e.g., Goodwin, 1992; Graham and Glaister, 2002; Goodwin et al., 2004; Bekken and Fearnley, 2005; Lee and Burris, 2005; Kuper and van Soest, 2006; Hughes et al., 2008; Santos, 2013; Lin and Prince, 2013). For example, Lee and Burris (2005) summarized the short- and long-run generalized-price elasticities of travel demand on a selected highway section. The results showed that the possible price elasticities of demand range from −0.22 to −3.7 in the short-run, and from −0.57 to −5.1 in the long-run. Graham and Glaister (2002) assessed the extent to which income and price affect automobile fuel demand and found that the short-run price elasticity (−0.3) is relatively lower than the long-run price elasticity (between −0.8 and −0.6). In their study, both the short- and long-run impacts of gasoline prices on fuel consumption are found to be greater than those on traffic levels. Goodwin et al. (2004) reviewed the literature of the elasticities of road traffic and fuel consumption with respect to price and income. Their comprehensive survey showed that the income elasticities are greater than the price elasticities and the long-run elasticities are greater than the short-run elasticities in most cases. Bekken and Fearnley (2005) also examined the price elasticities of travel demand in public transportation; the estimated short-run (long-run) elasticities of demand with price are between −0.61 and −0.44 (−0.98 and −0.76).

More recently, an asymmetric effect of fuel price changes has been raised as an important research issue in the empirical literature of transportation (Hanly et al., 2002; Bachmeier and Griffin, 2003; Fosten, 2012; Sentenac-Chemin, 2012; Kwon and Lee, 2014; Gillingham et al., 2015). For example, Bachmeier and Griffin (2003) applied an error correction model to estimate the asymmetric price responsiveness of gasoline demand and found no evidence of asymmetry with respect to wholesale gasoline prices. Sentenac-Chemin (2012) analyzed asymmetric demand effects of increases and decreases in gasoline prices in two countries. The results showed that consumers are more responsive to price increases than price decreases in the United States, while there is no evidence of asymmetric demand responses to gasoline price changes in India. Gillingham et al. (2015) examined how drivers change the amount they drive in response to gasoline price changes and the heterogeneity in this response by type and age of vehicles. Their study found that the drivers of vehicles in the lowest fuel economy bracket and the drivers of vehicles in the age bracket of 3–7 years are highly responsive to changes in gasoline prices. Kwon and Lee (2014) investigated the asymmetric adjustment of the Korean highway travel demand to changes in fuel price. Their results showed that positive and negative fuel price changes have asymmetric effects on highway traffic volume.

As fuel prices became increasingly volatile over the past

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decades, recent studies have focused on testing whether fuel price volatility has a significant influence on travel demand. For example, Kuper and van Soest (2006) showed empirical evidence that fuel price uncertainty leads to an asymmetric response of fuel demand; the results showed that a high level of price volatility renders changes in fuel use more sluggish. Lin and Prince (2013) assessed the effect of gasoline price volatility on demand for gasoline and found that consumers become less sensitive to changes in gasoline price when price volatility is medium or high. Kwon and Lee (2014) found that fuel price uncertainty weakens the adverse impact of fuel price changes on highway traffic volume when fuel prices rise, supporting that fuel price uncertainty leads an asymmetric price response of highway travel demand.

Although the relationship between fuel price and travel demand has been studied extensively, limited attention has been paid to assessing the potential asymmetric responses of motor-vehicle travel to the direction of fuel price changes. To date, only a few studies have explored the issues of asymmetric effects of fuel price fluctuations in the context of travel demand. To our knowledge, Kwon and Lee (2014) is the only study that investigated the asymmetric impacts of fuel price changes and fuel price volatility on motor-vehicle travel. To avoid a spurious result due to non-stationary time-series, Kwon and Lee (2014) relied on the first difference estimator which takes first differences of all variables. However, this method has the potential for an erroneous representation of the dynamic relationship among the variables. The valuable information contained in levels of time-series will be lost after taking first differences and therefore, it may not be suited for assessing the underlying long-run relationship among the level forms of variables (Wooldridge, 2012). Moreover, there is a lack of information on the short- and long-run effects of fuel price changes and volatility in existing literature. Since the short-run adjustment process of drivers' responses to fuel price changes and uncertainty can be different from the long-run process, both the short- and the long-run dynamics should be incorporated in a model.

