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Rebound effect of efficiency improvement in passenger cars on gasoline consumption in Canada

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ABSTRACT

The fossil fuel-driven transport sector has been one of the major contributors to CO_2 emission across the world keeping it on the energy policy agenda for the past three decades. Canada ranks second in gasoline consumption among OECD countries and Canadian gasoline expenditure share has been increasing since the 1990s. Fuel efficiency policies aim to decrease gasoline consumption; however, the effect can be mitigated by changes in consumer behavior such as traveling more distances — a rebound effect. Thus, the effectiveness of fuel efficiency policy is dependent on the magnitude of the rebound effect. In this paper, we estimate the rebound effect for personal transportation in Canada using data from the household spending survey for the period 1997–2009. The model includes a system of expenditure share equations for gasoline, other energy goods, and non-energy goods specified by AIDS and QUAIDS models and estimated by the nonlinear SUR method. Our estimation results show a rather high average rebound effect of 82–88% but with significant heterogeneity across income groups, provinces, and gasoline prices. Specifically, the rebound effect ranges from 63 to 96% across income groups and provinces and increases with gasoline prices.

1. Introduction

The rise in oil prices in the 2000s, along with increasing concerns about greenhouse gas (GHG) emissions, spurred policy makers and the auto-manufacturing sector to adopt more stringent fuel efficiency standards. Fuel efficient cars use less gasoline per kilometer resulting in saving on fuel cost and reductions in GHG emissions. However, the new fuel efficiency standards may also trigger a rebound effect: a tendency for drivers to increase distance traveled or to switch to larger vehicles thus offsetting some of the initial gains on fuel efficiency. A high rebound effect implies that an increase in efficiency itself cannot achieve the desired targets for emission reduction and should, therefore, be coupled with other policies to dis-incentivize gasoline consumption. The magnitude of the rebound effect is thus critical for the proper design of policies to reduce gasoline consumption and GHG emissions.

Fuel efficiency can create multiple feedback effects on gasoline consumption.[1] The direct effect arises from increased energy use induced by the reduction of fuel cost due to the higher efficiency. A secondary complementary effect is associated with an increase in consumption of all other goods and services whose production and use require energy. There is also an economy-wide and international effect which arises from changes in labour markets and international trade affecting the aggregate output and energy consumption. Finally, fuel efficiency may bring about changes in consumer tastes which may have an impact on energy consumption.[2] In this study, we not only focus on the direct rebound effect, but also offer some insights on the interactions between gasoline and other energy and non-energy goods, as well as on the changes in consumer tastes over time.

Canada produces about 2% of global greenhouse gas emission while having only 0.5% of the world's population. Based on OECD rankings for high-income countries, Canada is second highest in terms of gasoline consumption per capita, and its CO_2 emissions from fuel combustion have increased by about 24% between 1990 and 2010. Emissions from transportation are the largest contributor to Canada's GHG emission

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[1] See Turner (2013) for a critical view on different classifications of rebound effect.

[2] Consumer preferences with regard to product attributes may change as energy use become more efficient. For instance, fuel efficiency may lead individuals to spend more time driving, get involved in more vehicle based recreational activities, or switch to larger and heavier cars which offer more comfort options. Fuel efficiency may also affect the choice on where to live and work.

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with about 75% of oil-related GHG emission coming from fuel used by vehicles (Environment Canada, 2013). To curb GHG emissions, Canada has adopted fuel efficiency standards such as the 2010 Passenger Automobile and Light Truck Greenhouse Gas Emission Regulation (LDV1). The fuel efficiency of new passenger light trucks is expected to increase by 37%, decreasing gasoline consumption of new cars from 8.6 L/100 km to 6.4 L/100 km in 2020.

There are many studies on the rebound effect in OECD countries but the number of studies in Canada, particularly at the micro level, is limited. Canada is a geographically large country with a low density population and heterogeneous provinces in terms of economic activities, energy consumption, and emission levels. Since natural resources and energy management, as well as environmental policies, are primarily under provincial jurisdiction, studies at the provincial level will shed more light on the dynamics of energy demand and rebound effects in Canada.

Energy demand is also heterogeneous across income groups leading to different rebound effects across income groups. Low income households spend more on energy relative to their income than high income households so higher income households can better afford to switch to larger cars when gasoline prices fall. Rebound effects are also expected to increase with energy prices, as fuel efficiency will generate more savings when prices are higher.

In this paper, we estimate demand for gasoline to identify the direct rebound effect for three income groups and nine provinces using the Canadian Survey of Household Spending data for the period 1997–2009. Unlike many other studies in the rebound effect literature, this study uses a demand system which allows for interactions among gasoline, other energy goods (natural gas, electricity, and others), and non-energy goods. We also estimate the rebound effect for the pre- and post-2000 periods to evaluate how the effects have changed under different gasoline price levels.

