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Gasoline price and new vehicle fuel efficiency: Evidence from Canada☆

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ABSTRACT

Using data on all new vehicles registered in Canada from 2000 to 2010, we estimate the elasticity of the fuel economy of the new vehicle stock with respect to gasoline price. We find that a 10% increase in gasoline price causes a 0.8% improvement in the fuel economy of new vehicles. However, we also show that consumers respond much more strongly to fuel taxes than to other components of the gasoline price. Finally, we provide evidence that consumers in dense urban areas are more responsive to changes in fuel prices than consumers living on the urban periphery.

1. Introduction

Vehicles are a major source of pollution in most countries. In Canada, for instance, light duty vehicles generated 82 million tonnes of greenhouse gases, approximately 12% of the country's total emissions (Canada, 2015). Vehicles also produce other pollutants that adversely affect human health and well-being. These including nitrogen oxides, carbon monoxide, and particulate matter among others. Pollution from cars and trucks is often viewed as the archetypal economic externality: the costs associated with emissions accrue to society but are not fully borne privately by drivers. Reducing transportation-related gasoline consumption has, unsurprisingly, become a focus of policy makers.

An expanding array of policies have targeted vehicular emissions in Canada (Antweiler and Gulati, 2013). Several provinces have offered rebates for the purchase of fuel efficient vehicles such as hybrid-electric or electric vehicles (Chandra, 2010). Ontario and the federal government used a system of taxes and rebates based on fuel economy (Rivers et al., 2017; Sallee and Slemrod, 2012). British Columbia, Alberta, Ontario, and Quebec apply a carbon price as a disincentive on the consumption of fossil fuels (Antweiler and Gulati, 2016; Rivers et al., 2015), and similar carbon prices are required across all provinces by 2018 under the *Pan-Canadian Framework on Green Growth and Climate Change*. The federal government has provided a tax credit to encourage commuting by public transport rather than private vehicle (Rivers and Plumptre, 2016; Chandler, 2014) and recently adopted new vehicle greenhouse gas intensity regulations requiring manufacturers to achieve specific targets for fleet-wide emissions per kilometre.[1] The optimal stringency of each of these programs depends, at least to some degree, on the responsiveness of the fuel economy of vehicles to the price of gasoline. Policy makers therefore require reliable estimates of key elasticities relating to the choice of and use of the vehicle stock in response to gasoline prices and other policies. Yet, despite the breadth of attempts to address externalities from automobile

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[1] See http://www.gazette.gc.ca/rp-pr/p2/2014/2014-10-08/html/sor-dors207-eng.php.

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usage, little is known about how gasoline prices actually influence consumer decision-making with respect to new vehicle fuel economy.

We estimate the elasticity of new vehicle fuel efficiency with respect to gasoline price by exploiting a rich dataset covering gasoline prices, vehicle registrations, vehicle fuel economy, and demographic variables at the neighborhood level in 42 Canadian cities from 2000 to 2010. Our data and econometric models enable us to credibly control for unobserved time-varying and cross-sectional variables that may otherwise bias estimates of the elasticity. Our main finding is that a 1% increase in gasoline prices leads to a 0.08% improvement in the fuel economy of new vehicles. This elasticity is slightly smaller (in absolute value) than previous estimates, suggesting that consumers may be less responsive to gasoline prices than previously thought.

Having established this main result, we proceed to show that the responsiveness to gasoline prices is greater in more urbanized regions compared to less urban regions. In particular, we use four proxies for the level of urbanization in each of the neighborhoods in our data set: (1) the distance to the urban core (more "urban" neighborhoods are closer to the urban core); (2) the population density (more "urban" neighborhoods have higher population densities); (3) the mode share of public transit (more "urban" neighborhoods have a higher mode share of commuting by public transit); and (4) city population (more "urban" cities are larger). We interact each of these proxies with the gasoline price variable in our main regression and find stronger responses to increased gasoline prices in more "urban" areas, which are robust to our classification of "urbanization". While we lack the data to explore the mechanisms behind this differential response, the finding that vehicle choice in more urban areas is more sensitive to gasoline prices than in peri-urban areas is novel and interesting on its own.

Finally, we demonstrate another important result, similar to one that has been found in a range of recent work: consumers are more responsive to changes in excise taxes than to equivalent changes in gasoline prices due to other factors. This larger responsiveness to changes in taxes has been noted in several papers focused on gasoline demand (Rivers et al., 2015; Li et al., 2014; Scott, 2015; Lawley and Thivierge, 2018) and, more recently, in another Canadian study by Antweiler and Gulati (2016) on vehicle choices. Our results suggest that consumers respond to a change in excise taxes by improving fuel efficiency four to ten times as much as to an equivalent change in tax-exclusive prices. This has important implications for policy makers considering using excise taxes as a way to encourage more fuel efficient vehicle choices.

