Energy Policy 122 (2018) 528–541

Contents lists available at ScienceDirect

Energy Policy

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

Impacts of fuel economy improvements on the distribution of income in the U.S

David L. Greene[a,*], Jilleah G. Welch[b]

[a] Howard H. Baker Jr. Center for Public Policy, Department of Civil and Environmental Engineering, University of Tennessee, 1640 Cumberland Avenue, Knoxville, TN 37996, United States

[b] Howard H. Baker Jr. Center for Public Policy, University of Tennessee, 1640 Cumberland Avenue, Knoxville, TN 37996, United States

ARTICLE INFO

JEL:
Q52
H24
L51
D62
R40

Keywords:
Income effects
Fuel economy

ABSTRACT

We estimate the impacts of passenger car and light truck fuel economy improvements in the U.S. since 1975 on the real monetary incomes of U.S. households by income quintile over the period 1980–2014. We limit our analysis to the direct monetary impacts (fuel savings minus increased vehicle costs) and do not attempt a full welfare analysis. We include all vehicle purchases, new and used. Household fuel expenditures come from the U.S. Consumer Expenditures Surveys (CES). Costs of increased new passenger car and light truck fuel economy were obtained from four National Research Council (NRC) studies plus a literature review of earlier estimates. The NRC cost functions provide a unique time series of technology supply functions constructed by balanced expert panels and comprised of specific technologies proven to increase fuel economy. Effects of fuel economy improvements on used vehicle prices are based on an analysis of the CES data. Retrospective analysis indicates that all income quintiles received net savings and that the effect on the distribution of income was progressive. A prospective analysis of future fuel economy improvements produced similar results. Sensitivity analysis indicates that these findings are relatively robust.

1. Introduction

The distributional effects of energy and environmental policies have been a concern of policy analysis for decades (e.g., Baumol and Oates, 1975, ch. 13). In the past, more attention was given to energy and environmental taxes but recently studies have addressed the impacts of regulatory standards, in part because of concern about the distributional effects of policies to mitigate greenhouse gas emissions (GHG) (Fullerton and Muehlegger, 2017). Existing studies of fuel economy and GHG standards have focused on changes in vehicle prices induced by regulations rather than on technology adoption. In this paper we provide a different perspective that focuses on the role of technology in increasing vehicle fuel economy.

We estimate the impacts of passenger car and light truck fuel economy improvements in the U.S. since 1975 on the real monetary incomes of U.S. households by quintile. We estimate only the dollar value of fuel savings minus the increased vehicle costs attributable to fuel economy improvements. We do not attempt to estimate consumers' satisfaction with higher fuel economy vehicles or impacts on the industry's profits. We do not estimate the value of increases in acceleration performance that could have been achieved with smaller increases in fuel economy (e.g., Leard et al., 2017). We do not estimate the impacts of fuel economy improvements on vehicle scrappage rates (e.g., Jacobsen and Van Bentham, 2016), although the data we use to estimate vehicle costs and fuel savings does reflect actual vehicle ownership and usage rates for the period 1980–2014. We do include a rebound effect due to reduced fuel costs per mile. We do not evaluate the impacts of fuel economy or greenhouse gas standards, per se, but rather the impacts of the fuel economy improvements that occurred for any reason. We combine a retrospective analysis covering 1980–2014 based on Consumer Expenditures Survey (CES) data and National Research Council (NRC) technology cost estimates with a prospective estimation of the monetary effects of the fuel economy regulations to 2025 (EPA, 2017a) using Energy Information Administration projections (EIA, 2017).

We estimate the costs of fuel economy improvements separately for

* Corresponding author.
E-mail addresses: dgreen32@utk.edu (D.L. Greene), jgwelch@utk.edu (J.G. Welch).

https://doi.org/10.1016/j.enpol.2018.08.005
Received 19 March 2018; Received in revised form 25 July 2018; Accepted 2 August 2018

passenger cars and light trucks. In part, this is because the CES does not identify household vehicles at a consistent level of detail over time.[1] Also, our sources for the cost of fuel economy improvement provide vehicle class-specific functions in some years but only passenger car and light truck cost functions in others. Finally, the distinction between passenger cars and light trucks is consistent with the structure of fuel economy and GHG regulations in the U.S. The implications of aggregating to two vehicle types are discussed in subsequent sections of the paper.[2]

Previous analyses of the distributional impacts of fuel economy policies are reviewed in Section 2. The question of consumers' willingness to pay (WTP) for fuel economy is considered in Section 3. Section 4 presents the fuel economy cost functions and how they were used to estimate the effect of fuel economy improvements on new vehicle prices. Section 5 describes the CES data. Section 6 explains our econometric analysis of the transmission of price increases for new vehicle fuel economy to the used vehicle market. The estimation of fuel savings by income quintile using decomposition analysis is described in Section 7. Sections 8 and 9 present results of the retrospective and prospective estimation of net effects on income.