The household spending data overcomes the shortcomings associated with the small sample size in aggregate level studies. It also allows us to examine the heterogeneity in income effects while controlling for the impact of demographical changes. Using the household spending data, we can also incorporate the interaction between various energy sources and non-energy goods in the consumption basket, an option which is not available in the partial demand models using transportation survey data.

Our estimation results show that demand for gasoline in Canada is inelastic with a significant rebound affect higher than the average effect in other OECD countries. The results also indicate heterogeneity in demand elasticities and rebound effects across Canadian provinces and income groups and at different gasoline price levels. Specifically, the rebound effect rises with income (both across families and across provinces) and increases with gasoline prices.

The rest of the paper is organized as follows: Section 2 reviews the literature while Section 3 discusses the theoretical background. Sections 4–6 present and discuss the data and the results. Section 7 draws conclusion.

2. Review of Previous Studies

Studies on the rebound effect started in the early 1980s but only recently has the topic received growing interest in academic and policy circles. Empirical, as well as some theoretical, papers on the rebound effects are now numerous with a wide range of reported results for different countries.[3] Researchers have used a variety of models, econometric techniques, data types, and time periods to estimate the rebound effect in different sectors of the economy, but the use of two different data types, transportation surveys versus household budget surveys, may primarily explain the differences in results. Table 1 presents a summary of the selected studies on fuel efficiency rebound effect for OECD countries.

There have been also some reviews of the literature summarizing the hugely varying estimates in the rebound effect across countries. The earlier studies focus mainly on the price elasticity of gasoline demand, which can be used to derive the rebound effect. For instance, Dahl and Sterner (1991), one of the earlier surveys on the gasoline demand estimation, cover >250 estimations by various methods and data types with reported price elasticities between −0.08 and −0.41 in the short run and −0.21 and −1.05 in the long run. These imply the rebound effects in the range of 8 to 105%. They also report income elasticity in the range of 0.14 to 0.45 and 0.64 to 1.31 in the short run and long run, respectively. Goodwin (1992) also reviews >50 studies and reports the price elasticity of fuel consumption in road traffic within a range of −0.27 to −0.73 in the short-run and long-run, respectively. Graham and Glaister (2002), however, report a higher value (−0.8) for long-run price elasticity. In more recent studies, Goodwin et al. (2004) and Graham and Glaister (2004) carry out two parallel blind reviews of 69 studies on road traffic and fuel consumption in OECD countries covering periods from 1929 to 1998. Goodwin et al. report price elasticities of fuel consumption within a range of −0.25 to −0.60 and income elasticity within a range of 0.39 and 1.08 in the short-run and long-run, respectively. Graham and Glaister report similar results. The implied rebound effects in the reviews above range from 25 to 80%.

More recent studies also report different results on the price elasticity of gasoline and rebound effects depending on type of the data used. Overall, studies that use aggregate data tend to report a lower price elasticity and implied rebound effect than those that use household budget survey data. For instance, the rebound effects obtained from national or state/provincial level data by Matos and Silva (2011) for Portugal (1987–2006), Brännlund et al. (2007) for Sweden (1980–1997), Small and Van Dender (2007) for the US (1966–2001), and Barla et al. (2009) for Canada (1990–2004) are in the range of 5 to 50%. However, household level studies by West (2004) for the US (1997), Frondel et al. (2008) for Germany (1997–2009), Weber and Farsi (2014) for Switzerland, and Chitnis et al. (2014) for the UK report rebound effects in the range of 25 to 87%.[4] Nicol (2003) also estimates a system of expenditure share equations for the US and Canada for the period 1969–1992 and reports a range of price elasticities for gasoline demand in Canada between −0.13 and −0.89 and income elasticities between 0.32 and 1.30.

A few studies have also attempted to estimate the rebound effects across income groups and price levels. For instance, Small and Dender (2007) estimate rebound effects using travel data in US states for the period 1966–2001 and find that the rebound effects decline with income, but increase with the gasoline price. However, the income effects on which these results are obtained are based on the rebound effect estimations in different time periods with aggregate income variations. Those findings cannot be considered as the direct estimations for different income groups because, as the authors note, the rebound effects estimated for different time periods are not necessarily related to income changes. Santos and Catchesdies (2005) estimate the price elasticity of millage using aggregate data on vehicle use in the UK in 1999–2000 to examine the effects of tax reform on the households' cost of living across income groups and regions. They review opposing findings in the UK studies, and show that the price elasticities decline slightly with income and increase with population density across rural and urban areas. Gillingham (2011) also uses vehicle surveys in California in 2001–2008 to estimate the price elasticity of mileage across income, region, and vehicle types. He finds that medium income households with SUVs and pickups are most sensitive to price changes and that the elasticities for households living in suburbs are greater than for those

[3] Most of the rebound effect studies have focused on the US and some European countries. The number of studies for Canada is very limited (see Table 1).

[4] de Borger al. (2015) is a micro-level study that reports a rather low rebound effect in Denmark. They use a panel of the car registry data for a single car household and estimate demand for kilometers driven in a first-difference form.