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Studying fuel and car tax policies using microdata: evidence from Finland, Sweden and Norway

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Abstract

This report examines fuel and car tax policies using microdata for Finland, Sweden and Norway. In terms of fuel taxes, we analyze the degree of heterogeneity in diesel tax pass-through in Finland and the distributional consequences of the 2012 fuel tax reform. In terms of car taxes, we examine the effects of changes in car taxes on the new car fleet and the CO2 emission intensity of the car fleet.

The results suggest that the pass-through of the diesel tax increase was heterogeneous and regressive, with a 15 to 20 percentage point difference in the estimated pass-through rates in the lowest and highest income and wealth groups. Similar divergence in pass-through was found with respect to population density and between rural and urban areas, with lower pass-through in more densely populated and more urban areas. Overall the estimated pass-through rates fall short of full pass-through. For the highest income and wealth and population density groups and most urban areas with estimated values are on the order of 60 percent, for the lowest groups slightly below 80 percent.

The results on car taxes are the first, preliminary results of an extensive research agenda and definite conclusions on the effectiveness of the policy measures call for more work. The preliminary results point to clear anticipatory responses in the number of cars relative to car tax changes as well as some longer term impacts on the number of newly registered cars, especially after the 2003 and 2012 reforms. Relative to Swedes and Norwegians, Finns were found to drive older, lower quality cars, but the 2003 car tax reform helped somewhat reduce the gap. A similar but smaller in magnitude pattern was observed for other car tax reforms. The CO2 emission intensity of newly registered cars does seem to respond to car tax rates, although the changes are not large. The share of diesel cars also seemed to increase sharply in all the three countries after the introduction of CO2-based taxes. Exits from the car fleet on the other hand do not seem not to respond much to car tax rates.

Appendix A Sample filling stations 2011 to 2012 and comparison of monthly average gasoline prices

Appendix B Excise taxes on gasoline and diesel in Finland, Sweden and Norway from 2005 to 2017

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Tiivistelmä

Tutkimus arvioi polttoaine- ja autoverojen muutoksia Suomen, Ruotsin ja Norjan mikroaineistojen avulla. Polttoaineverojen osalta tutkitaan, erosiko Suomen vuoden 2012 polttoaineverojen korotuksen läpimeno kuluttajahintoihin tulo- ja varallisuusluokittain tai alueen väestötiheyden mukaan. Autoveromuutosten osalta tarkastellaan erityisesti vaikutuksia uusiin autoihin autokannassa sekä CO_2-päästöintensiteettiin.

Tulosten perusteella dieselveron korotuksen läpimeno hintoihin oli regressiivinen. Alimmissa tulo- ja varallisuusryhmissä veronkorotuksesta siirtyi hintoihin 15-20 prosenttiyksikköä enemmän kuin ylimmissä tulo- ja varallisuusryhmissä. Myös tiheämmin asutuilla ja kaupunkimaisimmilla alueilla veronkorotuksesta siirtyi hintoihin pienempi osa. Kaikilla alueilla vain osa veronkorotuksesta siirtyi hintoihin. Suurimpien tulojen, varallisuuden ja väestötiheyden alueilla sekä kaupunkimaisimmilla alueilla veronkorotuksen läpimeno oli noin 60 prosenttia, alimpien tulojen, varallisuuden ja väestötiheyden alueilla sekä maaseutumaisimmilla alueilla hieman alle 80 prosenttia.

Autoverojen osalta raportoidaan laajan tutkimusohjelman ensimmäiset, alustavat tulokset. Vahvat päätelmät toimien tehokkuudesta vaativat vielä lisätyötä. Alustavien tulosten perusteella autojen määrässä havaitaan selvää ennakointikäyttäytymistä autoveromuutosten edellä. Autoveromuutokset heijastuvat myös pidemmällä aikavälillä ensirekisteröityjen autojen lukumäärään varsinkin vuosien 2003 ja 2012 verouudistusten jälkeen. Suomalaisten havaittiin myös ajavan vanhemmilla ja laadultaan heikommilla autoilla kuin ruotsalaisten ja norjalaisten, mutta vuoden 2003 autoverouudistus pienensi tätä eroa hieman. Muilla veromuutoksilla havaittiin samankaltainen, suuruusluokaltaan pienempi vaikutus. Veromuutokset näyttävät heijastuvan uusien autojen CO_2-päästöintensiteettiin, mutta muutokset päästöissä eivät ole suuria. Dieselautojen osuus näytti myös lisääntyvän jyrkästi kaikissa kolmessa maassa CO_2-perusteisten verojen käyttöönoton jälkeen. Veromuutokset eivät juuri näytä heijastuneen vanhojen autojen poistumiseen autokannasta.

Appendix A Sample filling stations 2011 to 2012 and comparison of monthly average gasoline prices

Appendix B Excise taxes on gasoline and diesel in Finland, Sweden and Norway from 2005 to 2017

Tämä julkaisu on toteutettu osana valtioneuvoston vuoden 2017 selvitys- ja tutkimussuunnitelman toimeenpanoa (tietokayttoon.fi).

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Sammanfattning

Studien analyserar förändringar av bränsle- och bilskatterna med hjälp av mikromaterial från Finland, Sverige och Norge. För bränsleskatternas del undersöks hur höjningen av bränsleskatterna i Finland 2012 påverkade konsumentpriserna enligt inkomst- och förmögenhetsklass eller områdets befolkningstäthet. När det gäller de ändrade bilskatterna granskas särskilt inverkan på fordonsbeståndets nya bilar och på CO2-utsläppsintensiteten.

På basis av resultaten var dieselskatten regressiv. Överföringen av skattehöjningen på priserna var 15–20 procentenheter större i de lägsta inkomst- och förmögenhetsgrupperna än i de högsta inkomst- och förmögenhetsgrupperna. Även i mer tätbebyggda och urbana områden överfördes en mindre andel av skattehöjningen på priserna. I alla områden överfördes bara en del av skattehöjningen på priserna. I områden med de högsta inkomsterna och största förmögenheterna samt i de mest tätbebyggda och urbana områdena överfördes cirka 60 procent av skattehöjningen. I områden med de lägsta inkomsterna och minsta förmögenheterna samt i de minst tätbebyggda och rurala områdena överfördes knappt 80 procent.

För bilskatterna rapporteras de första, preliminära resultaten av ett omfattande forskningsprogram. För att kunna dra några långtgående slutsatser om åtgärdernas effektivitet krävs det ytterligare arbete. Enligt preliminära resultat kan man när det gäller antalet bilar se en tydlig framförhållning inför ändringar av bilskatter. Bilskatteändringar avspeglas också på lång sikt på antalet nyregistrerade bilar särskilt efter skattereformerna 2003 och 2012. Man fann också att finländarna kör med äldre och sämre bilar än svenskarna och norrmännen. Bilskattereformen 2003 reducerade skillnaden lite. Man kunde iaktta en liknande, om än mindre, inverkan med andra skatteförändringar. Skatteförändringar ser ut att avspeglas i nya bilars CO2-utsläppsintensitet men förändringarna av utsläppen är inte stora. Dieselbilarnas andel såg också ut att öka drastiskt i alla tre länder efter att CO2-baserade skatter tagits i bruk. Skatteförändringarna ser inte ut att ha avspeglats i en minskning av antalet gamla bilar i bilbeståndet.

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1. INTRODUCTION

Climate change mitigation calls for substantial reductions in CO_2 emissions from road transport. The EU seeks to meet its Paris Climate Agreement pledges through emission reductions obtained by the EU emissions trading scheme (EU ETS) and through a separate reduction target for the sectors that are not included in the EU ETS, the so called non-ETS sectors. The non-ETS emission reduction targets have been allocated for the member countries. In Finland road transport produces close to 20 percent of the overall CO_2 emissions and is scheduled to produce a substantial share of the non-ETS emission reductions. The target path for emissions foresees reducing the emissions from road transport by as much as 50 percent, relative to 1990, by 2030.

Many countries, including Finland, apply emission-based taxes as well as other environmental policies to try to control emissions from road transport. Vehicle-related policies include fuel taxes, car taxes or vehicle first registrations fees for new cars, annual vehicle taxes, fuel economy or emission standards for car producers (see Sallee 2010), as well as subsidies for low emission vehicles and scrappage of old, typically relatively high emission vehicles.[1] Both vehicle first registration fees (car taxes) and annual vehicle taxes may depend on the fuel economy or emission intensity of the vehicle.

With ambitious targets for climate change mitigation, an important question is how successful the various environmental policies actually are in reducing the emissions from road transport. Another important question is the potential distributional impact of these policies. In particular fuel taxes often gain public discontent due to their perceived regressivity.[2] Besides differences in consumption, the allocation of the tax burden among households depends on various other factors, such as behavioral responses to price changes and their heterogeneity over the income distribution, the chosen time horizon, changes in the car fleet, and how the additional tax revenue is recycled. While early empirical evidence might have lent support to the regressivity hypothesis, but more recent studies utilizing richer datasets and employing more sophisticated methods suggest that fuel taxation has different distributional implications in different countries and that regressivity may not be a concern as much as previously thought.

Most studies evaluating policies for curbing emissions from road transport analyze data from the United States, and European evidence is relatively scarce. However, fuel tax rates as well as and transportation possibilities and preferences in European countries differ notably from those in the United States (see e.g. Bureau 2011), and results from the United States may not generalize to Europe.

This study extends the literature evaluating fuel and car tax policies by providing new evidence for the Nordic countries Finland, Sweden and Norway. We use several tax reforms in the period 2003-2012 as plausibly exogenous sources of variation. We provide descriptive evidence on the suggestive effectiveness of national policies against the backdrop of the general trends by comparing the three countries that have policy changes at different points in time. The study focuses on two road transport policies: fuel taxes and car taxes. In terms of fuel taxes, we focus on the degree of heterogeneity in diesel tax pass-through in Finland and the distributional consequences of the 2012 fuel tax reform. An earlier study by Harju et al. (2016) reported the average pass-through of the same tax reform. It terms of car taxes, we examine the effects of changes in car taxes on the new car fleet and the CO_2 emission intensity of the car fleet.

Our findings show that there are quite drastic trends in the average CO2 emissions of new cars. This seems to happen in all three countries that we compare. It seems to be challenging to tease out the causal effect of various policies against the background of drastic

[1] To speed the adoption and diffusion of electric vehicles, many countries also offer subsidies to charging stations as well as non-monetary benefits (such as access to high occupancy vehicle lanes) to electric vehicles.

[2] This concern stems from the presumption that low-income households spend a larger portion of their income on fuel and transportation than do high-income households. Moreover, these expenditures are often considered necessities. Hence, the burden from fuel tax increases would be borne more heavily by low-income households than others.

changes in the global trends. Suggestively it seems policies that treat all cars in an equal manner seem to create lesser impacts on cars than policies that treat one group of cars differently than another group of cars. Thus, according to our results, it seems that substitution effects need to be taken into account when designing policies.

The report is organized as follows. The following section first discusses the economic theory related to (i) policies for reducing emissions from road transport, and (ii) tax incidence and pass-through. The discussion is followed by reviews of the empirical literature on fuel tax pass-through and the effects of car taxes. Section 3 describes the 2012 fuel tax reform and evaluates heterogeneity in the pass-through of the 2012 diesel tax increase. Section 4 first discusses car tax policies and policy reforms in Finland, Sweden and Norway, and then provides descriptive evidence for the effects of car taxes.

2. MECHANISMS AND LITERATURE REVIEW

2.1. Mechanisms related to emissions from road transport

This section briefly describes the economic theory related to policies for reducing emissions from road transport, relying largely on Anderson and Sallee (2016).

In principle, policies aiming at curbing emissions from traffic could induce various behavioral responses. These could affect the fuel economy of cars produced and bought, the number of new cars introduced to car fleet, the time cars stay in the fleet before they are scrapped and the amount an average car is driven. Successful policies would reduce emissions from all of these sources: fewer cars in general, the average new car is more fuel efficient, and cars are driven less.

An important distinction in car tax policies is whether they are only fuel-economy related, or attribute-based. The latter policies could depend on the weight of a car, or value of a car. We review mechanisms related to Finnish environmentally-motivated fuel and car taxes. The EU has average fuel economy standards for car producers, and Finland imposes car taxes that are partly fuel-economy related in that car and annual vehicle tax rates depend on CO_2 emissions, and partly attribute-based in that car taxes depend on the value of a car.

In a first-best Pigouvian tax regime there would be no need to single out cars for taxation, as all uses of fuel would be taxed at a rate equal to the marginal social damage created. Fuel taxation set at this optimal level would be sufficient to influence both car-buying choices towards more environmental direction as well as influence the amount of driving to the desired level. Even without an economy-wide tax on pollution, a fuel tax represents an appealing policy because it induces behavioral responses on all of the key margins for carbon dioxide mitigation.

The literature has noted that fuel taxes might not be sufficient to induce all desired environmental margins if individuals buying cars do not fully anticipate the effect of their car choices on future fuel economy and cost of driving (see Anderson and Sallee 2016 for a review of the literature). Many reasons could cause individuals not fully anticipating these margins, especially when fuel prices are volatile over time. Therefore, it could be optimal to complement fuel taxes with car fuel economy standards and/or emission dependent car taxes and rebates. Another reason that such policies could be valuable in complementing fuel taxes is if knowledge spillovers from technological change create a second market failure.

A more specific effect of fuel taxes on cars is that they increase fuel prices, and thus increase incentives to purchase cars with better fuel economy. Fuel taxes also implicitly affect other car attributes related to fuel economy, for example, more fuel-efficient cars tend to weigh less but they also can be less safe in the traffic.

In addition, fuel taxes increase the cost of driving which in turn reduces incentives to purchase a car by raising the total cost of ownership. Individuals thus ought to buy fewer new cars. Furthermore, higher fuel prices induce individuals to drive less. Regarding the effects on average mileage, policies that lead to increases in fuel economy could cause a relatively well known "rebound effect" which means that an increase in the fuel economy decreases the costs of driving per-kilometer, and then emission reductions from better fuel economy could be offset by more driving due to the savings in fuel costs. This effect has been found to be smaller than the first order effect of higher fuel prices reducing average mileage. Therefore, a common view is that the rebound effect modestly reduces the expected fuel conservation from policies. In terms of economic efficiency, the rebound effect is a major reason why fuel taxes are believed to be superior to policies that target fuel economy of new vehicles directly, including both vehicle tax schemes and fuel economy standards.

The USA, EU and many other countries have average fuel-economy standards for car producers. These aim to incentivize car makers to produce cars with better fuel-economy. In theory, these should maker car fleet more fuel-efficient. These standards also create rebound effect, as cars with higher fuel-economy can be driven more with the same fuel costs than otherwise similar but less fuel-efficient cars. In this case the rebound effect could lead to increase aggregate mileage, because there is no direct incentive to reduce mileage that exists in the case of fuel taxes. Another adverse effect is that in theory higher fuel-economy standards could prolong the life cycle of inefficient used cars in the car fleet and thus lead to lower levels of scrappage of inefficient cars (Jacobsen and van Benthem 2015). This is because higher fuel-economy standards could lead to less inefficient and large new cars, and the best substitute for them would be inefficient and large used car. With less this type of new cars available, individuals could keep their used inefficient cars longer before scrapping them. Empirically this depends on what kinds of cars are substituted with each other.

