Energy Policy 80 (2015) 54–64

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Gasoline taxes or efficiency standards? A heterogeneous household demand analysis

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HIGHLIGHTS

- Model household gasoline demand using a semiparametric approach.
- Estimate heterogeneous price elasticity and fuel efficiency elasticity.
- Assess the effectiveness of gasoline taxes and efficiency standards.
- Efficiency standards offset the impact of gasoline taxes on fuel consumption.
- The offsetting effect differs by household demographics.

ARTICLE INFO

Article history:
Received 10 October 2014
Received in revised form
17 December 2014
Accepted 22 January 2015

Keywords:
Semiparametric Estimation
Efficiency Standards
Gasoline Tax
Elasticity

ABSTRACT

Using detailed consumer expenditure survey data and a flexible semiparametric dynamic demand model, this paper estimates the price elasticity and fuel efficiency elasticity of gasoline demand at the household level. The goal is to assess the effectiveness of gasoline taxes and vehicle fuel efficiency standards on fuel consumption. The results reveal substantial interaction between vehicle fuel efficiency and the price elasticity of gasoline demand: the improvement of vehicle fuel efficiency leads to lower price elasticity and weakens consumers' sensitivity to gasoline price changes. The offsetting effect also differs across households due to demographic heterogeneity. These findings imply that when gasoline taxes are in place, tightening efficiency standards will partially offset the strength of taxes on reducing fuel consumption.

1. Introduction

Carbon emissions from the transportation sector have been a significant source of greenhouse gas emissions. According to the 2012 EPA Greenhouse Gas Inventory Report, about 82% of greenhouse gases in the United States are carbon dioxide, and automobile transport accounts for approximately 28% of the total carbon emissions. Various policy instruments have been pursued to control emissions from motor vehicles, among which gasoline taxation and regulations on vehicle efficiency are the dominant ones.

As of April 2014, the average fuel tax in the U.S. including federal and state taxes is 49.9 cents per gallon. The representative regulatory policy in the U.S. is the Corporate Average Fuel Economy (CAFE) Program that requires the sales-weighted average efficiency of new vehicles from a manufacturer to meet certain standards.[1] The growing concerns of greenhouse gas emissions and climate change have been driving CAFE standards to increase rapidly. As a result, the average fuel efficiency of all vehicles has shown a modest increase, rising 8.4% in the last 15 years.[2]

Gasoline taxation internalizes the external costs of driving and fuel consumption through market incentives, but by how much it reduces fuel consumption and carbon emissions crucially depends on consumers' response to the increased gasoline price, namely the price elasticity of gasoline demand. The estimate of the price elasticity in the literature varies depending on the data and the method used. Dahl and Sterner (1991) suggest a range from −0.5 to −1.1. Hausman and Newey (1995) find an estimate of −0.81

[1] All manufactures that sell more than 10,000 passenger vehicles per year in the U.S. must comply with the standards.

[2] National Transportation Statistics 2013, Bureau of Transportation Statistics, RITA.

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http://dx.doi.org/10.1016/j.enpol.2015.01.029

based on U.S. data collected between 1979 and 1988. Schmalensee and Stoker (1999) using household data of 1991 report price elasticities between −0.72 and −1.13. West (2004) provides a mean estimate of −0.89 using 1997 data. In contrast, studies using more recent data have reported relatively lower estimates of the price elasticity. For instance, Basso and Oum (2007) summarize a number of survey papers (e.g. Graham and Glaister, 2002, 2004; Goodwin et al., 2004) and suggest a range between −0.2 and −0.3; Kayser (2000) reports a price elasticity of −0.23; Nicol (2003) estimates a range between 0 and −0.6. The Congressional Budget Office (2003) uses −0.38 as the price elasticity to measure the effect of raising gasoline tax.[3] More recently, Small and van Dender (2007) estimate a (long run) price elasticity between −0.33 and −0.42; Manzan and Zerom (2010) report an interval from −0.2 to −0.5; Wadud et al. (2010b) provide a broad range between −0.1 and −0.9; Liu (2014) suggests that the state level price elasticity in the U.S. varies between 0 and −0.2. The general consensus of these studies is that the demand of gasoline is fairly inelastic, thus without a sufficiently high tax rate, significantly lowering fuel consumption by taxation would be difficult.