2. Studies estimating the distributional impacts of fuel economy standards

Distributional impacts of fuel economy standards between 1997 and 2001 were estimated by Jacobsen (2013), emphasizing the use of pricing to shift sales toward higher fuel economy vehicles.[3] Jacobsen added an analysis of the "possibility for endogenous technology improvements in fuel efficiency" (p. 176) using a cost function from NRC (2002). However, the NRC cost function was used in a way that contradicted its premises. In footnote 54 Jacobsen states, "These curves contain a number of negative net cost improvements (worthwhile even without a CAFE standard) that must be reconciled with the observed technology choices in the baseline data. To do this, I assume that the observed fuel economies are rational for producers in that the marginal technology cost in the baseline equals the value of fuel saved plus the shadow cost of CAFE." In other words, he moves up the technology cost curve assuming that technologies that would have paid for themselves on a financial basis alone had already been adopted. This discards low-cost technologies identified by the NRC (2002) committee, contradicting the method used to construct the cost curve and greatly increasing the marginal cost of fuel economy. The NRC committee (comprised of experts in automotive engineering, economics and market research among other professions) constructed the curve with existing technologies proven to increase fuel economy, taking into account the extent to which the technologies had been adopted in base year 1999 vehicles.

Indeed, the key technologies included in the NRC (2002) study were adopted after 1999. The engine technologies identified in NRC (2002) include multi-valve engines (e.g., 4 vs. 2 valves), variable valve timing (VVT) and VVT with lift control, gasoline direct injection (GDI), turbocharging with engine downsizing (Turbo), engine off at idle (Stop/Start) and cylinder deactivation at low engine loads. Of these, only multi-valve had attained an important market share in the U.S. in 1999 (Fig. 1) (EPA, 2017b). The remaining engine technologies in the NRC study (friction reduction and reduced parasitic loads) are difficult to attribute to an identifiable technology. The ratio of horsepower to cubic inch displacement (HP/CID) is a good indicator of overall engine efficiency (US EPA, 2017b).[4] From 1985 to 2017 the average HP/CID ratio increased 125%.

The transmission technologies considered by the NRC (2002) committee included increasing the number of gears from 4 to 5 or 6 and continuously variable transmissions (CVT). Again, only 5-speed transmissions had a non-trivial market share in 1999. The more advanced transmissions were adopted afterwards (Fig. 2).

Increasing fuel economy by using pricing to shift sales rather than adopting technology is the basis of Davis and Knittel's (2016) analysis of the short-run distributional effects of fuel economy standards. "Automakers have two margins to adjust in meeting CAFE constraints: (1) adjusting quantities and (2) buying/selling permits." (Davis and Knittel, 2016, p. 9). They use an estimate of the price of fuel economy credits from Leard and McConnell (2017)[5] as a shadow price of the fuel economy constraint. Leard and McConnell's estimates were based on two data points for the year 2013, only one of which was an actual credit trade between Tesla and Fiat-Chrysler. Three pairs of firms traded credits in 2013 but credit trading decreased to a single bilateral trade per year in 2015 and 2016. Despite the thin market, Davis and Knittel assumed that the standards were a binding constraint on all manufacturers. They calculated the tax or subsidy for vehicle j, t_j, as the product of the estimated shadow price of the emission regulation (λ) times the difference between the vehicle's rated emissions and its target emissions, times the average lifetime vehicle miles of travel (VMT) for cars or light trucks.

$$\sum_{j=1}^{n} t_j = \sum_{j=1}^{n} \lambda[(emissions_j - target_j)VMT_j] = 0 \tag{1}$$

Eq. (1) is a first order condition for a manufacturer's constrained profit maximization problem.[6] It implies that a firm's pricing will be revenue neutral; the sum of subsidies and taxes over vehicle sales will be zero. If distributions of vehicles by emissions (or fuel economy) purchased and owned by income groups are similar, the net effect on income of such pricing will be small. Available evidence, reviewed below, indicates that the average fuel economies and even the fuel economy distributions of vehicles purchased and owned by income groups are almost identical, except when fuel economy is rapidly increasing.

Levinson (2016) also treats energy efficiency standards as equivalent to a tax on inefficient vehicles in his analysis of the effects of fuel economy standards on income groups. The analysis is static and the option to use technology to increase fuel economy is not considered. Recognizing that a tax on inefficiency is also a subsidy for efficiency, Levinson concludes that the impacts on households of different incomes will depend on the efficiencies of the vehicles they buy and how many

[1] Vehicle make and model are available from 1980 to 2006 although the level of detail in models is less in years 2003–2006. From 2007–2014, only vehicle make is available and other vehicle characteristics such as number of cylinders and indicators for automatic transmission, four wheel drive, a turbo charged engine, power brakes, and power steering were not collected during these years. Section 5 provides a detailed description of the CES data used.

[2] The definition of passenger cars and light trucks we use is based on the CES' definition. This does not exactly match the definition the EPA uses for regulatory purposes, a definition modified in 2011. As long as the fuel economy values we assign to the CES passenger cars and light trucks are a reasonably accurate, our calculations for the two vehicle classes should be approximately correct.

[3] Greene (1991) estimated that use of pricing to increase fuel economy was much more costly in terms of lost consumers' surplus than adopting fuel economy technologies.

[4] The efficiency of a heat engine is measured by the ratio of work done to heat provided. At any given engine speed horsepower is proportional to work done and heat provided is proportional to displacement.

[5] The final version of the Leard and McConnell report is cited here but the values are the same as the earlier version cited by Davis and Knittel (2016). After 2013, Tesla's SEC 10-K forms do not distinguish between credit trade revenues received for California Zero Emission Vehicle credits and those received for EPA GHG emission credits.

[6] As Davis and Knittel note, this condition does not consider the effects of the efficiency tax/subsidy on vehicle sales. If the induced sales shifts are not large, the equation will be approximately correct.