As noted above, Finland has car tax for new cars and annual vehicle taxation, both of which have fuel economy and attribute elements. In general, emission-based car taxes have tax (fee) and rebate parts, where fuel-efficient cars are subsidized and less efficient cars face fees. For these reasons the common term for these policies are feebates. Feebates could create very similar effects to average fuel economy standards in car markets. In practical terms they could have some benefits including distributional effects and creating tax revenue allowing lower taxes in some more distorting tax bases. The attribute-based part in Finnish car taxes is that they also depend on taxable value of cars. In principle the effect of the attribute part is that it lowers the value of cars, which taken alone is an unnecessary distortionary effect. However, given that higher value of a car is associated with higher engine power and more emissions, there could be a secondary effect reducing the fuel-economy of new cars. This latter thought does not apply that well to expensive electric or hybrid cars. Finally, the taxable value basis could lead to later scrappage of used cars, because higher tax rate means new cars are more expensive and the substitute for them could be to keep used cars in use for a longer time.

2.2. Tax incidence and pass-through

The economic incidence of the tax may differ from its statutory incidence. For example, imposing a fuel tax on suppliers is likely to increase the price of fuel and make consumers reduce their fuel consumption, to which firms react by reducing supply. Consequently, both consumers and suppliers may bear a part of the tax burden. Pass-through is a central concept in determining the incidence of a tax between consumers and suppliers. As suppliers usually bear the statutory burden of excise taxes, the term pass-through refers to the extent to which the tax is "passed through" to consumers. It describes the consumer price reaction to imposing or increasing a tax, and thus the allocation of economic costs between consumers and suppliers: a high pass-through rate indicates that consumers bear most of the burden whereas low pass-through indicates that the costs fall mostly on the supply side.

We consider a quantity tax of t per liter of fuel, which is paid by the distributor (supplier). Consumers' aggregate demand is given by $Q^D = D(p,X)$, where p denotes the tax-inclusive price of gasoline and X represents exogenous demand shifters. The marginal cost function is $MC(q,t,W)$, where t is the tax parameter and W represents cost shifters, such as the wholesale price and transport from wholesale terminals. If firms behave competitively, they produce to the point where price is equal to the marginal cost. The market-clearing price will be influenced by the tax rate and supply and demand shifters. If markets are not perfectly competitive, the price will be influenced by factors that affect firms' marginal cost and marginal revenue. In that case, the price is given by $p=f(t,X,W,Z)$, where Z represent variables that describe the market power of the firms.

In a perfectly competitive market, theory suggests that the fraction of tax that is passed on to consumers will be given by

$$\frac{dp}{dt} = \frac{\eta}{\eta - \varepsilon}, \tag{1}$$

where η and ε are the price elasticities of supply and demand. That is, the rate of pass-through increases with the elasticity of supply and decreases with the elasticity of demand, and will be less than or equal to 100%.

In imperfectly competitive markets the pass-through rate can be below or above 100% (Katz and Rosen 1985, Seade 1985, Stern 1987, Hamilton 1999). While demand and supply elasticities still affect tax incidence, it also depends on the shape of the demand and supply curves (Weyl and Fabinger 2013).

Heterogeneous pass-through

Local and regional markets may differ in terms of the degree of competition and consumer preferences, which translates into differences in the pass-through rate. If these differences are systematically related to household income and wealth or distinct regional characteristics, pass-through may have distributional consequences among consumers.

Demand in a given local market is likely to be partly determined by factors such as the degree of urbanization, availability of public transportation, driving preferences, and a wide variety of household characteristics. Price elasticity might be lower and demand more curved, for instance, in rural areas due to long distances and a poor public transportation network. The elasticity may also be related to household income, where the direction of the potential relationship cannot be inferred from theory. The relationship between market power by firms and pass-through is also theoretically ambiguous. It should be noted though that if certain market conditions tend to arise in regions with high or low income, regional differences in market competition may have considerable distributional effects.

2.3. Literature review on fuel tax policies

Aggregate estimates

Empirical estimates of fuel tax pass-through are quite scarce. Most studies use monthly state-level panel data from the United States and exploit variation in state-level fuel taxes to estimate the average pass-through rate. All the studies obtain pass-through estimates close to 100 percent. Chouinard and Perloff (2004) used data from the contiguous United States between 1989–1997 and found an average pass-through of the state gasoline tax of almost exactly 100 percent. Alm, Sennoga and Skidmore (2009) arrived at an identical conclusion using data on all the United States states and years 1984 to 1999. Marion and Muehlegger (2011) concluded that both state gasoline and diesel taxes were fully or even slightly overshifted in a study area that included twenty-two states over the period 1983–2003. Kopczuk, Marion, Muehlegger and Slemrod (2016) in turn found that the pass-through of state diesel taxes was on average over 90 percent between 1986–2006. Doyle and Samphantharak (2008) analyzed the effects of ad valorem gasoline tax repeals and the subsequent reinstatements in the neighboring states of Illinois and Indiana during 2000–2001. They found that the pass-through of the repeals was 70 percent while pass-through in the reinstatements was 80–100 percent.

Stolper (2016a, 2016b) is to our knowledge the first to use detailed station-level data to study fuel tax incidence in a European country. Stolper (2016b) examines variation in state-level diesel taxes in Spain between 2007–2013 and weekly station-level data from more than 2500 individual gas stations. This enables controlling for station characteristics as well as municipality-level market conditions and socioeconomic factors. Stolper (2016b) obtains an average pass-through estimate of 95 percent, which is consistent with the estimates for the United States.

Even though the evidence from Spain in Stolper (2016b) is in line with the evidence from the United States, drawing conclusions on fuel tax pass-through from studies still almost exclusively examining United States tax changes may lead to erroneous generalizations. Compared to European countries, fuel prices and fuel tax levels are notably lower and private passenger car us of higher importance in the United States.[3] If these differences play a role in determining the price elasticity of fuel demand or other factors affecting the pass-through rate, results may not generalize to European countries.

Evidence on heterogeneity in pass-through

Nearly all the studies on pass-through also examine some potential source of heterogeneity. Chouinard and Perloff (2004) find that a lower share of gasoline sales, obviously related to the size of the state, is associated with higher pass-through: the disparity in shares translates up to a 25 percentage point difference in pass-through between states. Alm, Sennoga and Skidmore (2009) examined heterogeneity with respect to the degree to which an area is urban. The results suggest some heterogeneity in pass-through, but the results are not robust to the choice of model specification and the relationship appears non-monotonic. Stolper (2016a, 2016b) explores whether pass-through in Spain is related to the degree of competition, likely related to how urban an area is. Stolper (2016a) compares pass-through rates between gas stations near state borders and those further away. Stations close to a state border share a market with competitors across the border and might not fully shift unilateral tax increases to prices. He finds that the average pass-through among stations within 5 kilometers of a state border is about 73 percent, more than 20 percentage points lower than the nation-wide pass-through. Among stations with at least one cross-border rival within a 5-minute driving distance, the pass-through rate was only 57 percent; here the number of stations was small though, at 31. Stolper (2016b) refines the analysis by introducing three different measures of the degree of competition: the concentration of stations under the same refinery brand, the proportion of stations under the same ownership and the number of rival stations within a 5-minute driving distance. The results suggest an association with less competition and higher pass-through in terms of all three measures. The models do not allow a causal interpretation, however, as gas station location choices may be systematically related to location-specific unobservable characteristics that also affect pass-through. Stolper (2016b) also illustrates the heterogeneity at the station-level by estimating station-specific pass-through rates which he finds to range from 70 up to 120 percent.

Stolper (2016b) also considers heterogeneity with respect to regional wealth, proxied by house prices. He finds that pass-through increases with regional house prices. This positive correlation has r distributional implications in so far as house prices are a suitable proxy for wealth. However, the sample of filling stations is limited to urban areas, which may differ from rural areas in terms of pass-through.

Marion and Muehlegger (2011) analyze whether more inelastic fuel supply, related to constrains in the supply chain, is associated with lower pass-through. Comparing pass-through rates in time periods or states where supply constraints were present to those with no constraints, Marion and Muehlegger (2011) found descriptive evidence of a positive relationship between the price elasticity of supply and pass-through. For example, when refinery capacity utilization was more than 95 percent, diesel tax pass-through was only 41 percent; however, no similar relationship was identified for gasoline tax pass-through.

[3] For example, the share of trips made by cars is about 1.5 times higher in the United States than in Germany and the per capita kilometers traveled by car twice those in Germany (Buehler 2011).

Kopczuk et al. (2016) argue that pass-through is likely to be lower if tax evasion is relatively effortless, and that the point of collection of the fuel tax in the supply chain is related to tax evasion opportunities, with evasion being is more difficult for prime suppliers fewer in number. They find that pass-through obtains the highest value when state diesel tax is collected at the bulk terminal, second highest when the tax is collected at the distributor level, and lowest when the tax is remitted by retailers. The changes in the level of pass-through after a change in the point of collection also appear discontinuous, which supports a causal interpretation.

Distributional aspects of fuel taxes: budget share comparisons

If low-income households devote a larger share of their income to fuel expenditure, they bear a larger monetary burden relative to their income than their high-income counterparts, which would make fuel taxes regressive. This section briefly reviews empirical studies from Europe that are based on budget share comparisons. It should be noted though that static budget share comparisons ignore the dynamic effects of taxation, such as households' behavioral responses and general equilibrium effects.[4] Furthermore, based on studies comparing the budget shares of fuel across different households, it is not always the case that budget shares are highest among low-income households.

The distributional effects of fuel taxes have been studied primarily by using household survey data to compare the reported budget shares of fuel across households, where households have been grouped by annual income. Comparing the budget shares of fuel expenditure across annual income deciles around the year 2006 in a study covering six European countries, France, Germany, Serbia, Spain, Sweden and the United Kingdom, Sterner (2012) concludes that fuel taxes were slightly regressive in five of the countries. The income grouping based approach has been challenged by Poterba (1989, 1991), who argues that annual total consumption better reflects a household's ability to pay taxes in the long run. Sterner (2012) also examines a grouping based on annual consumption. The results from the consumption-based analysis suggest that taxes are close to proportional or even progressive, with the exception of Italy. Santos and Catchesides (2005) studies United Kingdom data for years 1999 and 2000. They found that while the fuel tax was neither regressive nor progressive over the income distribution on the whole, the tax was regressive among households that owned a car, a result explained by owning a car being less common in low-income households than in other income groups. Tuuli (2009) carried out a similar analysis for Finnish data covering six different years within the period 1985–2006; he also found that the degree of progressivity, based on income grouping, differed between car owners and the population on the whole. He found fuel tax to be slightly progressive among the population on the whole and nearly proportional among car owners.

To summarize, budget share comparisons from European countries do not provide clear support for the assertion that fuel taxes are regressive. It should be noted though the studies mostly do not analyze the long-run distributional effects arising from, for instance, changes in the car fleet and also ignore effects related to externalities, such as congestion and air pollution.

Two assumptions regarding the pass-through of fuel taxes to fuel prices characterize the studies discussed in this section. First, pass-through is assumed to be 100 percent so that consumers bear the entire burden of the tax. While this is a reasonable assumption based on both theoretical arguments and the empirical evidence presented above, it is not universally applicable considering the empirical estimates of less than full pass-through. Second, pass-through is assumed to be uniform across the entire market. Stolper (2016b) points out this gap in the literature and argues that ignoring heterogeneity in pass-through may lead to incorrect conclusions on the distributional effects of fuel taxes.

A limitation in Stolper's (2016b) study is that the distributional analysis is restricted to gas stations in urban areas. Given that incomes and the degree of competition are often lower in rural areas and that the study suggests a negative relationship between competitiveness and pass-through, focusing only on urban areas may provide an incomplete picture of the

[4] For a review of studies addressing demand response and general equilibrium effects, see Palanne (2018).

variation in pass-through. The objective of the empirical analysis in this study is to add to this limited evidence by examining the existence of pass-through heterogeneities in Finland, based on data covering both urban and rural areas.

2.4. Literature review on car tax policies

The previous empirical literature has studied the effects of various tax and regulation policies on the characteristics of the car fleet. From this literature some general lessons regarding the impact of these policies can be learned, and we summarize these below. Before that we mention caveats regarding the applicability of these results to policy discussion in Finland. The first is that many of the existing studies are from the US or other countries, where the car tax policies and consumption patterns of cars might differ from Finland significantly. The second is that the methods employed in many previous papers leave room for improvement. Many reduced form empirical studies lack a credible control group coming potentially from another country, and structural estimates often rely on the structure employed more than any exogenous variation affecting behavior. In the latter case it is difficult to know to what extent the structure applies to any empirical car markets or to Finnish car markets in particular.

Stitzing's (2016) doctoral dissertation might be the only prior academic exercise analyzing the Finnish car taxes, or the 2008 car tax reform in particular. Essay 2 in the dissertation analyzes the effects of the 2008 car tax reform in Finland in reduced form fashion. The reform introduced CO_2 rates to the previously uniform car tax schedule reducing tax burden for new cars with better fuel economy and increasing it for cars with worse fuel economy. The analysis suffers from the lack of control group. It is difficult to know how the demand for different kinds of cars would have evolved in the absence of the reform and what would have happened to the total number of new cars over time. Stitzing acknowledges this to some extent in the dissertation. The result Stitzing finds is that the 2008 reform seems to be associated with a modest improvement in the fuel economy of an average new car. Essay 1 in the thesis builds a structural model to estimate the equilibrium response to the car tax policy, and to study both the environmental and distributional aspects of the policy. The main distributional question is to what extent car producers or dealers benefited from policy and to what extent consumers. He finds that the average tax reduction associated with the 2008 reform benefited mostly car buyers but at the same time increased firm profits by around 20 per cent. With a control group that would have not been affected by the policy, the result could deviate from this.

Klier and Linn (2010) estimate the effect of higher gasoline price on the demand for cars with better fuel-economy in the US. They utilize car make and model fixed effects as an identification strategy, and associate variation in monthly sales amounts with monthly fuel prices conditional on keeping fuel economy of car make and model fixed. They find that nearly half of the decline in sales of low fuel-economy cars in the US could be related to higher fuel prices. Thus, fuel price does seem to affect new-car fuel-economy rather much. They do cast doubt on the effectiveness of fuel taxes on new car purchases by noting that fuel prices increased four-fold from 2002 to 2008 because of increases in crude-oil prices. This kind of increase might not be politically feasible to achieve with fuel taxes alone.