Regulations on efficiency standards reduce fuel consumption and carbon emissions through technological improvement, and an additional benefit is to lower dependence on imported oil. However, rebound effects and high social costs have drawn criticism to this type of policy. The rebound effect refers to the increased travel demand due to an improvement in vehicle fuel efficiency, assuming mobility is a conventional good. Although the estimated magnitude varies (West, 2004; Small and van Dender, 2007), the existence of the rebound effect has been widely accepted in the literature. Meanwhile, the implementation cost of efficiency regulations such as the CAFE program is much higher than taxation (Crandall, 1992; Portney et al., 2003; Kleit, 2004; Austin and Dinan, 2005; Jacobsen, 2013). In addition, improvement of vehicle efficiency encourages driving which causes external costs such as traffic congestion and accidents. Portney et al. (2003) find that the traffic congestion and accident externalities resulted from tighter efficiency standards may offset 95% of the benefits of oil dependency and reduced carbon emissions.

Regardless of their own strengths and weaknesses, both policy instruments aim at curbing greenhouse gas emissions from motor vehicles by reducing the consumption of gasoline. This raises the questions of how effective these policies are, and whether it is beneficial to parallel the two instruments. Using detailed household survey data (CEX, 1997–2002), this paper addresses these challenges by empirically assessing the fuel reduction effects of gasoline taxes and vehicle efficiency standards from the demand perspective. This study has three major contributions to the existing literature.

First, a dynamic semiparametric demand model is employed to rigorously estimate elasticities of gasoline demand at the household level. This specification allows for functional coefficients to accommodate heterogeneity of fuel demand elasticities associated with various household characteristics. The heterogeneous price elasticity can be used to evaluate the effects of gasoline policies on various consumer groups, and possibly serve as a guidance for future policy changes that aim at lowering fuel consumption and the resulted environmental damages more efficiently. Besides estimating the price elasticity and income elasticity, this paper provides an estimate of the fuel efficiency elasticity which is in the range of −0.2 to −0.6. These elasticity estimates can be the basis for assessing the relative impacts of fuel taxation and fuel efficiency standards on consumption of gasoline.

[3] The Economic Costs of Fuel Economy Standards Versus a Gasoline Tax, Congressional Budget Office, the Congress of the United States, December 2003.

In addition, this paper reveals an interaction effect between vehicle fuel efficiency and the gasoline demand price elasticity. More specifically, households with more efficient vehicles are less responsive to changes in gasoline price. Such an interaction effect implies a trade off between gasoline taxation and efficiency regulations: the strength of gasoline taxes will be partially offset by higher efficiency standards on vehicles. To further examine this offsetting effect, I conduct a scenario analysis that compares the fuel savings from three policy alternatives. Results show that raising efficiency standards and gasoline taxes together cannot produce the cumulative effects of each individual policy.

This study further explores the heterogeneity in the offsetting effect that is associated with various household demographics. For instance, the price elasticity of low income households is not very responsive to changes in vehicle fuel efficiency, and rural families with three or more vehicles have a higher interaction effect than others. These findings suggest that higher efficiency standards do not equally offset the strength of gasoline taxes among all households, and the magnitude of the tradeoff depends on household demographics.

The following section provides a detailed description of the CEX survey data, the dynamic semiparametric gasoline demand model, and the estimation strategy. Section 3 presents the empirical results as well as a discussion on demand elasticities and the interaction effect. Section 4 provides a scenario analysis that projects the outcomes of three policy alternatives. The last section summarizes and concludes.

2. Methods

2.1. Data

The data used in this paper are generated from the quarterly interview survey of the U.S. Consumer Expenditure Survey program (CEX, Bureau of Labor Statistics, 1997–2002). The CEX quarterly interview survey is designed to collect data on major expenditures of American households, as well as information on household demographics, such as family size and residential location. The survey also records information on vehicle ownership and transportation, such as the number and the type of vehicles and quarterly fuel expenses. The respondents are interviewed every 3 months for four consecutive quarters. The initial interview time can take place in any month of the year, and may not be the same for all households. As a result, each household that has completed all four surveys provides 1 year of continuous quarterly data, although the starting time varies across households. A sample of 7500 households are used for further analysis after excluding those who did not complete all four interviews or changed their vehicles during the study period. With four periods for each household, this sample yields a balanced panel with 30,000 observations.

Information on household demographics is summarized in Table 1. Almost 90% of the households in the sample are located in urban areas, the majority of households have at least two vehicles, and the mean household quarterly income is 9072.2 dollars, etc. The distribution of observations over the study period is presented in the bottom panel of Table 1. Except for year 1997 with only 9.18% of the observations, the rest are relatively evenly divided across 5 years.

In addition to variables collected in the survey, each vehicle is assigned a fuel efficiency (measured in miles per gallon) based on its model year. The fuel efficiency information on different vehicles is found in Heavenrich (2006).[4] For households with more than one vehicle, the average fuel efficiency of all owned vehicles is used.