Income and Fuel Price Elasticities of Car Use

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Abstract

Understanding how car travel and ownership respond to income and fuel prices, and how that response varies between households is crucial for car use policies and forecasts. This thesis, consisting of two papers, aims to investigate this by estimating the intemporal income and fuel price elasticities of car use using micro registry panel data on all Swedish households from 1998 to 2018. In Paper I, the income and fuel price elasticities of vehicle kilometres travelled (VKT) is estimated for all Swedish households using a linear fixed effects model. In order to investigate how different groups respond, the elasticities are estimated by income group and municipality type. The effect of income and fuel prices on VKT is largest in the middle of the income distribution but is relatively stable across municipality types. The effect of fuel prices on VKT is largest in densely populated municipalities compared to rural municipalities. Moreover, it is shown that the income elasticity is underestimated if income variable is misspecified. Paper II utilises a discrete-continuous model accounting for the effect of income and fuel prices on car ownership. It is shown that income impacts car ownership and VKT conditional on car ownership of similar magnitude, while fuel prices primarily impact VKT conditional on car ownership. Furthermore, we also estimate the model on six partially overlapping sample periods and find that the income elasticity has decreased over time, while the absolute fuel price elasticity increased up until the early 2010s and decreased thereafter.

Keywords: Income elasticity, Fuel price elasticity, car use, car ownership, registry data, discrete-continuous model
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1. Introduction

Addressing the impact of car use on the local and global environment while maintaining social welfare, equity, and public acceptance in rural and urban areas is a key challenge for car and climate policies. With the ongoing electrification of the vehicle fleet and mandatory biofuel mandates we can expect large shifts in the cost of car use for different groups. Therefore, understanding how vehicle kilometres travelled (VKT) and car ownership respond to changes in income and fuel prices, and how the response varies among households, is decisive for policy makers and transport forecasters. Due to its policy relevance there is an extensive literature estimating how households adapt VKT to changes in income and fuel price using a large variety of data and models. However, the previous literature has primarily used aggregated time series data on countries or regions, or micro data based upon cross-sectional travel surveys. Therefore, they have been unable to account for unobserved household effects or spatial sorting related to household income and fuel prices, which may have led to increased bias. Moreover, the studies that have had access to micro panel data, either registry data or travel surveys, and controlled for unobserved effects have constrained their sample to car owners, or even smaller subsamples such as employed car owners. These studies may not capture the total effect on VKT since income and fuel prices also impact the choice whether to own a car or not. Furthermore, the previous studies using micro panel data have not accounted for that the income elasticity may depend on income level. This may lead to an underestimation of the income elasticity since less-responsive high-income households receive an excessive weight (Yitzhaki, 1996). Therefore, this thesis consisting of two papers estimates the income and fuel price elasticities, and accounts for the income elasticity varying dependent on income level. Furthermore, both papers control for the effect of unobserved household characteristics on the estimated elasticities and use a sample including the whole population.

This thesis uses micro registry panel data on households from 1998 to 2018 including all Swedish households (car owners and non-car owners). It is possible to follow the same households over time and to control for unobservable household characteristics. In both papers the main explanatory variables are real disposable household income and real petrol price at pump. We assume that petrol price changes also reflect changes in diesel and biofuel prices. The travel distance for each car is obtained from the mandatory annual vehicle inspection.

In Paper I, the income and fuel price elasticities of VKT are estimated for all Swedish households using a linear model on registry micro panel data. The elasticities are estimated for the whole population and by income group and municipality type. The income elasticity is largest in the middle of the income distribution but is more stable across municipality types while the absolute fuel price elasticity is largest in the middle of the income distribution but larger in densely populated municipalities compared to rural municipalities. It is shown that including income as a log-linear variable biases the income elasticity downwards as high-income households with a lower elasticity receive an excessive weight. This is a potential explanation for why earlier studies using micro panel data studies have found lower income elasticities. Paper II extends the analysis of Paper I by accounting for the effect of income and fuel prices on car ownership using a discrete-continuous model. It is shown that income
elasticity of car ownership is of the same magnitude as the income elasticity of VKT. This explains why studies only including car owners find a lower income elasticity of car use. The effect of including car ownership in the fuel price elasticity is relatively smaller, due to the fuel prices primarily impacting VKT conditional on car ownership. The paper also estimates the model on six partially overlapping sample periods and finds that the income elasticity has decreased over time, while the absolute fuel price elasticity increased up until the early 2010s and decreased afterwards.