Klier and Linn (2012) build a structural model and estimate the medium-term supply response to Corporate Average Fuel Economy (CAFE) standards in the US. The idea is that in the medium-term car producers can change the fuel economy of cars by altering, for example, the weight of a car without making significant changes to power train of a car, such as adopting a hybrid motor instead of traditional engine. The results from their structural model point to the direction that compliance costs to the CAFE standards are not as high as in previous papers, and thus might be more desirable policies than what older literature suggested.

Klier and Linn (2015) estimate an association between introducing fuel-economy related car or annual vehicle tax policies and the number of new car registrations in Sweden, France and Germany. The main point of the paper is to estimate the impact of car tax policies on market shares of particular type of new cars. They find an effect of introducing these fuel-economy policies reducing the market shares of high-emitting cars. However, an important caveat in this method is that the market shares could be affected by other concurring events, including the onset of European economic crisis in 2008. The economic crisis affects all countries in their analysis and could affect the market shares differently in different countries, especially because all of these countries have relatively strong car manufacturing industry in place.

Huse and Lucinda (2013) analyze the effects of green car rebates in Sweden, reducing the annual vehicle taxes for cars that fulfill the criteria of a "green car". For example, a vehicle utilizing only traditional fuels, such as gasoline, is defined as green car if CO_2 emissions are less than 120 g/km. They approach the question with a structural model, from which they estimate a counterfactual number for new car registration in the scenario where the green car rebate had not been introduced. Their results show that the green car rebate led to significant increases in the share of green cars among the Swedish new car registrations. However, it is important note that their model is based on rather demanding assumptions that are hard to externally verify.

A series of papers has studied whether consumers rationally value fuel economy in a present-discounted value sense when purchasing a car (Busse, Knittel and Zettelmeyer 2013, Allcott and Wozny 2014, Sallee et a. 2016, Grigolon et al. 2018). These studies all use variation in fuel prices, which create different cost of ownership shocks for more and less fuel efficient vehicles, to identify consumer demand responses while accounting for other differences in attributes across vehicles. Sallee et al. (2016), for example, utilized a setting where very similar cars have different current mileage at the time they are sold, and therefore different remaining lifetime. Their results suggest that consumers take expected fuel prices into account one for one in their valuation of the fuel economy of used cars. This is an important result, because if consumers do take fully expected fuel prices into account, fuel taxation set at optimal level might be enough to address negative externalities caused by pollution. That is, unless there are other reasons for supplementing environmental policy with car tax policies than to what extent consumers take future fuel prices into account in their car-buying choices. Grigolon et al. (2018) make a similar estimation for European countries but take into account consumer heterogeneity. They arrive at conclusion that consumers might undervalue the cost of future fuel economies, but still the fuel taxes are the most effective policy curbing emissions because they target the right consumers, essentially to those that make most of the emissions.

Jacobsen and van Bentham (2015) estimate the elasticity of used car prices on scrappage of used cars in the US. They interact their estimates with fuel economy related policies and instrument the estimates with gasoline prices. The reasoning why there should be an effect on the scrappage rates is that policies incentivizing new cars to be more fuel efficient can also affect the prices of used cars. When new cars become more expensive due to environmental policies, the equilibrium prices of used cars increase. This also incentivizes the owners of used cars to keep their used cars longer before scrapping them. They argue that this effect is even more pronounced for high-emitting cars, partly because fuel economy policies tend to affect these cars the most, and individuals keep the high-emitting old cars longer in the car fleet. They call these effects "used car leakage" from new car policies. They estimate this leakage effect being 13-16 percent in the US. This result suggests that the expected fuel economy savings are lower by this amount due to the used car leakage effect. This constitutes a significant effect hindering the effectiveness of fuel economy policies targeting new cars.

Alberini et al. (2018) estimate the impact of annual registration taxes that depend on fuel economy of cars on scrappage of old cars in Switzerland. They find only modest effects that are not very precisely estimated, similarly as Jacobsen and van Bentham (2015). Although the results in this study suffer from the lack of precision, the study illustrates that policies, such as the annual fuel-economy related vehicle taxes in the Nordic countries, could also affect the scrappage of used cars.

There are also several papers showing that car producers might respond to average fuel economy policies or car tax policies by manipulating the attributes of the car. The responses might be often responses to specific policy parameters and lead to undesired effects. For example, Sallee and Slemrod (2012) show that car producers alter the fuel economy slightly in order to end up at the better side of the rounded-up miles per gallon figure shown to consumers, and that this behavior leads to welfare losses. Ito and Sallee (2018) show that car producers in Japan respond to weight-based standards partly by increasing the weight of their cars. On the other hand, Gerlagh et al. (2018) found that the EU-level fuel economy standards contribute to the fuel efficiency of new cars markedly more than fuel-efficiency based car taxes. They found that 1.3 percent of the fuel-efficiency improvements were attributable to car taxes whereas the overall improvement was 12 percent over the period 2001-2010.

3. FUEL TAXES

3.1. Institutional setting and reforms

Transportation fuels are subject to both an excise tax and a value added tax (VAT) in Finland. The excise tax is defined in euro cents per liter and includes an energy content tax, a CO_2 tax and a security of supply fee. The CO_2 tax, introduced in 2011, constitutes 25 percent of the excise tax on gasoline and 37 percent of the excise tax on diesel. Overall, gasoline is taxed more heavily than diesel. The VAT on transportation fuels is currently 24 percent of the VAT-exclusive price, including the excise tax, and is remitted by retailers. Excise taxes are remitted by wholesalers.

Table 1 displays a decomposition of average fuel prices in 2017 in euro cents per liter. The taxes were 70.25 cents per liter on gasoline and 53.02 cents per liter on diesel. With average market prices of 1.46 euros per liter for the 95E10 gasoline and 1.29 euros per liter for diesel, taxes formed approximately 67.5 percent of the gasoline price and 60.5 percent of the diesel price.

Table 1. Decomposition of average gasoline and diesel prices in 2017 (c/l)

	Diesel	Gasoline (95E10)[5]
Market price	129.0	146.0
VAT	25.0	28.3
Energy content tax	32.8	52.2
CO_2 tax	19.9	17.4
Security of supply fee	0.4	0.7
Total excise tax	53.0	70.3
Price excluding taxes	51.0	47.4
Total taxes	78.0	98.6
Total taxes, %	60.5%	67.5%

The excise taxes on both fuels have been increased six times between 2004–2017. Five of the six tax reforms that took place between 2004 and 2017 featured a tax increase of 2–5 cents per liter on both gasoline and diesel. The 2012 reform instead increased the excise tax on diesel by 10.55 cents per liter, from 36.40 to 46.95 cents per liter on January 1, 2012. The excise tax on gasoline was increased by only 2.34 cents per liter, from 62.70 to 65.04 cents per liter.

This study analyzes the degree of heterogeneity in the pass-through of the 2012 the diesel tax increase. The notable increase in the tax on diesel enables discerning smaller percentage point differences in pass-through rates. It should be noted that the tax increases faced

[5] The gasoline blend in our analysis is 95E10, the most widely used blend in Finland with an octane rating of 95 and a maximum ethanol concentration of 10 percent.

by consumers differed from the increases for pure diesel and gasoline stated earlier. Gas stations sell blends containing biofuels and other additives, rather than pure diesel and gasoline. As biofuels and additives are taxed at rates different from pure diesel and gasoline, the excise tax per liter at the retail stage is slightly lower than the tax on pure diesel and gasoline, mainly because of the lower rate on biofuels. Monthly estimates of taxes on market blends, calculated by estimating the share of these biocomponents, are provided by Statistics Finland.

As VAT is also paid on the excise tax component of the fuel price, an excise tax increase contributes to the overall tax also through the VAT component. Table 2 shows the estimated overall tax increase in the market blend including the increase in the VAT component, 12.28 cents per liter on diesel and 1.94 cents per liter on gasoline.

Table 2. The exact excise taxes on gasoline and diesel in 2011 and 2012 (c/l)

Excise tax	Diesel			Gasoline (95E10)		
	2011	2012	Change	2011	2012	Change
Pure fuel	36.40	46.95	10.55	62.70	65.04	2.34
Market blend	36.28	46.27	9.99	60.79	62.37	1.58
Market blend×(1+VAT)	44.63	56.91	12.28	74.77	76.71	1.94

3.2. Data

Our primary data are station-level microdata on diesel and gasoline prices, collected by two websites (polttoaine.net and tankkaus.com) where individuals can self-report fuel prices observed at gas stations around Finland. The data cover January 2000 to October 2015, although for January 2000 – December 2006 data are available only for one of the websites. Individuals can enter prices to the websites in several ways: by filling an online form, by sending a text message or by sending email to the website moderator. The data include the prices of diesel and two types of gasoline, with octane ratings 95 and 98. The data also contain the exact location (municipality and address) and the name of gas station, including the branch name, as well as the exact time when the price was recorded.

As gas stations are identified only by a name, some stations are listed multiple times because of reporting under slightly different names or because they are reported on both websites. We draw a random sample of about 50 percent of the stations and identified the exact location of these stations, based on the station names and addresses reported on the two websites and coordinates obtained from Google Maps. A total of 1117 unique station-location pairs were identified in the sample between 2011 and 2012, the main period of interest in the analysis. Thirty-seven of these stations changed to a new gas station chain once and two stations twice during the two-year period. Because of incomplete information on the ownership the gas stations, we were not able to determine whether the ownership of these stations changed as well.

We complemented the price data with information on station specific characteristics for the 1117 station-location pairs based on the names and addresses of the stations. These characteristics include the type of station (fuel only or other services as well), the services provided, and information on whether the station is located near a highway, in a city or in a rural area. Postal code-level data on income, population density and average housing prices, measured by condominium prices for previously owned units from Statistics Finland, were also matched to each station-location pair. The income measure used here is the disposable income of individual adults (eighteen years or older).[6]

[6] Household income would have been a more accurate measure – the true financial situation of individual adults depends not only on their own income, but also the incomes of other household members, the number of people to provide for, and economies of scale in the household. Statistics Finland data on total household income do not specify the size and composition of the household, which prevents using these data as a sensible measure of variation between households.

Each postal code area was assigned a regional class (inner urban area, outer urban area, peri-urban area, local center in a rural area, rural area close to an urban area, rural heartland area or sparsely populated rural area) based on an urban-rural classification provided by the Finnish Environmental Institute (Helminen et al. 2014). Figure A1 in the Appendix visualizes the urban-rural classification of the stations. The map shows that most stations are concentrated in relatively large municipalities, the borders of which are indicated by the dark lines, whereas rural areas have a sparser station network.

The econometric analysis uses day-and-station level prices. The daily price of each fuel and each station was calculated as the average of the fuel-specific prices reported for the station within a day. Table 1 shows summary statistics for the fuel prices used in the analysis. The average diesel price was below the average gasoline price in both 2011 and 2012. The distribution of the number of observations per station (not shown) is skewed to the right, meaning that more frequently visited filling stations are overrepresented in the data. Thus, the analysis should be interpreted as measuring the differences in pass-through among the more popular filling stations, and the results might not generalize to the population of all gas stations. But at the same time this can be seen to weighting the estimates automatically so that they represent more the real responses for average consumer.

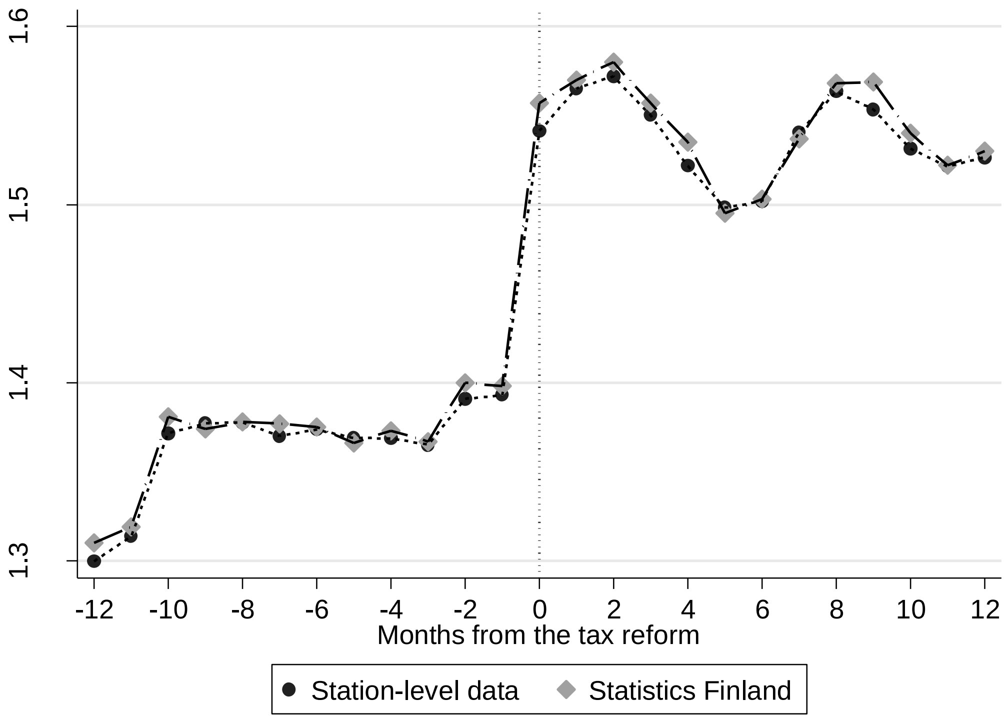
Table 3. Descriptive statistics of the price data in 2011 and 2012

	Diesel price		Gasoline (95E10) price	
	2011	2012	2011	2012
Number of day-and-station observations	56,503	54,259	55,759	52,513
Number of stations	1056	1041	1060	1027
Mean price (€/l)	1.36	1.54	1.55	1.66
Median price (€/l)	1.36	1.54	1.56	1.65
Standard deviation	0.05	0.05	0.05	0.06

A potential concern when using these data in econometric analysis is the possibility that individuals systematically record fuel prices incorrectly, intentionally or unintentionally. To remove obvious outliers, we restricted the data to observations with prices between 0.5–3.0 euros per liter. We also evaluated how serious the threat of misreporting might be by comparing the average monthly price levels calculated from the microdata to the evolution of the average gasoline and diesel fuel price components of the consumer price index (CPI), collected by Statistics Finland. The evolution of diesel prices in these two data sets is shown in Figure 1. The station-day microdata and CPI data on diesel prices develop very similarly over time. The difference in the average diesel prices in the two data sets is less than 1 euro cent in a month, on average. The station-day microdata and CPI data on gasoline prices exhibit a similar trend (Figure A2 in the Appendix). A caveat is that the price series in Figures 1 and A2 were calculated from six municipalities that are among the largest in Finland[7], as CPI data on fuel prices are only available for these locations. However, considering the accuracy of the microdata in the CPI sample municipalities and virtually identical trends in the microdata for other locations, we conclude that misreporting is not a significant concern.

[7] Helsinki, Mikkeli, Oulu, Rovaniemi, Seinäjoki and Turku.