The remainder of the paper is organized as follows. Section 2 presents our conceptual framework and offers a review of similar studies. Section 3 explains the data and empirical strategy. The main results are presented in Section 4, while the heterogeneity of these estimates is investigated in Section 5. Section 6 concludes.

2. Conceptual framework

Vehicle gasoline consumption can be decomposed as the product of three factors.[2] Denote the fuel efficiency of the on-road vehicle stock—i.e., the number of litres required to travel a kilometre—with F. Consumers consider the price of gasoline when selecting the fuel efficiency of vehicles, so F is a function of the price of gasoline, p. The second factor is vehicle utilization, D—i.e., the number of kilometres travelled per vehicle. Conditional on the fuel consumption rating of the vehicle as well as the price for gasoline consumers choose the distance to drive. Thus, this second factor, D, the intensity of vehicle use, is a function of both the price of gasoline, p, as well as fuel efficiency, F. Finally, $V(p)$ is the total number of vehicles in the fleet, also a function of the price of gasoline. Combining these three factors allows us to write a reduced-form expression for total gasoline consumption[3]

$$G = F(p)\cdot D(F(p), p)\cdot V(p)$$

Taking the total derivative of this expression yields a decomposition for the short-run elasticity of gasoline demand with respect to price that is comprised of distinct moving parts: the change in fleet fuel economy with respect to gasoline price, the change in distance travelled with respect to gasoline price, the change in fleet size with respect to gasoline price and the change in distance travelled with respect to fleet fuel economy. Referring to this elasticity as ϵ, we write

$$\epsilon \equiv \frac{dG}{dp}\frac{p}{G} = \eta(1+\theta) + \mu + \xi, \quad (1)$$

There are four parameters in this expression. First, $\eta \equiv \frac{\partial F}{\partial p}\frac{p}{F}$ is the elasticity of vehicle fuel efficiency with respect to gasoline price, and $\xi \equiv \frac{\partial V}{\partial p}\frac{p}{V}$ is the elasticity of aggregate vehicle stock with respect to gasoline prices. These elasticities, respectively, show the percent change in the per vehicle gasoline demand and the percent change in the number of vehicles in the fleet that result from a 1% increase in gasoline prices. The next two components are $\theta \equiv \frac{\partial D}{\partial F}\frac{F}{D}$ and $\mu \equiv \frac{\partial D}{\partial p}\frac{p}{D}$, the elasticities of distance driven with respect to fuel economy and gasoline price.[4] The product $\eta(1+\theta)$ describes the interaction between changes in fleet fuel economy and distance travelled, with the term in brackets often referred to as the "rebound effect". Rebound effects arise from the feedback between vehicles' fuel efficiency and the cost of driving – namely, increases in fleet fuel economy may result in additional driving demand by reducing the private cost of driving (Borenstein, 2013; Sorrell and Dimitropoulos, 2008; Chan and Gillingham, 2015).

Each of these key elasticities helps to determine the overall change in gasoline consumption in response to a change in gasoline price or other similar policy. Several studies exist that estimate μ. For example, Gillingham (2014), Gillingham et al. (2015) and Greene et al. (1999) estimate the elasticity of vehicle miles travelled with respect to gasoline price in the US, μ. The consensus value is approximately −0.2. Using aggregate data, Barla et al. (2009) find virtually identical estimates for Canada, while Moshiri and Kamil (2017) find a value of −0.12, or roughly half, using Canadian micro data.

This paper's focuses is on estimating η, the elasticity of fleet fuel economy with respect to gasoline price (since we do not observe actual driving behavior in the data for this paper, we have no way of estimating θ or μ). There are a handful of estimates for η, although few in Canada. Li et al. (2009) use detailed US vehicle registration data from 1997 to 2005 to determine how changes in gasoline prices

[2] Other factors such as average speed of driving and vehicle maintenance matter as well. Our decomposition assumes that these remain constant as gasoline prices change.

[3] Our analysis rules out income effects, so only requires total differentiation. However, Chan and Gillingham (2015) demonstrate that this reduced-form expression can be derived from a simple model of a utility-maximizing consumer behavior. Assuming utility is obtained from consuming transport services (D) and other goods (X, the numeraire good), such that $U = U(D, X)$, the consumer maximizes utility subject to a budget constraint: $p_D D + X = M$, where the price of driving is given by $p_D = pF$. This yields $F^* = F(p) = -\frac{1}{\lambda}\frac{U_D}{p}$ and $D^* = D(F(p), p) = \frac{M-X}{pF^*}$, where λ is the marginal utility of consumption. Gasoline consumption in vehicles is proportional to greenhouse gas emissions, so this expression can serve to evaluate changes in greenhouse gas emissions as well as gasoline consumption.

[4] Much of the literature assumes that $\theta = \mu$, such that consumer response to a change in fuel economy is the same as to an equivalent change in gasoline price. Chan and Gillingham (2015) caution that this assumption may not always be appropriate.