In the following section the previous literature is reviewed and in Section 3 a summary of the appended papers is presented.

2. Literature review

2.1 Income

There is a large variation in the estimated income elasticity found by the previous literature (Dunkerley et al., 2014) with the meta-studies finding an average income elasticity of around 0.5 (Goodwin et al., 2004). Earlier meta-studies based upon studies using aggregated time-series or cross-sectional micro data have not found any systematic pattern with regards to model specification (Goodwin et al., 2004), except that studies accounting for car ownership find larger income elasticities (Dunkerley et al., 2014). Studies using aggregate data on countries and regions tend to find a larger income elasticity (Dunkerley et al., 2014). A potential explanation is the difference caused by the creation of the income variable. Studies using aggregated data primarily use GDP per capita, which could capture the effect of other factors such as population growth and other economic activity not related to household income.

Studies using fixed effects estimators on micro panel data find a lower income elasticity compared to studies using micro cross-sectional or aggregated time series data and find an income elasticity in the range of -0.03 to 0.17 (De Borger et al., 2016; Gillingham and Munk-Nielsen, 2019). This can partly be explained by that accounting for unobservable household characteristics yields a lower estimated income elasticity, shown in Paper I. However, the previous studies using fixed effects have constrained their sample to car owners, and may thereby have underestimated the total effect of income, shown in Paper II. Moreover, an additional explanation is that all the previous micro panel data studies have included income as a linear or log-linear variable, which probably results in the highest income group receiving an excessive weight on the estimated income elasticity (Yitzhaki, 1996). Since these high-income households are less sensitive, the income elasticity estimated for the population is underestimated.

2.2 Fuel price

The fuel price elasticity of VKT has historically been of great interest to policy makers due to the tangibility of fuel prices. Meta-studies have found that the long-run fuel price elasticity of VKT is relatively similar between most studies and usually in the span -0.3 to -0.5 (Brons et al., 2008; Dunkerley et al., 2014; Goodwin et al., 2004; Graham and Glaister, 2002). The meta-studies find no systematic pattern of how the fuel price elasticity of VKT conditional on car
ownership differs depending on what type of data and model is used, except that studies pooling cross-sectional and time series data tend to find a smaller absolute fuel price elasticity of car ownership (Brons et al., 2008).

Most previous studies estimating the effect of fuel prices on car use have studied the effect on fuel demand rather than VKT. The fuel price elasticity of VKT can be considered as a component of the fuel price elasticity of fuel demand (see Brons et al. (2008))

\[ F_{it} = VKT_{it} * C_{it}/E_{it} \]  

where \( F \) is the fuel demand, \( C \) the car ownership and \( E \) the fuel efficiency of household \( i \) during year \( t \). The fuel price elasticity of fuel demand is often larger compared to the fuel price elasticity of VKT given that increases in fuel prices are often accompanied by increases in fuel efficiency (Goodwin et al., 2004). However, an increase in fuel efficiency may lead to an increase in VKT. This is known as the rebound effect, with recent micro panel data studies finding a relatively low effect of around 7.5 to 10% (De Borger et al., 2016). This indicates that household fuel efficiency has no major impact on household VKT.

3. Summary of articles

3.1 Paper 1

In the first appended paper of this thesis, we estimate the income and fuel price elasticities of household VKT. The elasticities are estimated for all Swedish households and for different income quartiles and municipality types using a fixed effects estimator. Previous literature using micro panel data and fixed effects estimators have neither used a sample representative of the whole population nor accounted for how the elasticities vary with income level. Moreover, since they do not consider how the elasticities vary depending on income level, they tend to underestimate the income elasticity as high-income households (that are less responsive) receive an excessively large weight shown by Yitzhaki (1996).

The paper uses a registry micro panel database from 1998 to 2018, created by Statistics Sweden, that includes information about all registered adult individuals’ income, car usage, and socio-economic background. Household VKT is collected from odometer readings at the yearly vehicle inspections. It is possible to follow the same individuals over a 20-year period. The data is aggregated up to the household level since cars are often shared within households resulting in 96.6 million observations. A fixed effects estimator, which utilises the variation in income and fuel price within households between years, is applied to estimate the income and fuel price elasticities of VKT. Moreover, since earlier studies have shown that households require time to adapt to changes in fuel prices, the long-run fuel price elasticity is also estimated (Goodwin et al., 2004).