Figure 1. Comparison of average monthly consumer prices of diesel (euros per liter): Consumer-reported microdata vs. CPI-data on diesel from Statistics Finland



To study heterogeneity in pass-through, we divided the station-location pairs into groups based on the income, housing price, population density and urban-rural classification of the gas station location, defined by its postal code. Income, population density, housing price and rural classification data are available at the postal code level only from 2012 onwards. The 2012 values were thus used for each station–location pair in both 2011 and 2012. Income and population density data were matched to gas stations at the three-digit postal code level, aggregating from Statistics Finland data for five-digit postal code areas.[8] Aggregation was not possible for housing prices as the number of condominiums within the five-digit postal code areas is not available, and analysis was carried out at the five digit level. Furthermore, housing prices were not available for some five-digit areas. Gas stations in these areas were excluded from the housing price analysis.

As the urban-rural classification has seven classes, we also divided the station-location pairs into seven groups by income, housing prices and population density. For the quantitative measures, the seven groups are equal in that each group, or septile, represents one seventh of the total number of station-location pairs in the analysis. The seven classes of the urban-rural classification were numbered in ascending order of urbanization so that 1 indicates “sparsely populated rural area” and 7 “inner urban area”.

The station-location data represent altogether 476 three-digit postal code areas and 727 five-digit postal code areas. Housing prices are available for only 540 of the five-digit areas. Urban-rural classes 2, 6 and 7 each include 150–160 five-digit areas and the other classes 50-70. These differences in the numbers of postal code areas are reflected in the number of stations and price observations in each class, as seen in Table 4.

The share of observations from more urban areas is larger than one would expect solely based on the numbers of postal code areas and stations. Although the number of postal

[8] Postal codes in Finland have altogether five digits; the first two indicate the municipality or municipalities that the postal code area belongs to while the other digits describe location in more detail. Defining location at the full five-digit detail is not possible as income data are not reported for some five-digit postal code areas, due to a small population and data protection constraints. Pricing decisions made by gas stations could also be influenced by the income and wealth of individuals living in their vicinity even where the total customer base covers a larger area. If this is the case, using a small area definition could obscure the true distributional effects. As a robustness check, the analysis was also repeated using the more detailed five-digit postal code areas and less detailed municipalities. Using the former produced very similar results. The results acquired with the latter were largely similar as well, although the pass-through rate did not change as linearly with income and the other classification variables as when using the postal code areas.

code areas is equal across the septiles for income, housing prices and population density, there are more price observations in the higher septiles. The skewedness of these distributions in the case of the urban-rural classification and the population density grouping is natural. That fact that the income and housing price septiles exhibit the same skewedness is at least partially explained by significant overlap in urban and relatively affluent areas.[9] However, the disparities are not as striking in the number of gas stations, and overall the data likely provide a sufficiently accurate representation of regional price levels and trends.

Table 4. Number of observations and filling stations in 2011-2012

Septile/	Income		Housing prices		Population density		Urban-rural class	
class	N	Stations	N	Stations	N	Stations	N	Stations
1	11,603	97	9797	106	8651	105	5629	83
2	19,269	143	14,761	144	6364	100	18,050	213
3	20,501	145	21,850	147	9328	112	8297	86
4	18,474	163	24,091	146	16,014	145	15,653	131
5	23,121	163	28,692	136	29,426	185	16,146	91
6	37,884	171	44,713	138	48,551	194	54,502	222
7	88,182	235	52,648	101	100,700	276	100,716	288
Total	219,034	1117	196,552	918	219,034	1117	218,993	1114

3.3. Research methods

Identification in our econometric analysis is based on comparing diesel and gasoline prices around the 2012 reform, using the approach as Harju, Kosonen and Laukkanen (2017) who estimated the average pass-through of the 2012 tax increase using the same station-level data. The potential heterogeneity in diesel tax pass-through in the 2012 reform is studied by employing a difference-in-differences (DID) approach. The treatment group here is diesel prices, the control groups gasoline prices and the treatment the diesel tax increase on January 1, 2012. Our focus is on how the pass-through rate varies across regional income and wealth measures, population density and urban versus rural areas.

In our basic DID model takes the form

$$P_{sft} = \beta_1 + \beta_2 D_f + \beta_3 A_t + \beta_4 D_f A_t + \varepsilon_{sft} \quad (2)$$

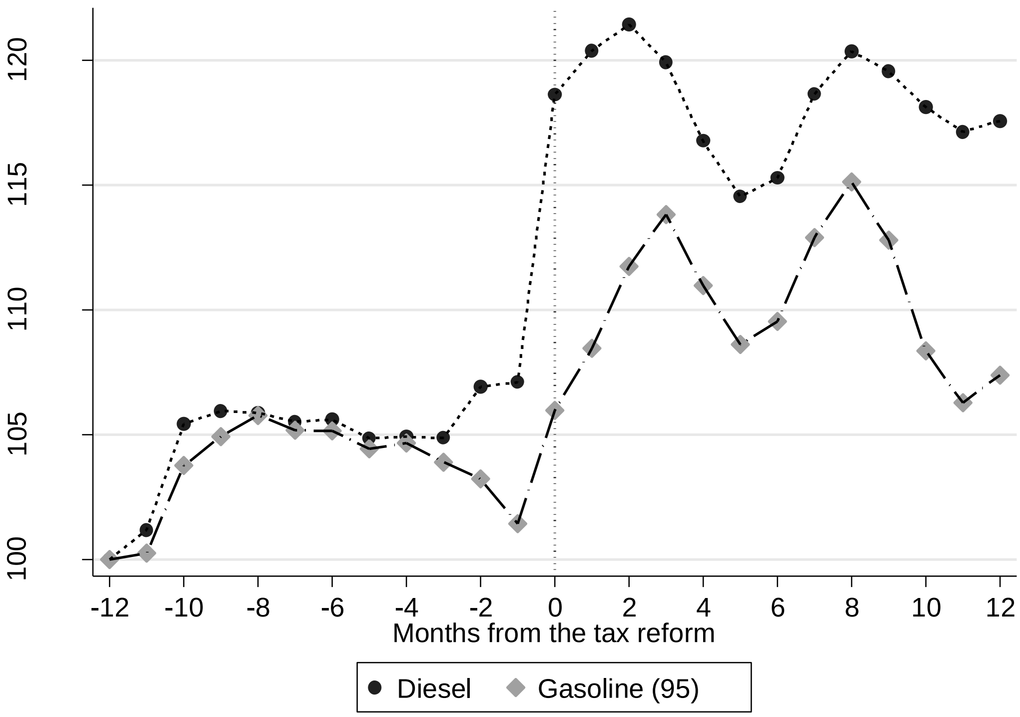
where P_{sft} is the price of fuel f at station s on day t, D_f is an indicator variable for diesel and A_t for the post-reform period. In other words, the potential prices of each fuel are determined by the sum of a time-invariant fuel-specific effect and a time-specific effect common to both fuels. The model assumes that the prices of both fuels would have followed parallel time trends in the absence of the treatment. Provided that the assumption of common trends holds, β_4 identifies the causal effect of the tax increase.

The credibility of the parallel trends assumption is examined by comparing the historical price trends of diesel and gasoline. Figure 3 plots the price changes of diesel and gasoline between 2011–2012. The two fuels exhibited similar trends both prior to and after the reform and the price of diesel increases sharply at the turn of the year (time 0). However, the prices diverge just before the turn of the year so that a slight increase in diesel prices coincides with a decline in gasoline prices. As noted by Harju, Kosonen and Laukkanen (2017), the divergence may be due to anticipation effects or reflect the transition to winter diesel. The amount of diesel imported to Finland nearly doubled in late 2011 only to return to its previous level immediately after the turn of the year, suggesting a clear supply-side anticipation

[9] Spearman's rank correlation is 0.72 between the urban-rural classification and the house price septile grouping, and 0.50 between the urban-rural classification and the income septile grouping.

effect. The potential impact of anticipation on market prices is unclear, though, as there might have been anticipation on the demand-side as well. Following Harju, Kosonen and Laukkanen (2017), an alternative model excluding six months around the reform is estimated to account for potential anticipation. Additionally, an indicator variable for winter months from October to March for the possible winter diesel effect is included in the main specification.

Figure 2. Price trends of diesel and gasoline



Differences in the average pass-through rates between the seven income, housing price, population density and urban-rural classification groups are estimated using a modified difference-in-differences regression. If the parallel trends assumption holds in every group considered, the model identifies the causal effect of the diesel tax raise. The basic equation to be estimated using ordinary least squares takes the form

$$\begin{aligned} P_{sft} = {} & \beta_1 + \beta_2 D_f + \beta_3 A_t + \beta_4 \boldsymbol{G}_s + \beta_5 D_f A_t + \beta_6 D_f \boldsymbol{G}_s + \beta_7 A_t \boldsymbol{G}_s \\ & + \beta_8 D_f A_t \boldsymbol{G}_s + \beta_9 \boldsymbol{X} + \delta_c + \varepsilon_{sft} \end{aligned} \quad (3)$$

where $\boldsymbol{G}_s$ is a vector of indicator variables representing each group (septile or class), and $\boldsymbol{X}$ is a vector of covariates that include the daily price of Brent crude oil, the daily EU ETS CO_2 emission permit price, the daily EUR/USD exchange rate, the winter diesel indicator and its interaction with D_f, and an indicator for unmanned stations[10]. Both these covariates, which represent fuel demand and supply shifters, as well as the station chain fixed effects δ_c are included to increase estimation precision. Lastly, to mitigate any bias emerging from a potential annual cyclical component in the difference between gasoline and diesel prices, the full calendar years of 2011 and 2012 are chosen as the pre and post-reform periods in the "whole period" model.[11]

[10] Whether or not a station is an unmanned self-service station largely determines the other station characteristics on which data were acquired. Thus, the other variables provide little additional information and are excluded from the model for parsimony.

[11] Historical data for diesel and gasoline prices suggest an annual cyclical component in the diesel and gasoline price difference, peaking during the summer months and being the lowest in December or January. This is probably explained by both the statutory replacement of regular diesel with a more expensive winter blend and higher production costs during the winter.

Interpretation and additional econometric considerations

The diesel tax increase considered in the analysis coincided with an increase in the gasoline tax, which complicates the interpretation of the coefficients in (3). In the absence of a gasoline tax increase, the β_5 coefficient would identify the causal effect of the diesel tax increase on diesel prices in the baseline group. The coefficients in vector β_8 in turn would indicate how the price changed in each group relative to the baseline group. Pass-through in the baseline group would be calculated as $\beta_5/\Delta t_d$, where Δt_d is the change in the diesel tax between 2011–2012. The pass-through difference in the other groups relative to the baseline group would be calculated by replacing β_5 with the appropriate coefficient in vector β_8.

With the concurrent increase in the gasoline tax, however, the estimated coefficients measure how much of the difference in the diesel and gasoline tax increases was passed through to diesel prices. Determining the pass-through rates then requires taking into account the change in the gasoline tax, Δt_g, as well. This is implemented here by dividing the estimated coefficients by $\Delta t_d - \Delta t_g$ instead of Δt_d. That is, the difference in price changes is proportioned to the difference in tax increases. Additionally, because P_{sft} is the VAT-inclusive retail price, Δt_d and Δt_g must also be defined as the VAT-inclusive excise tax raises calculated in Table 2. An alternative but identical approach would have been to define P_{sft} as the VAT-exclusive price and ignore the VAT component in Δt_d and Δt_g.

Interpreting the estimated pass-through as applicable to the overall diesel tax increase Δt_d, rather the only the diesel and gasoline tax increase differential $\Delta t_d - \Delta t_g$, requires assuming that the true unobserved pass-through rates of the gasoline and diesel tax increases were equal (in addition to the assumption of parallel trends).[12] The same holds true group-specific estimates in coefficient vector β_8.[13]

Finally, the standard ordinary least squares method requires observations to be independently and identically distributed so that the estimated standard errors are unbiased. It seems unlikely that fuel prices at different stations would be completely independently determined; for example, prices in certain regions or stations in a station chain are likely to be interdependent. This interdependence means that the error terms, ε_{sft}, are correlated both in time and between observations. We account for the error correlation by using a sandwich estimator that allows for correlation within specific clusters of data and results in more correct standard errors. The estimator still assumes independence of errors across clusters. Even if this assumption does not hold, the cluster robust standard errors are preferable compared to the standard non-robust errors.

The sandwich estimator provides consistent estimates of the standard errors only when the number of clusters approaches infinity (Cameron, Gelbach and Miller 2008). We cluster the errors in the difference-in-differences regression on municipalities. The number of clusters could be increased by clustering on the three-digit postal code areas. However, Cameron and Miller (2015) remark that while there is no rule for choosing the appropriate level of clustering, the consensus among empirical researchers is to cluster on the broadest possible level on which errors are likely to be correlated, as long as the number of clusters re-

[12] Denoting the difference between the average prices of diesel in the pre- and post-reform periods by Δp_d, and the corresponding difference in gasoline prices by Δp_g, the estimated coefficient $\hat{\beta}_5$ in Equation (3) can be expressed as follows:

$$\hat{\beta}_5 = \Delta p_d - \Delta p_g = \Delta t_d PT_d + \Delta p_{t,d} - \left(\Delta t_g PT_g + \Delta p_{t,g}\right) \tag{4}$$

where PT_d and PT_g are the pass-through rates of the diesel and gasoline tax respectively and $\Delta p_{t,d}$ and $\Delta p_{t,g}$ are the potential price changes in the absence of tax increases. If the assumption of parallel trends holds, these potential price changes are equal, $\Delta p_{t,d} = \Delta p_{t,g}$, and the expression simplifies to $\hat{\beta}_5 = \Delta t_d \times PT_d - \Delta t_g \times PT_g$. Hence, assuming that the trends were in fact parallel, and dividing $\hat{\beta}_5$ by $\Delta t_d - \Delta t_g$, the estimated diesel tax pass-through, $PT_{d,est}$, is:

$$PT_{d,est} = \frac{\hat{\beta}_5}{\Delta t_d - \Delta t_g} = \frac{\Delta p_d - \Delta p_g}{\Delta t_d - \Delta t_g} = \frac{\Delta t_d \times PT_{d,act} - \Delta t_g \times PT_{g,act}}{\Delta t_d - \Delta t_g} \tag{5}$$

where act refers to the true unobserved pass-through rates. From Equation (5), $PT_{d,est} = PT_{d,act}$ if and only if $PT_{d,act} = PT_{g,act}$.

