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Ex-ante impact evaluation of Corporate Average Fuel Economy standards on energy consumption and the environment in South Korea

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ABSTRACT

To address the global concerns about climate change, South Korea adopted the Corporate Average Fuel Economy (CAFE) standards to reduce energy consumption and CO_2 emissions in the transport sector. However, the effectiveness of CAFE standards in South Korea remains controversial because no significant reductions in energy consumption and CO_2 emissions have been reported since these standards were introduced. This study aims to analyze the effectiveness of CAFE standards in South Korea, by developing a two-stage model to describe the automobile purchase and usage behavior of consumers sequentially. This study also simulates the effectiveness of CAFE standards in South Korea under short- and long-term scenarios. According to the results, when automobile manufacturers reduce the relative prices of economy and subcompact automobiles by 20% in the short-term, the total fuel consumption and CO_2 emissions will decrease by 0.381% and 0.408%, respectively, compared with the conditions in 2012. In the long-term, when manufacturers improve the fuel efficiency of diesel and gasoline automobiles by 20%, the corresponding reductions will be by approximately 2.83% for each. In addition, this study verifies that the rebound effect is a crucial aspect when evaluating energy demand management policy. Failing to consider such an effect could lead to overestimating the amount of energy conservation. Such ex-ante analysis provides significant implications for policymakers to enhance policy effectiveness in this domain.

1. Introduction

Energy consumption in the transport sector, especially oil consumption, has significantly increased over the past 50 years due to the dramatic increase in operational vehicles during this time. In 2010, the number of vehicles in operation globally passed 1 billion units, a 714% increase from 1960 (Ward's Communications, 2013). Moreover, in the OECD countries, the number of passengers and goods travelling or transported via road transport has increased by 35% and 70%, respectively,

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since 1990 (OECD/ITF, 2012). Accordingly, the world's total final energy consumption in the transport sector has increased by 132% over the past 40 years.[1] Further, in 2012, 93% of the world's energy consumption in the transport sector was reliant on oil-based products (IEA, 2014a). This increase in oil consumption in the transport sector has led to serious environmental concerns such as air pollution and climate change.[2] According to the IEA (2014b), CO_2 emissions in the transport sector accounted for 22.6% of the total emissions in 2012, with that from road transport constituting 16.9%.

In South Korea,[3] the number of registered vehicles was 19 million units in 2012 (a 456% increase from 1990), and the number of vehicles per 1000 people reached 372, exceeding the world average of 148 (Ward's Communications, 2013). In the transport sector, the final energy consumption in 2012 was 37 Mtoe (a 162% increase from 1990). The CO_2 emissions in the sector also increased at an average annual growth rate of 4.68% during this period, accounting for 14% (85.6 $MtCO_2$) of the total CO_2 emissions in 2012 (Greenhouse Gas Inventory and Research Center of Korea, 2014). Moreover, the fact that 94.2% of the CO_2 emissions in the transport sector were emitted by road transport increases the severity of the rising number of vehicles on the environment in South Korea.

As energy consumption and CO_2 emissions in the transport sector grow rapidly, many countries have sought to control its effect on the environment against the backdrop of global concerns about air pollution and climate change. Table 1 describes various environmental policies in the transport sector.

Fuel economy regulations are one of the most common types of environmental policies in the transport sector. The Corporate Average Fuel Economy (CAFE) standards have been implemented in major OECD countries, such as the United States (U.S.) and Japan as well as across the European Union (EU). Similarly, the Korean government has also recently adopted the CAFE standards. These standards restrict the annual average fuel efficiency of automobiles by imposing a penalty on automobile manufacturers that fail to meet these standards, thereby aiming to reduce energy consumption and CO_2 emissions in the transport sector. However, some researchers have questioned the effectiveness of CAFE standards owing to the negative effects of such a fuel efficiency regulation (Bernstein, 2003; Crandall and Graham, 1989; Passell, 1995). Specifically, consumers who decide to purchase a full-size automobile might not prefer a fuel-efficient economy or subcompact automobile even when relative prices fall, but would rather have an incentive to drive more often as their fuel efficiency improves (i.e., the rebound effect[4]). Nevertheless, to our best knowledge, no studies have thus far evaluated the effectiveness of CAFE standards considering the realistic automobile purchase behavior of such consumers and the rebound effect.

In this context, there is a controversy regarding the effectiveness of CAFE standards in South Korea[5] because CO_2 emissions have never decreased, with the country's increasing trend only slowing since the CAFE standards came into effect in 2006 (Greenhouse Gas Inventory and Research Center of Korea, 2014; Ministry of Land, Infrastructure and Transport, 2014). Based on the foregoing, this study evaluates the impact of CAFE standards on energy consumption and CO_2 emissions in South Korea by considering consumers' automobile purchase behavior and the rebound effect simultaneously. We develop a two-stage model to analyze consumers' automobile purchases and sequential automobile usage, and examine the environmental effects of implementation of CAFE standards under short- and long-term scenarios.

The remainder of this paper is organized as follows. Section 2 reviews the CAFE standards-related previous literature. Section 3 outlines the structure of the two-stage model and the survey data used in this study. Section 4 presents the results of the estimations and simulations. Finally, Section 5 provides conclusions and the implications of this study.

2. Literature review

Previous studies on the effectiveness of CAFE standards can be broadly categorized into two groups according to their point of analysis. First, "ex-post evaluation" studies (e.g., Crandall and Graham, 1989; Goldberg, 1998; Greene, 1990; Jun et al., 2016) analyze how the implementation of CAFE standards has influenced automobile sales, energy consumption, and CO_2 emissions by using simple econometric models and historical data. Second, "ex-ante evaluation" studies (e.g., Jacobsen, 2013; Kleit, 1990, 2004) forecast the effects of CAFE standards by using supply and demand models for the automobile industry with hypothetical regulation scenarios.

Ex-ante evaluation studies can be classified according to their method of treating automobiles (Shiau et al., 2009). The first group of studies (e.g., Ferrara, 2007; Greene, 1991; Kleit, 1990; Thorpe, 1997) assumes that all automobiles are identical regardless of manufacturer, while the second group (e.g., Jacobsen, 2013; Kleit, 2004) treats automobiles

[1] The world's total energy consumption was 1081 Mtoe in 1973 and reached 2507 Mtoe in 2012.

[2] Air pollutants such as hydrocarbons (HC), nitrogen oxides (NOx), carbon monoxide (CO), and carbon dioxide (CO_2) are emitted when oil products are burned, and these could negatively affect climate change and air pollution (Harrington and McConnell, 2003).

[3] South Korea became the world's ninth-largest energy consumer in 2012, using 208 Mtoe (BP, 2013), and the world's seventh-largest CO_2-emitting country in 2013, releasing 584 $MtCO_2$. As 96% of the total energy in the country is imported, the government has strived to reduce energy consumption and CO_2 emissions (Enerdata, 2015).

[4] The rebound effect means when the expected reduction in energy consumption is not achieved because a drop in relative prices caused by the improvement of energy efficiency leads to an increase in energy consumption. This effect can also be observed when the fuel economy of automobiles improves (Greene, 1992; Greene et al., 1999; Jones, 1993).

[5] At present, only small automobiles and vans with a carrying capacity of less than 10 passengers must adhere to CAFE standards. However, the Korean government plans to tighten the regulation in 2016 by extending this regulation to automobiles and vans with a carrying capacity of less than 15 passengers.