The fixed effects estimator yields a lower income elasticity and larger absolute fuel price elasticity than a pooled OLS. This indicates that by not controlling for unobservable household effects the income elasticity is overestimated. The difference in the estimated fuel price elasticity is most likely caused by pseudo-correlation in the pooled OLS from the same household being observed repeatedly over time. To investigate the presence of reverse causality
bias from households accepting a larger wage for a longer commuting distance, we apply an instrumental variable estimator using Earned Tax Credits. We do not find any such bias but a localized average treatment effect showing that households impacted by the instrument, found in the middle of the income distribution, are more sensitive to changes in income. This is also shown by estimating how the elasticities vary between income quartiles, presented in Figure 1, which shows that the income and absolute long-run fuel price elasticities are largest in the middle of the income distribution.

![Elasticity vs Income Quartiles](image)

**Figure 1: Income and fuel price elasticity of VKT**

The lower income elasticity for the household in the lowest income quartile can be explained by them being constrained, and therefore not able to adjust their car usage due to changes in income and fuel price. The low elasticities for the richest households can be explained by them reaching a saturation point with regards to car use (Tanner, 1978). Including income as a log-linear variable gives an excessive weight to high income households, which would underestimate the elasticity in the population (Yitzhaki, 1996).

We show that the estimated absolute fuel price elasticity is larger in rural municipalities than in large cities and city municipalities. A potential explanation is that households living in cities have already adapted to high costs of owning and operating a car. Thus, further increases in the fuel price may impact them relatively less compared to households living in rural municipalities.

As a sensitive analysis we estimate how the fuel efficiency among car owners impacts household VKT. We find that fuel efficiency has a minor impact on VKT, indicating a small rebound effect, implying that policies related to improving vehicle fuel efficiency have a limited impact on car usage.
3.2 Paper 2

The second appended paper estimates a discrete-continuous model that explicitly accounts for the effect of car ownership on household VKT. By not explicitly accounting for how income and fuel prices impact car ownership, the total effect on VKT may not be captured or may risk model misspecification. Previous discrete-continuous studies have not accounted for unobservable household characteristics which can lead to biased elasticities. Moreover, no previous discrete-continuous studies have accounted for the fact that the income elasticities vary depending on income level, which gives high-income households an excessive weight on the estimated elasticities if not accounted for (Yitzhaki, 1996).

The paper uses the same registry micro database as in Paper I, with the same household level information about income, socio-economic background, VKT and car ownership. The preferred discrete-continuous model, the Two-Part model, assumes that the two decisions, whether to own a car and how much to drive given car ownership, are independent, allowing us to estimate the models separately and merge the elasticities to obtain the total elasticity of VKT. The car ownership model is a probit model that bounds the probability of owning a car between zero and one. The non-linearity of the probit model results in us not being able to use standard fixed effects methods to control for unobservable household effects since they yield asymptotically biased elasticities (Wooldridge, 2010). Instead we use the Correlated Random Effects approach which assumes that the unobservable effect and explanatory variables are correlated through a level effect. Therefore, by including the average household value of an explanatory variable there is no correlation between the unobserved effect and the explanatory variable.

The results show that income elasticity of car ownership and VKT conditional on car ownership are of the same magnitude; therefore both impact household VKT almost equally. Moreover, we find that the income elasticity is underestimated if the car ownership decision is not explicitly accounted for. Furthermore, we find that the income elasticity is overestimated if we do not account for the unobservable household characteristics and underestimated if the excessive weight of high-income households on the estimated income elasticity is disregarded. The fuel price has a relatively lower impact on car ownership compared to the effect on VKT conditional on car ownership. However, we still find a larger fuel price elasticity in the discrete-continuous model compared to a fixed effects model on the whole population that does not explicitly account for the car ownership decision, indicating that the latter model is misspecified.

In order to investigate how the elasticities have changed over time, the income and fuel price elasticities are estimated for six partially overlapping sample periods. We find that the income elasticity has decreased for high-income households but remained stable for other households. This can be explained by the fact that high-income households are moving towards a saturation point with regards to car use. For the absolute fuel price elasticity we find that the elasticity increased up until the early 2010s and decreased thereafter. A potential explanation is that up until that point there was a real increase in petrol price which households are more sensitive to.

Lastly, since the number of car-owning households has remained stable over the study period but the number of cars has increased, we estimate the effect of income on the number of cars
the household owns using an ordered probit. We find that income has a larger impact on owning two or more cars compared to owning one car, and the effect is largest in the middle of the income distribution.
References


Papers

The papers associated with this thesis have been removed for copyright reasons. For more details about these see:

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