[13] Applying Equation (5) to each group separately implies that if, say, the true gasoline tax pass-through was higher in richer regions while the true unobserved diesel tax pass-through was constant across the regions, the model in (3) would result in a higher diesel tax pass-through estimate for poorer regions.

mains sufficiently large. In this sense we argue that the municipality level is the most appropriate level of clustering in our study.[14]

3.4. Results

Pass-through across income groups

Table 5 presents the pass-through results by income septile as well as the average pass-through for the data on the whole. Columns (1) and (2) show the results for models using data for the entire period 2011–2012, and columns (3) and (4) for models where the three months preceding and following the tax reform have been excluded. The estimated average pass-through gives the proportion of the difference in diesel and gasoline tax increases, $\Delta t_d - \Delta t_g$ or 10,34 c/l, that was passed on to consumer prices. The results by income group clearly indicate heterogeneity in the price impacts of the diesel tax increase: the estimated coefficients of the three-way interactions between the fuel variable, the post-tax increase period and the income septile are all negative and decrease with regional income. The corresponding pass-through rates were calculated by dividing the sum of the estimated coefficients in the first septile and the septile of interest by the difference in diesel and gasoline tax increases. The pass-through rates range from 75 to 80 percent in the lowest income septile and from 61 to 67 percent in the highest income septile.

Figure 3 plots the three-way interaction coefficient from the second column of Table 5 divided by the difference in diesel and gasoline tax increases, together with 95 percent confidence intervals, and illustrates the clear monotonic decrease in pass-through with respect to income septile.

The models where the three months preceding and following the tax reform have been excluded produce lower pass-through rate estimates as they ignore both the divergence in the price trends of diesel and gasoline prior to the tax reform and the sharper increase in diesel prices immediately after the reform. The degree of asymmetry in the price responses, however, is slightly higher in these models.

The results are also virtually unaffected by the inclusion of control variables, which only increase estimation precision. Although the estimated coefficients are statistically significant at the 5 or 1 percent level only in the three highest septiles, the evident negative linear relationship between income group and the estimated size of the coefficient lend support to the hypothesis of heterogeneity in pass-through. The joint significance tests of the three-way interactions also clearly support this conclusion at the 5 percent level in all the specifications except for the third.

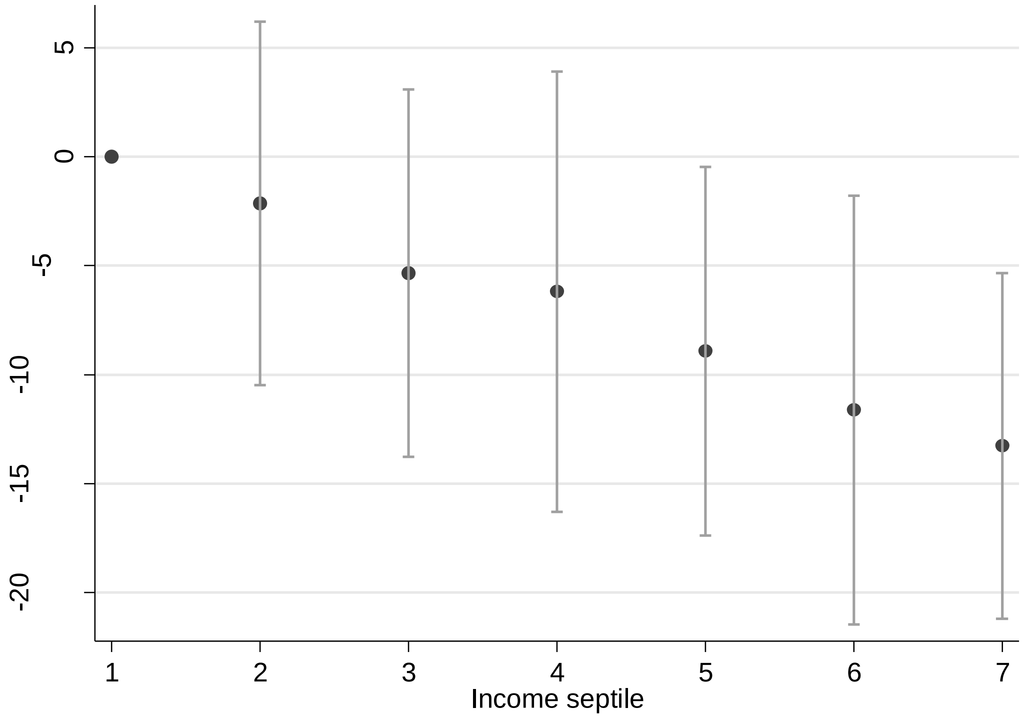
[14] As a robustness check, we considered an alternative specification that clustered the errors on station chains. Since this clustering only produced eleven clusters, which falls below the minimum number of clusters for the sandwich estimator suggested by Cameron and Miller (2015), we instead employed a wild bootstrap method of estimating cluster-robust standard errors. This method has been deemed to produce accurate rejection rates with as few as 5–10 clusters (Cameron et al. 2008). The results were found reasonably robust to the choice of the clustering variable (the full results, not reported here at the interest of space, are available in Palanne 2018).

Table 5. Pass-through results by income septiles

	Whole period		Six months excluded	
	(1)	(2)	(3)	(4)
Estimated coefficients				
D	-0.199***	-0.224***	-0.211***	-0.223***
	(0.004)	(0.004)	(0.004)	(0.003)
A	0.108***	0.084***	0.112***	0.116***
	(0.003)	(0.003)	(0.005)	(0.004)
D×A	0.082***	0.083***	0.077***	0.079***
	(0.004)	(0.004)	(0.005)	(0.004)
D×A×G 2nd septile	-0.003	-0.002	-0.004	-0.004
	(0.005)	(0.004)	(0.005)	(0.004)
D×A×G 3rd septile	-0.006	-0.006	-0.010	-0.009
	(0.005)	(0.004)	(0.006)	(0.005)
D×A×G 4th septile	-0.009	-0.006	-0.009	-0.008
	(0.006)	(0.005)	(0.007)	(0.006)
D×A×G 5th septile	-0.007	-0.009*	-0.007	-0.010*
	(0.005)	(0.004)	(0.006)	(0.005)
D×A×G 6th septile	-0.012*	-0.012*	-0.013*	-0.015**
	(0.006)	(0.005)	(0.006)	(0.006)
D×A×G 7th septile	-0.013**	-0.014**	-0.014**	-0.016***
	(0.005)	(0.004)	(0.005)	(0.005)
Constant	1.564***	1.383***	1.567***	1.270***
	(0.008)	(0.012)	(0.007)	(0.014)
Controls	No	Yes	No	Yes
Pass-through				
Average	70.2%	70.6%	64.2%	64.8%
1st septile	79.5%	80.1%	74.5%	76.3%
2nd septile	77.0%	78.0%	70.8%	72.1%
3rd septile	73.5%	74.8%	64.9%	67.6%
4th septile	70.6%	73.9%	65.5%	68.5%
5th septile	72.4%	71.2%	67.6%	66.5%
6th septile	68.2%	68.5%	61.6%	62.0%
7th septile	67.2%	66.9%	61.2%	61.0%
F-test D×A×G all	3.18**	4.16***	2.02	2.91**
	[0.005]	[0.001]	[0.063]	[0.009]
N	219,034	219,034	163,693	163,693
R^2	0.81	0.88	0.82	0.89

The dependent variable is fuel price in euros per liter. The controls include the daily Brent crude oil price, the EU ETS CO_2 price, the EUR/USD exchange rate, dummies for winter diesel, unmanned stations and station chains. Pass-through in septile s is the sum of the coefficients on $D \times A$ and $D \times A \times G_s$ divided by the difference between the VAT-inclusive diesel and gasoline tax changes, or 0.1034. Standard errors (in parentheses) are clustered at the municipality level. The p-value of the joint significance test of all the D×A×G coefficients is in brackets. *, ** and *** denote significance at the 5%, 1% and 0.1% level respectively.

Figure 3. Difference in pass-through by income septiles



Pass-through across housing price groups

Table 6 presents the results by housing price septile. The estimated three-way interaction coefficients and the corresponding pass-through rates show that higher regional housing prices are associated with lower diesel tax pass-through. The individual coefficients are statistically significant only in the highest septiles, but the F-test results indicate that the group differences as a whole are statistically significant in all the model specifications. The differences in pass-through are slightly more pronounced than those across income septiles, at 76 to 82 percent in the lowest housing price septile and 58 to 65 percent in the highest housing price septile. These results are also robust to including control variables and station chain fixed effects, both of which serve to increase precision. Echoing the results across income groups, pass-through rates are 5 to 7 percentage points lower in the specifications in columns (3) and (4) and exhibit a steeper downward slope with respect to housing prices. The latter is, again, driven by the asymmetric turn-of-the-year price dynamics between the septiles.

Insofar as housing prices are a suitable proxy for wealth, the results across housing price groups and income groups both suggest regressivity in diesel taxation.

Table 6. Pass-through results by housing price septiles

	Whole period		Six months excluded	
	(1)	(2)	(3)	(4)
Estimated coefficients				
D	-0.200***	-0.225***	-0.210***	-0.223***
	(0.004)	(0.004)	(0.003)	(0.003)
A	0.106***	0.078***	0.112***	0.112***
	(0.004)	(0.004)	(0.006)	(0.006)
D×A	0.084***	0.086***	0.079***	0.081***
	(0.004)	(0.004)	(0.004)	(0.004)
D×A×G 2nd septile	-0.006	-0.007	-0.003	-0.006
	(0.005)	(0.004)	(0.006)	(0.005)
D×A×G 3rd septile	-0.008	-0.008	-0.004	-0.006
	(0.005)	(0.005)	(0.005)	(0.005)
D×A×G 4th septile	-0.012*	-0.011*	-0.014**	-0.013**
	(0.005)	(0.004)	(0.005)	(0.005)
D×A×G 5th septile	-0.009*	-0.009*	-0.011*	-0.011**
	(0.005)	(0.004)	(0.005)	(0.004)
D×A×G 6th septile	-0.014**	-0.015***	-0.016**	-0.018***
	(0.005)	(0.004)	(0.005)	(0.005)
D×A×G 7th septile	-0.017***	-0.019***	-0.018***	-0.021***
	(0.004)	(0.004)	(0.005)	(0.004)
Constant	1.568***	1.385***	1.570***	1.272***
	(0.007)	(0.012)	(0.006)	(0.014)
Controls	No	Yes	No	Yes
Pass-through				
1st septile	81.6%	82.7%	76.0%	78.1%
2nd septile	76.1%	75.5%	73.1%	72.6%
3rd septile	74.3%	75.0%	71.8%	72.3%
4th septile	70.1%	71.8%	62.8%	65.1%
5th septile	72.9%	74.3%	65.2%	67.2%
6th septile	68.0%	68.2%	60.6%	60.8%
7th septile	65.1%	64.2%	58.6%	57.8%
F-test D×A×G all	4.62***	5.65***	5.02***	6.44***
	[<0.001]	[<0.001]	[<0.001]	[<0.001]
N	196,552	196,552	146,603	146,603
R^2	0.81	0.87	0.83	0.89

The dependent variable is fuel price in euros per liter. The controls include the daily Brent crude oil price, EU ETS CO_2 price, the EUR/USD exchange rate, dummies for winter diesel, self-service stations and station chains. Pass-through in septile s is the sum of the coefficients on $D \times A$ and $D \times A \times G_s$ divided by the difference between the VAT-inclusive diesel and gasoline tax changes, or 0.1034. Standard errors (in parentheses) are clustered at the municipality level. The p-value of the joint significance test of all the D×A×G coefficients is in brackets. *, ** and *** denote significance at the 5%, 1% and 0.1% level respectively.

Pass-through across population density groups and urban-rural classification

Table 7 displays the pass-through results by population density septiles. The results are similar to those obtained from the income and housing price regressions: the estimated pass-through decreases with population density nearly linearly – the difference between the first and the seventh septile is about 13 percentage points in all four model specifications. The estimated pass-through rates again range between 60 and 80 percent, and the differences relative to the first septile are statistically significant in the highest septiles. The F-tests also support the existence of group differences. Figure 4 plots the coefficients from the model in column (2) as well as their 95 percent confidence intervals, illustrating lower pass-through in densely than in sparsely populated areas.

The pass-through results across the urban-rural classes, reported in Table 8, exhibit the same pattern of heterogeneity as the previous three sets of regressions. Pass-through appears to fall with urbanicity as well, and the difference between the most urban and most rural regions is close to 15 percentage points.

Figure 4. Difference in pass-through by population density septiles

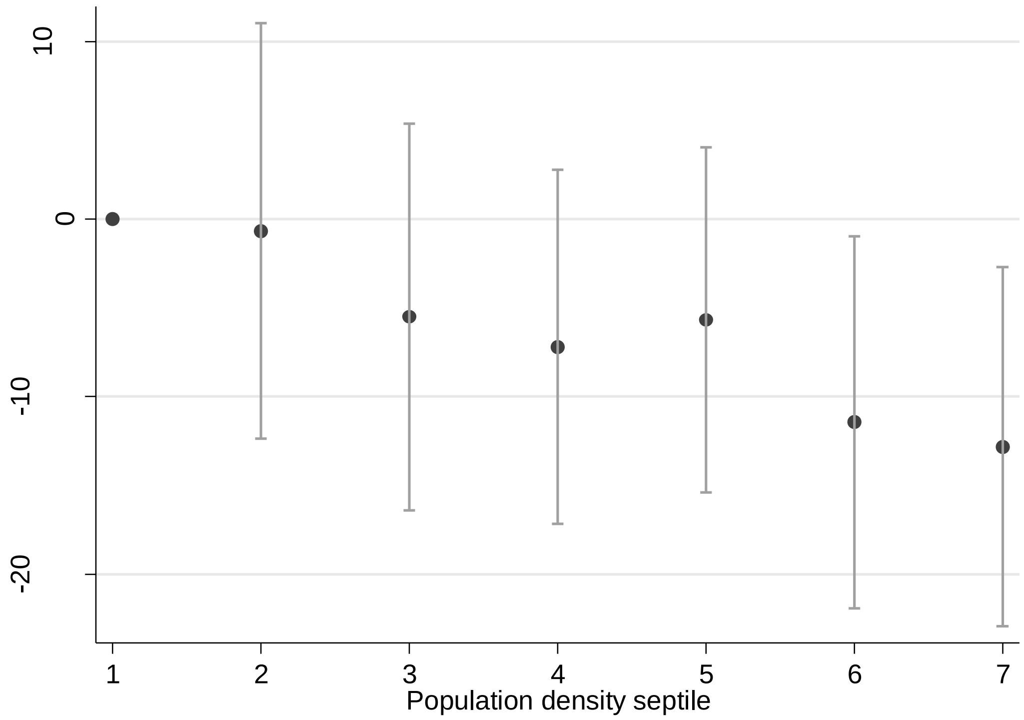


Table 7. Pass-through results by population density septiles

	Whole period		Six months excluded	
	(1)	(2)	(3)	(4)
Estimated coefficients				
D	-0.200***	-0.224***	-0.210***	-0.221***
	(0.005)	(0.005)	(0.004)	(0.004)
A	0.109***	0.084***	0.117***	0.119***
	(0.004)	(0.005)	(0.006)	(0.006)
D×A	0.082***	0.083***	0.075***	0.077***
	(0.005)	(0.005)	(0.006)	(0.005)
D×A×G 2nd septile	0.001	-0.001	0.002	0.000
	(0.007)	(0.006)	(0.007)	(0.006)
D×A×G 3rd septile	-0.003	-0.006	0.005	0.001
	(0.006)	(0.006)	(0.007)	(0.007)
D×A×G 4th septile	-0.006	-0.007	-0.004	-0.006
	(0.006)	(0.005)	(0.007)	(0.006)
D×A×G 5th septile	-0.006	-0.006	-0.004	-0.004
	(0.006)	(0.005)	(0.006)	(0.006)
D×A×G 6th septile	-0.012*	-0.012*	-0.009	-0.010
	(0.006)	(0.006)	(0.006)	(0.006)
D×A×G 7th septile	-0.012*	-0.013*	-0.013*	-0.014*
	(0.005)	(0.005)	(0.006)	(0.006)
Constant	1.576***	1.385***	1.577***	1.271***
	(0.007)	(0.012)	(0.006)	(0.014)
Controls	No	Yes	No	Yes
Pass-through				
1st septile	79.4%	80.3%	72.1%	74.1%
2nd septile	80.1%	79.7%	73.8%	74.2%
3rd septile	76.3%	74.8%	77.1%	75.2%
4th septile	73.2%	73.1%	67.7%	68.0%
5th septile	73.3%	74.7%	68.0%	69.8%
6th septile	68.0%	68.9%	63.2%	64.1%
7th septile	67.5%	67.5%	59.9%	60.2%
F-test D×A×G all	2.90**	2.60*	3.55**	3.46**
	[0.009]	[0.018]	[0.002]	[0.003]
N	219,034	219,034	163,693	163,693
R^2	0.81	0.88	0.83	0.89