To this end, this paper adopts an asymmetric nonlinear autoregressive distributed-lag (ARDL) model, with positive and negative partial sum decompositions of fuel prices. The focus of the paper is an empirical assessment of the short- and long-run relationships among motor-vehicle travel, positive and negative fuel price changes and fuel price volatility. To retain the long-run information contained in levels of variables and avoid a spurious regression at the same time, a nonlinear ARDL model, proposed by Shin et al. (2014) is employed. The nonlinear ARDL model has advantages over the conventional approach of Johansen and Juselius (1990). It can be valid irrespective of whether the underlying regressors are $I(0)$, $I(1)$, or mutually cointegrated, as opposed to the Johansen and Juselius approach assuming that all variables must be integrated at the same order. In addition, an error correction model (ECM) can be derived from ARDL through a simple linear transformation. This approach, therefore enables us to determine whether an asymmetric response of travel demand exists in the short-run, in the long-run, and both.

Motivated by Kwon and Lee (2014), this study addresses three core issues by using data from South Korea (Korea from hereon). First, we test whether road traffic volume responds differently depending on the direction of fuel price changes in Korea. If fuel price changes have asymmetric effects, what is the magnitude of the effects of price increases and decreases? Second, we address the question of whether fuel price uncertainty significantly affects travel demand. Does a high level of fuel price volatility decrease road traffic volume? Finally, we attempt to identify the key short- and long-run determinants of motor-vehicle travel demand. Is the real income a more important determinant than the fuel price for Korean drivers?

To the best of our knowledge, this study is the first that uses an asymmetric nonlinear ARDL approach for assessing the short- and long-run responses of motor-vehicle travel to positive and negative changes in fuel price and fuel price volatility. The empirical findings from this study can provide important implications regarding the government's fuel tax policy. The remainder of the paper is organized as follows. Section 2 outlines a nonlinear ARDL procedure to test the hypothesis of asymmetric responses of motor-vehicle travel to fuel price changes. Section 3 is devoted to describing the data, the measure of fuel price volatility, and the empirical results with special emphasis on coefficient estimates. Section 4 provides our main conclusions and important policy implications.

2. The method

While earlier research typically assumes that positive and negative changes in fuel price have the same impact on travel demand, recent studies found evidence that these price changes can have asymmetric effects. For example, Kwon and Lee (2014) investigated the asymmetric demand response to fuel price changes and found that highway traffic volume is more sensitive to price changes when prices fall than when prices rise, yielding larger elasticity estimates under fuel price decreases. In this paper, we follow the new approach of Shin et al. (2014) to separate fuel price increases ($\ln P_t^+$) from decreases ($\ln P_t^-$) to test the hypothesis of asymmetric response to fuel price changes:

$$\ln P_t^+ = \sum_{j=1}^{t} \Delta \ln P_j^+ = \sum_{j=1}^{t} \max(\Delta \ln P_j, 0), \tag{1}$$

$$\ln P_t^- = \sum_{j=1}^{t} \Delta \ln P_j^- = \sum_{j=1}^{t} \min(\Delta \ln P_j, 0), \tag{2}$$

where Δ is the difference operator and $\ln P_t^+$ and $\ln P_t^-$ are the partial sum process of positive and negative changes in fuel price at time t, respectively.

To analyze the impacts of fuel price changes and fuel price volatility on travel demand, this paper develops three models: 1) Model I is a reduced-form equation of travel demand without considering the asymmetric response to fuel price changes and the fuel price volatility; 2) Model II incorporates the asymmetric impacts of fuel price increases and decreases; and 3) Model III includes both fuel price asymmetry and uncertainty. The three models can be represented in logarithms as follows:

$$\text{Model I:}\ \ln D_t = a_0 + a_1 \ln P_t + a_2 \ln Y_t + a_3 \ln H_t + u_t \tag{3}$$

$$\text{Model II:}\ \ln D_t = b_0 + b_1 \ln P_t^+ + b_2 \ln P_t^- + b_3 \ln Y_t + b_4 \ln H_t + v_t \tag{4}$$

$$\text{Model III:}\ \ln D_t = c_0 + c_1 \ln P_t^+ + c_2 \ln P_t^- + c_3 \ln V_t + c_4 \ln Y_t + c_5 \ln H_t + \varepsilon_t \tag{5}$$

where D_t is the measure of demand for motor-vehicle travel at time t; P_t is the price of road transport fuel; Y_t is the real gross domestic product (GDP); H_t is the total length of road; V_t is the measure of fuel price volatility; and u_t, v_t, and ε_t are the error terms. This study uses four measures of motor-vehicle travel demand: the number of vehicle trips (D_t^v), the number of passenger vehicle trips (D_t^{pv}), vehicle-kilometers (D_t^{vk}), and passenger vehicle-kilometers (D_t^{pvk}).

Regarding the signs of the coefficients, we expect that the fuel