The dependent variable is fuel price in euros per liter. The controls include the daily Brent crude oil price, the EU ETS CO_2 price, the EUR/USD exchange rate, dummies for winter diesel, self-service stations and station chains. Pass-through in septile s is the sum of the coefficients on $D \times A$ and $D \times A \times G_s$ divided by the difference between the VAT-inclusive diesel and gasoline tax changes, or 0.1034. Standard errors (in parentheses) are clustered at the municipality level. The p-value of the joint significance test of all the D×A×G coefficients is in brackets. *, ** and *** denote significance at the 5%, 1% and 0.1% level respectively.

Table 8. Pass-through results by urban-rural classes

	Whole period		Six months excluded	
	(1)	(2)	(3)	(4)
Estimated coefficients				
D	-0.198***	-0.221***	-0.207***	-0.218***
	(0.005)	(0.005)	(0.005)	(0.005)
A	0.110***	0.086***	0.117***	0.120***
	(0.004)	(0.005)	(0.005)	(0.006)
D×A	0.083***	0.083***	0.079***	0.080***
	(0.005)	(0.006)	(0.006)	(0.006)
D×A×G 2nd class	-0.004	-0.003	-0.003	-0.003
	(0.006)	(0.006)	(0.007)	(0.007)
D×A×G 3rd class	-0.006	-0.008	-0.004	-0.008
	(0.007)	(0.006)	(0.008)	(0.007)
D×A×G 4th class	-0.004	-0.005	-0.004	-0.005
	(0.006)	(0.006)	(0.007)	(0.007)
D×A×G 5th class	-0.013	-0.012	-0.013	-0.013
	(0.008)	(0.008)	(0.008)	(0.009)
D×A×G 6th class	-0.012*	-0.011	-0.014*	-0.013*
	(0.006)	(0.006)	(0.006)	(0.006)
D×A×G 7th class	-0.014*	-0.013*	-0.016*	-0.017**
	(0.006)	(0.006)	(0.006)	(0.007)
Constant	1.575***	1.385***	1.575***	1.271***
	(0.004)	(0.012)	(0.004)	(0.014)
Controls	No	Yes	No	Yes
Pass-through				
1st class	80.6%	80.7%	76.2%	77.2%
2nd class	77.0%	78.2%	73.1%	74.8%
3rd class	74.8%	72.9%	72.4%	69.4%
4th class	77.0%	75.6%	72.4%	72.0%
5th class	68.5%	69.2%	63.4%	64.9%
6th class	69.2%	70.5%	62.8%	64.2%
7th class	67.6%	67.7%	60.4%	60.7%
F-test D×A×G all	3.13**	2.63*	3.69**	3.60**
	[0.006]	[0.017]	[0.002]	[0.002]
N	218,993	218,993	163,656	163,656
R^2	0.81	0.87	0.82	0.89

The dependent variable is fuel price in euros per liter. The controls include the daily Brent crude oil price, the EU ETS CO_2 price, the EUR/USD exchange rate, dummies for winter diesel, self-service stations and station chains. Pass-through in septile s is the sum of the coefficients on $D \times A$ and $D \times A \times G_s$ divided by the difference between the VAT-inclusive diesel and gasoline tax changes, or 0.1034. Standard errors (in parentheses) are clustered at the municipality level. The p-value of the joint significance test of all the D×A×G coefficients is in brackets. *, ** and *** denote significance at the 5%, 1% and 0.1% level respectively.

Validity of the results in light of the simultaneous gasoline tax increase

As pointed out in Section 3.3, the estimated diesel tax pass-through rates are unbiased only if the assumption of parallel trends holds and the true unobserved gasoline tax pass-through rates were equal to those of the diesel tax. We next discuss the implications of a possible divergence between the true diesel and gasoline pass-through rates for our results.

The diesel tax change in 2012 was much larger than the simultaneous gasoline tax change, at $\Delta t_d = 12.28$ and $\Delta t_g = 1.94$ in euro cents per liter. Suppose that that the assumption of parallel trends holds. We then have

$$\frac{\partial PT_{d,est}}{\partial PT_{g,act}} = \frac{-\Delta t_g}{\Delta t_d - \Delta t_g} \approx -0.19 \quad (6)$$

That is, given the true diesel tax pass-through rate, a 10-percentage point difference between the true pass-through rates of diesel and gasoline produces a 1.9 percentage point error in the opposite direction in the estimated diesel tax pass-through rate.

The differences in the estimated pass-through rates between the highest and lowest septiles or classes, for all the grouping variables, are 13–18 percentage points. Only a substantial divergence of the true gasoline tax pass-through rate from the true diesel pass-through rate would completely invalidate the results suggesting heterogeneity and regressivity in the pass-through of diesel taxes.[15]

3.5. Future data collection and research needs

One of this project's objectives was to study the impacts of fuel tax changes on fuel demand in Finland. We explored the possibilities for obtaining data on the quantities of fuel sold, at al sufficiently disaggregated level. However, up until fall 2018, no official data on quantities sold in retail have been collected. The only data source with somewhat disaggregated information on retail quantities for Finland has been the Finnish Petroleum and Biofuels Association (ÖBA), an organization representing the interests of the industry. ÖBA has collected information at the level of month and municipality and month and station brand (corporation). These data are not sufficiently detailed to allow for reliable estimation of demand effects or demand elasticities.

As ÖBA will close down at the end of 2018, even aggregate information on retail quantities will not be collected unless another organization steps in. For reliable information on the relationship between fuel prices and -taxes and fuel quantities sold, it would be important to systematically collect data on quantities at the gas station and day level.

Future research could examine potential anticipatory behavior by fuel buyers before tax increases. Coglianese et al. (2017) provide evidence that large elasticity estimates found in literature instrumenting gasoline prices using gasoline taxes may be an artifact of not having accounted for shifts in gasoline purchases in anticipation of gasoline tax changes. Forward-looking fuel buyers - final consumers as well as wholesale distributors and retail gas stations - are likely to take upcoming tax changes into account when deciding how much fuel to buy and store. In Finland, fuel excise taxes are remitted at the distributor level. That is, excise taxes are paid by distributors at the time fuels are transferred from a refinery or importer to domestic distributor storage. As fuels have a long storage lifespan, distributors and retailers may anticipate tax changes by filling up their storage tanks right before the higher tax goes into effect, and consumers may fill up their tanks one last time right before the tax change. Such anticipatory behavior could affect the level of pass-through.

[15] The multiplicative difference-in-differences model was also estimated using Swedish diesel prices as a control. The Swedish price data used here are mean daily prices of diesel at all manned Circle K stations in Sweden. Using Swedish diesel prices produces higher pass-through estimates, with the average pass-through estimates above 90% for all models. Regarding heterogeneity, the picture emerging from these results is largely consistent with the main results. First, pass-through rates are the highest in the least affluent and the most rural regions and the lowest in the wealthiest and the most urban regions. The difference in pass-through between the lowest and highest septiles or urban-rural classes was again 13–18 percentage points. The full results are documented in Palanne (2018).

Another future research topic would be to study the response to smaller tax changes. There are intuitive reasons for why pass-through could be different for large and small tax changes. Large tax changes are likely to receive significant media attention and are thus more evident for consumers, retailers and distributors. In particular, the supply side response to a large tax change may differ from the response to a small change, especially if the change is known well before implementation.

Finally, one obvious explanation for heterogeneity in pass-through is competition. The degree of competition could affect pass-through and be behind the heterogeneity in pass-through suggested by our results. Pass-through could be higher in areas where there is no or only little competition compared to areas of close to full competition. To offer a more complete view of the reasons behind the observed price responses and heterogeneity in pass-through, the analysis could be extend to examine the role of competition.

4. CAR AND VEHICLE TAXES

4.1. Taxes on vehicles in Finland

Car taxation and reforms

Almost all cars driven in Finland are imported. Finland levies a tax on all vehicles imported into Finland – passenger cars, vans, buses, motorcycles, etc. – whether the vehicle is new or old, and which must be remitted before a vehicle's introduction to or first registration in Finland. We will refer to this as the car tax. From the beginning of 2017 the car tax is collected by the Finnish Tax Administration, both for vehicles imported into Finland and the very few vehicles manufactured in Finland.[16] In this way the car tax is applied to both new and used vehicles upon their registration in Finland. The person entered in the register as the owner of the vehicle is liable for the car tax. However, if the vehicle is imported into Finland by a business that Tax Administration has authorized as a registered agent, the registered agent is liable for the car tax.[17]

Finland has had a long history of taxing cars; the very first car imported to Finland in 1900 faced a heavy duty. After that, cars newly registered in Finland have faced high taxes in the form of duties, or since 1958 in the form of car taxes. Since 1994, a car tax of almost 100% (tax-exclusive) has been levied on the import value of the car.[18] In addition, value-added tax (VAT) of 22% was due on the car-tax-inclusive value of the car. Thus, the total tax burden facing new cars was more than 130% of the import value of a car.

The 2003 reform

The pre-2003 car tax system was particularly unfavorable for imported used cars as Finnish Customs estimated the taxable value of imported cars to be very high, based on the taxable value of a similar new car in Finland with 5% annual depreciation rate based on the age of the car. This created large car taxes on used imported cars, in many cases over 200% tax rates. In September 2002 the European Court of Justice saw this distorting the EU inner markets and thus Finland was forced to change the car tax law so that the amount of the tax should not exceed the residual tax incorporated in the value of a similar vehicle on the Finnish car market.

[16] From the beginning of 2017 the collection of car taxes was transferred from the Finnish Customs to the Finnish Tax Administration.

[17] If the tax cannot be collected from the registered agent, the person entered in the register as the vehicle's owner is liable for the tax, unless he or she can demonstrate having paid to the registered agent or its representative an amount expected to be the tax liability.

[18] Finlex 1482/1994.

Major changes were made by a car tax law[19] passed in May 2003 that applied to cars imported to Finland as of January 2003.[20] The two major changes that applied to all cars were (1) to change the definition of the tax base of cars and (2) to reduce car tax rates. The tax base, which had been tax-exclusive, became tax-inclusive. Customs began to collect data on the prices of cars in Finland to determine the general retail sales price of a car, which is the average consumer price of a similar car in Finland, so that the car tax base now also included possible profit margins of retailers and transaction costs in Finland. The car tax rate applied to this taxable value was set to 28% after the reform.

An example illustrates this somewhat complicated system. Consider a new car that is imported to Finland with a price tag of 10,000 euros. Prior to May 2003, the tax base was 10,000 euros minus a deduction of 770 euros. Thus the 100% car tax was 10,000–770 = 9,230 euros. VAT was owed on top of this at the rate of 22%, so that total tax-inclusive price of the car amounted to (10,000+9,230)*1.22 = 23,460.60 euros (assuming full pass-through of the tax). After May 2003, the same car would be subject to a tax-inclusive definition of the tax base (minus an exemption of 650 euros) with a lower tax rate of 28%. Thus, we need to first add the car tax to the import value and then add the VAT to get an estimate for the general retail sales value of a car. The car tax is added to that value. The all-tax inclusive value of the car would then be (10,000*1.28*1.22–650)*1.28 = 19,156. Thus, our example car would have been about 18% less expensive than before the reform assuming full pass-through to prices of each tax, but not taking into account potential profit margins in the general retail sales value (the tax base).

The 2008 reform

The next major change took effect on January 1, 2008[21], when the car tax schedule was altered to depend on the CO2 emissions of the car. This was a major change, as prior to this reform the car tax rate was approximately 28% for all cars. Now the car tax rate varied between 12.2% and 48.8%, depending on the CO2 emissions, with the highest tax rate for cars with CO2 emissions exceeding 360 g/km. If the CO2 emissions were not available for a car, then the total weight and the motive power source of the car (petrol/diesel) entered into a formula for a presumptive CO2-emission level, which then defined the car tax rate.

The 2009 reform

Before April 2009 value added tax (VAT) was paid according to the taxable value of a car. From April 2009 this was abolished but the share of VAT was mechanically calculated into the car tax rate. Thus, the reform of April 2009 did not change the tax burden of new or imported old cars. This change was made due to the rulings of European Court of Justice, where it concluded that Finnish tax law was not compatible with EU laws.

The 2012 reform

In April 2012 the government reformed the car tax law by reducing the tax rate for low-emission vehicles and increasing it for high-emission vehicles. Before the reform the car tax rates varied between 12.2% and 48.8%, and after the reform 5% and 50% depending on the amount of CO2 (g/km). The tax rate schedule imposed in 2012 is the current tax schedule.
The values for acceptable deduction were also changed in 2012 reform. The standard deduction amounts to 5% of the price plus €750, or a single sum of €1500, whichever is larger. The amount of deductions can be no more than 30% of the asking price.

From the beginning of 2015 there was also a change for migration cars. They were tax exempted up to the value of 13,450 euros, and from the beginning of 2015 this exemption was abolished. According to a transit rule, those cars that were purchased before the end of 2014 could still benefit from the exemption, if they are imported to Finland before the end of 2017.

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[19] Finlex 266/2003.

[20] The motivation for this change was that the EU Court of Justice ruled that the Finnish tax system of used cars was too heavy and thus favored new cars. This change reduced the taxation of used cars in general, and especially for recently produced used cars.

[21] Finlex 1292/2007.

Car taxation in the present day

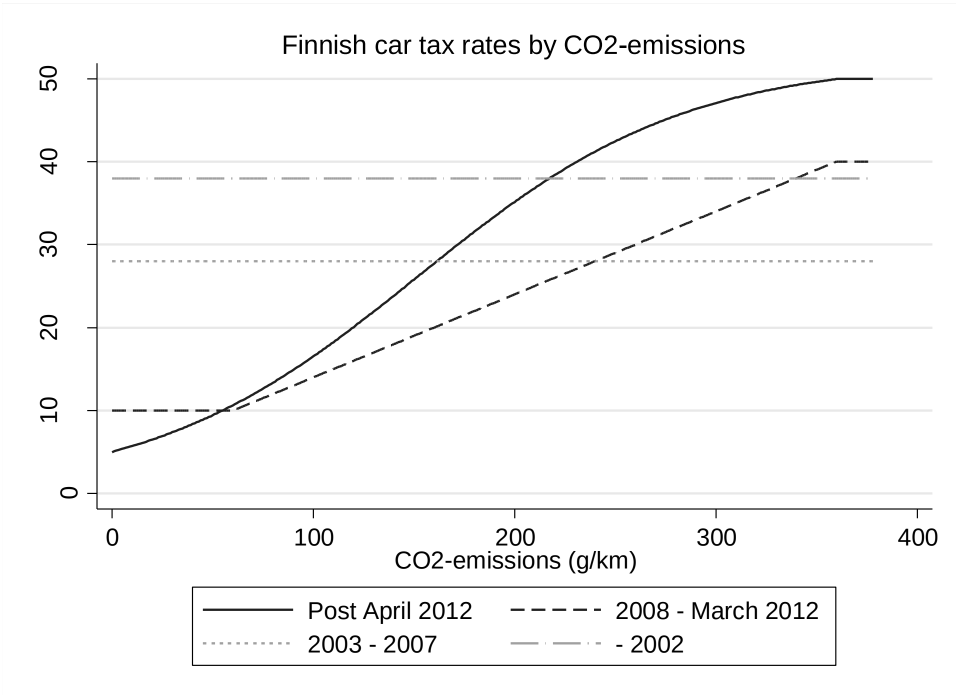
The Customs estimates the value of used vehicles to determine the taxation value. The estimation procedure is not exactly known to us, or to general public. However, Customs explains in their web page that the estimation is based on the price of comparable used cars sold in Finland and is seemingly based on finding a matching vehicle based on the characteristics of the vehicle. The characteristics are some combination of make, model, year, mileage (for used imported cars), gear (automatic/manual), engine power and condition of the vehicle. The Finnish customs also provide example cases for the general public of what they think a value of certain car could be, although these only gives rough guidelines.

We cannot replicate exactly the regression that the Customs uses, which more cleanly distinguish the determination of the taxable value and the tax rate. We observe all the relevant characteristics in the data we have. The variable list in the data is the same that the customs uses in car tax decisions. We also observe the actual car tax appraisals, and the value on which it is based. Thus, we can see how much each characteristic of a car affected the value of a car as evaluated by the Customs in the past. Moreover, we have data on the value of used cars sold in Finland. These data allow us to replicate the estimation, although the data may not be exactly the same data that the Customs utilize.

The car tax rates apply similarly for new and used vehicles. However, often the CO2 emission information is not available for used vehicles. In these cases, the car tax rate is based on the total weight and whether the vehicle has diesel or petrol engine.

Finally, Figure 5 shows the car tax rates by CO2 emission values (g/km) in the four most important regimes for this paper.

Figure 5. Car tax rate schedule by CO2 emissions in different car tax regimes



Vehicle taxation and reforms

The vehicle tax consists of two different parts in Finland: a basic tax and a tax on motive power. The tax on motive power is added on top of the basic tax for all cars that have other motive power than petrol, i.e. diesel or electric cars.

The amount of basic tax for passenger cars and vans depends on the levels of carbon dioxide (CO_2) emissions reported by the vehicle manufacturer. For new vehicles, the tax levied is based on CO_2 data, while older vehicles are taxed on the basis of their total mass if the CO_2 emission data is not available from the vehicle manufacturer. If the car does not have emission data in the official Vehicular and Driver Data Register, the tax is based on the total mass of the vehicle. The basic tax is increasing with the level CO_2 emissions from 106 euro per year for a car with 0 g/km CO_2 emissions to 655 euro per year for a car with 400 g/km or more in year 2018.

From 2000 to 2003 the level of basic tax was fixed to 84 euros per year for cars with year model of 1994 and older, and 117 euros for newer cars. In 2004 the tax was changed to daily-based taxation, 0.26 euros per day for cars of year model 1994 and older, and 0.35 euros for newer cars. In 2010 the above described CO_2-based tax was introduced.

The tax on driving power is levied 5.5 and 1.5 cent/day for every 100 kilograms weight of diesel and electricity vehicle post-2013, respectively. Before 2013 the daily rates for these vehicles were 6.7- and 0.9-euro cent/day. Therefore, the total vehicle tax on cars with motive power of diesel is clearly higher than gasoline cars.

Fuel taxes and reforms

Finland also applies separate excise taxes on gasoline and diesel as is described already in detail in Section 2. Figures B1 and B2 in Appendix B show the levels of these taxes over time from 2005 to 2017 for all three countries Finland, Sweden and Norway that we are focusing on in this report. Both of these taxes have an increasing trend over this time period in Finland, and also in all other countries. However, there are two larger reforms that both increased these taxes in Finland, in 2008 for both fuel types and in 2012, especially for diesel, clearly visible from Figure B2.

4.2. Taxes on vehicles in Sweden

Sweden does not apply car taxes on vehicles at the time of their first registration. However, there is a very small fee that must be paid at the time of registration. The fee is only few hundred euros and is independent of the characteristics of a car.

Both fuel taxes and vehicle taxes are applied in Sweden. The levels of these taxes are very similar to those applied in Finland. Also, the structure of the vehicle taxes is similar to Finland, they depend on CO_2 emissions of cars, on top of which diesel cars are taxed with additional tax that depends on the weight of a car.

Fuel taxes have been increased multiple times during this millennium in Sweden. Most of these reforms have been only small adjustments, and the changes are often similar for both gasoline and diesel, see Figures B1 and B2 in Appendix B.

Vehicle taxation has been rather constant over time, except for two rather large reforms. First, Swedish parliament decided to increase the vehicle tax on gasoline cars from the beginning of October 2006. This reform was made based on the environmental reasons as the level of annual vehicle tax started to depend on the level of CO_2 emission levels of cars. This favored diesel cars over gasoline-powered cars as commonly the CO_2 emission levels are lower for diesel-powered cars that are otherwise similar to each other.[22]

[22] Sweden has also applied the green car rebate April 2007 onward to promote the sales of environmentally friendly cars, so called green cars with varying thresholds and upper limits in different years.

4.3. Taxes on vehicles in Norway

Norway has applied the CO2 element in their car/registration tax since January 2007. Before 2007 this tax contained three different elements that defined the amount of taxes due to registering a vehicle in Norway: weight, engine power and engine size. From January 2007 onwards the engine size was replaced by a progressively increasing tax rates with CO2 emission levels. Also, in 2009 Norway adapted policies favoring low emitting vehicles by allowing tax rebates below certain CO2 emission level thresholds. Small adjustments have been made to the car tax schedule since, targeting higher tax rates for high emitting cars. More details of the Norwegian car tax schedule and changes in it during this millennium can be found from Yan and Eskeland (2016) that also summarizes some effects of the CO2 based car taxes on Norwegian car fleet. [23]

Norway has also employed vehicle taxes. These taxes are based on how many days the car is registered during a year, similarly as in Finland and Sweden. The rates have varied over time, but the overall annual tax payment has been rather low and constant over time, approximately 300-400 euros per year. The excise taxes on both gasoline and diesel have also been used in Norway and the levels in these have been very similar to neighboring countries, as is visible from Figures B1 and B2 in Appendix B.

4.4. Data and methods

The data we use come from several different sources: Finnish Customs, the Finnish Transport Safety Agency (FTSA) and Statistics Sweden and Norway. The data include all cars (and other vehicles) in the car fleet as a cross section each year, in Finland from 2000 to 2015 and in Sweden and Norway from 2000 to 2014. From the Finnish Customs data we have detailed information on all cars imported or newly registered to Finland. In these data we observe the key characteristics of the cars, such as make, model, year model, type of car, weight and CO2 emissions as well as some other technical features. The Swedish and Norwegian data are aggregated to a fine level of make, model at specific level, year model, number of seats in a car, fuel, gender of owner and some other characteristics. The data contain information on the number or cars each such car class contains in Sweden and Norway each year. In most of our following analysis, we aggregate the Finnish data to the same level to facilitate comparisons between countries.

Our main empirical method is to compare the development of either sales of new cars or some other aspects of car fleet around the policy changes that take place in different points of time in different countries. The benefit of comparison is firstly to avoid substitution effects across countries. It is a relatively mild assumption that policy changes in one of the small countries do not have effects on car buying choices in the other countries. The second advantage is that all the countries are affected by global changes in car production in a similar manner. All are affected by corporate fuel economy standards affecting car producers in Europe, US and also Japan. Moreover, all countries are relatively high-income Nordic countries with similar institutions and climate. Despite these similarities, some caveats may exist. One is that Sweden has more extensive own car production (Volvo) than the other countries, and Norway is slightly higher income country with higher average wages (and living costs) than the other countries. The economic development has been slightly less favorable after the European economic crisis in Finland than in the other two countries.

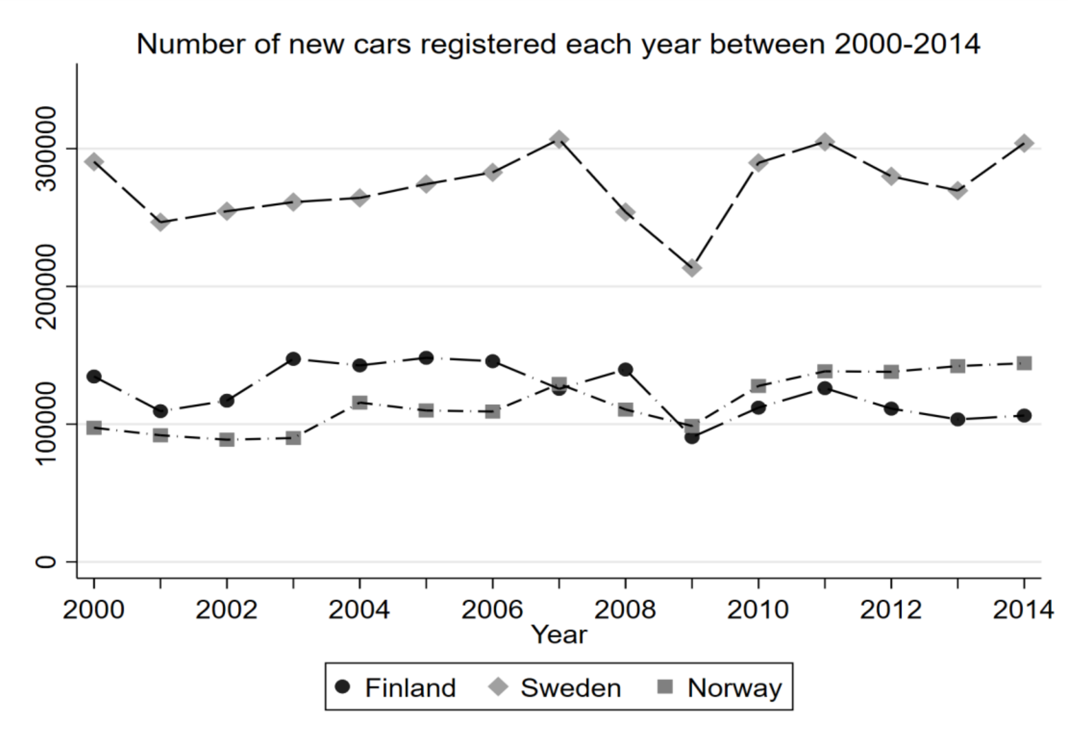
[23] The full structure of car taxes in Norway over time is provided in Appendix Table A2 by Yan and Eskeland (2016).

4.5. Descriptive evidence

Long-run development

We begin by describing different aspects of the car fleets in Finland, Sweden and Norway over longer time period. As a background for our analysis, in Figure 6 we first show the number of annual new car registrations in Finland and Sweden over the period from 2000 to 2014.[24] Noticeably, the overall trend in the number of new registered cars is quite similar over time in these selected countries. The large decline in 2009 in the number of cars registered in both countries likely corresponds to the economic recession starting in these countries. The fact that the Swedish car numbers recover faster after 2009 likely corresponds to the somewhat better economic recovery in that country compared to Finland. The similar patterns across countries over time show that cross country comparisons could be reasonable method to study how different policy measures are affected the car fleets.

Figure 6. Number of new cars registered in Finland, Sweden and Norway over time

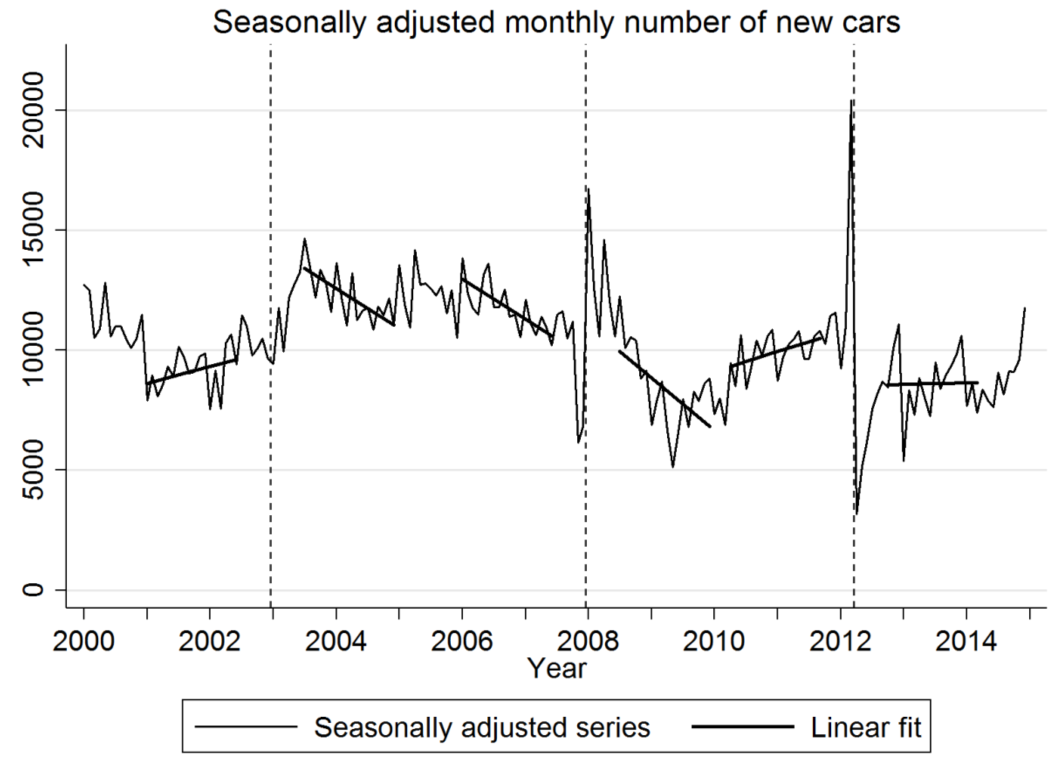


To focus more on Finland and especially on short-term impacts of car tax changes, Figure 7 shows the development of new car registrations by months from 2000 to 2015. Three vertical dashed lines show the most important car tax reforms during this time period. In the figure, we take into account the within year seasonal variation by using 12 month moving average in new car registration to be able to isolate this effect from the overall trend. In addition, we add a linear fit excluding six months from before and after each reform and including one-and-half years before and after the excluded period into the figure. The figure shows that the short-term anticipation and after the reform responses to tax changes are quite pronounced for the 2008 and 2012 reforms. The former decreased tax rates on average and the number of new cars decline sharply before the reform and consequently increase sharply after the reform, suggesting large short-term anticipation effects to the reform. The 2012 reform instead increased car tax rates, on average. The anticipation response is again evident, the number of cars increased right before the reform and decreased sharply afterwards. The 2003 reform does not create such a clear effect on short-term registrations.

[24] Figure 3B in the Appendix also shows the number of new cars registered *per capita* by years in Finland, Sweden and Norway from 2000 to 2014.

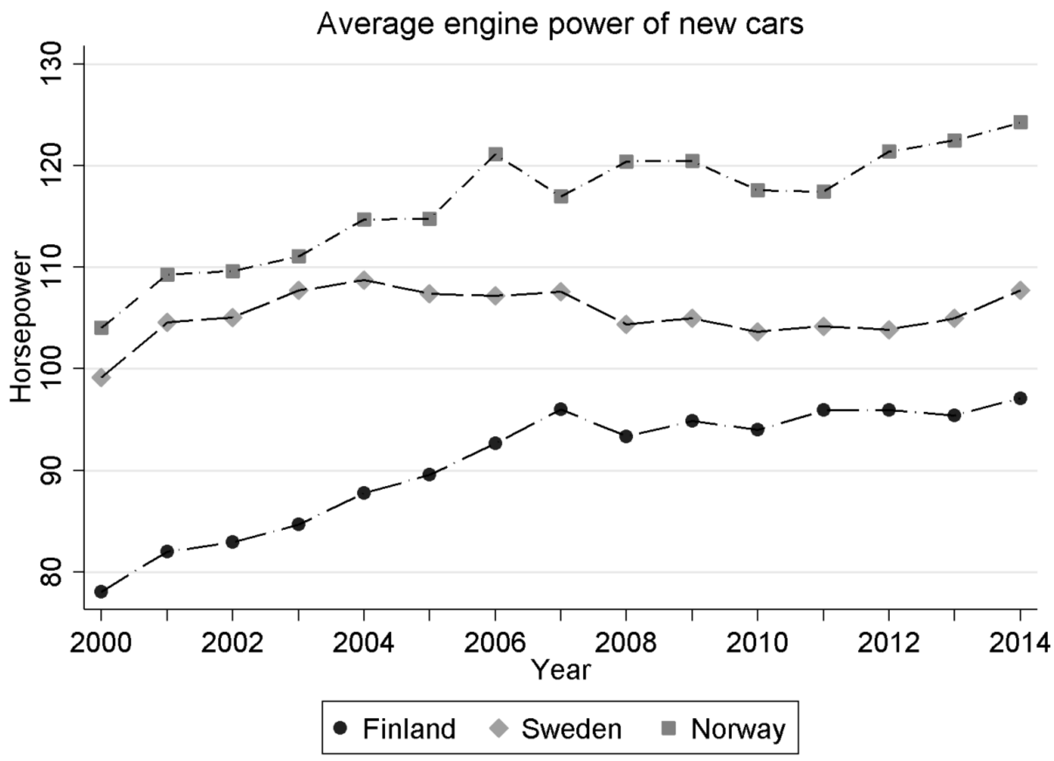
Likely explanation for this is that the reform was implemented quickly, making it hard to anticipate. However, it seems that the overall level of new car registrations somewhat increases after the beginning of 2003.

Figure 7. Monthly level seasonally adjusted number of new car registrations in Finland



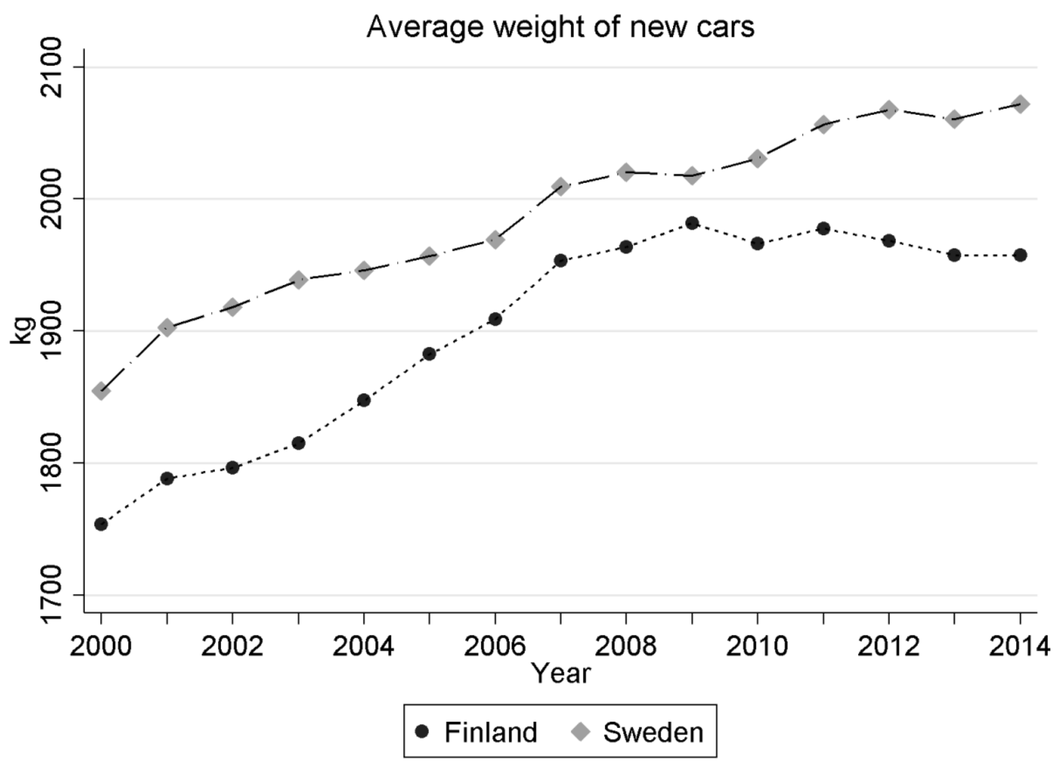
Next, we describe the average characteristics of newly registered cars by country, aiming to show the differences across countries in levels and changes in them. Figure 8 shows the average engine power (horsepower) of new cars in each of the three countries. Four main findings raise from the Figure. First, the average engine power in Finland is clearly lowest over the whole time period. Second, during the years from 2000 to 2007 the average engine power is gradually increasing in Finland, leveling out after that. Third, in Sweden, the development is rather stable over the whole time period. Fourth, new cars in Norway are, on average, more effective compared to Sweden and Finland over the whole period, but the overall trend is rather similar compared to Finland.

Figure 8. Average engine power of new cars over time by country



In our data set we only have the car-level (total) weight information from Sweden and Finland. Figure 9 plots the development of average weight of new cars over time for these countries. The total weight of cars is highly correlated with the engine power, and thus it is unsurprising that the Figure shows very similar patterns as does Figure 8 above.

Figure 9. Average weight of new cars over time by country



The value of car fleets in the three countries in 2014

Next, we describe the differences in value of cars in the car fleets in Finland, Sweden and Norway for 2014, the most recent year that we have data for all countries. To be more specific, with this analysis our aim is to compare the quality of cars using a single-dimension value metric. The value of cars depends on many different factors: certain car makes and models are more valuable than others, older cars are less valuable than newer cars, certain car-level attributes are more valuable, for example, higher engine power tends to be higher valued, and so on. Thus, the value of a car is also positively associated with CO2 emissions of the same car, but not perfectly.

We do the value prediction for new cars using a regression framework. We begin by regressing the log of taxable value of cars in Finland against make, model, engine power and weight, and then predict the value of cars in Sweden and Norway based on the same explanatory variables. The benefit of this approach is that the resulting value is comparable across countries, i.e. it shows what the predicted taxable value for each car would be in Finland. Therefore, the differences in the distribution of predicted values of new cars illustrate the quality variation among new cars across countries.

To offer evidence on the usability of our approach, we first examine the fit between predicted and observed taxable values of the Finnish newly registered cars. Figure 10 shows the comparison of real and predicted car value distribution in logs for Finland in 2014. The fit of the predicted taxable value seems to be rather good with the actual taxable value, although some differences remain in specific parts of the distribution. However, this legitimizes the use of the predicted measure to make comparisons of distributional level differences across countries.

Figure 10. Actual and predicted taxable value of new cars in Finland in 2014

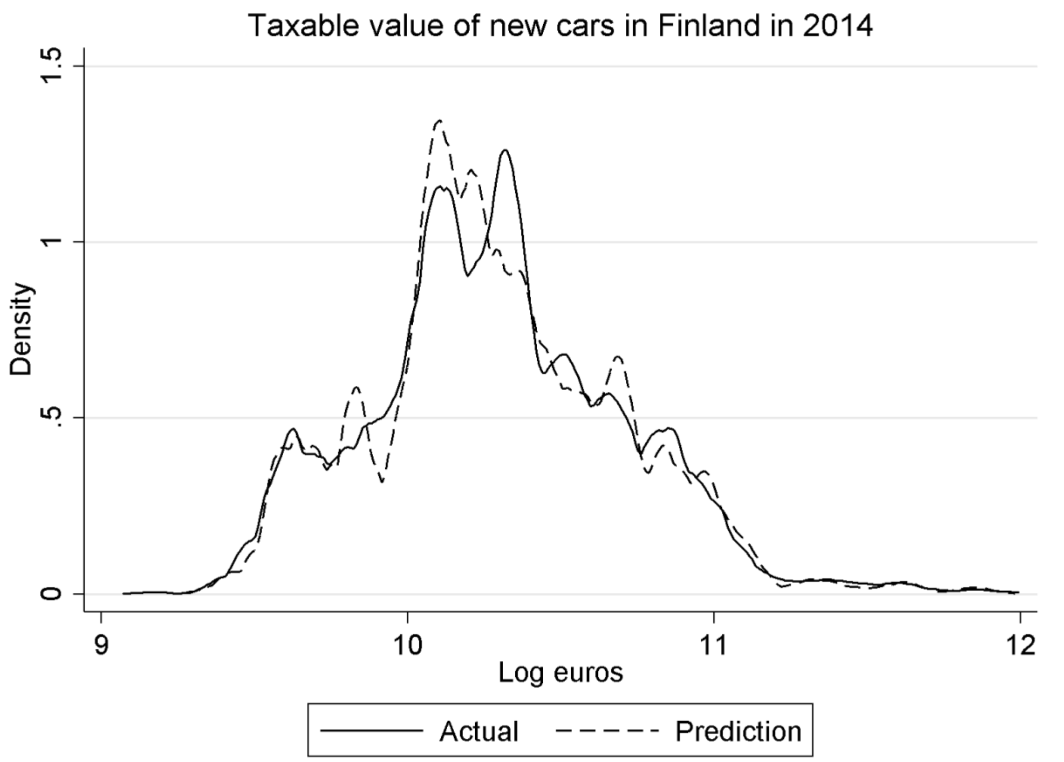
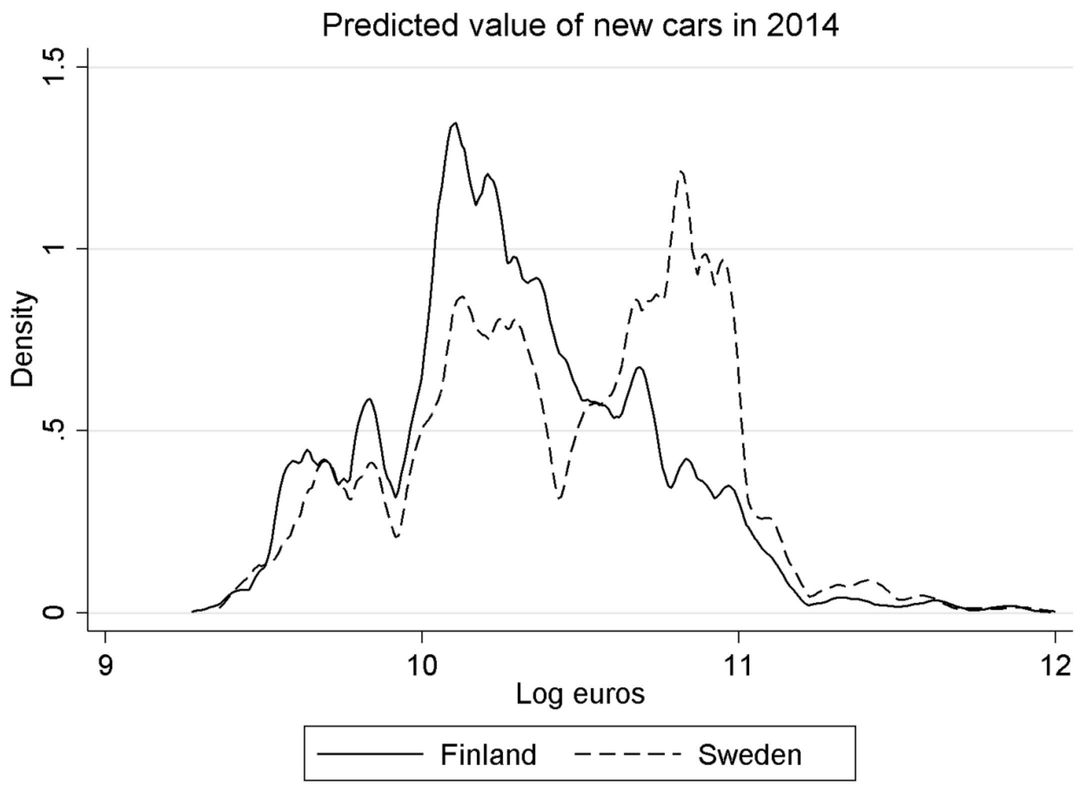
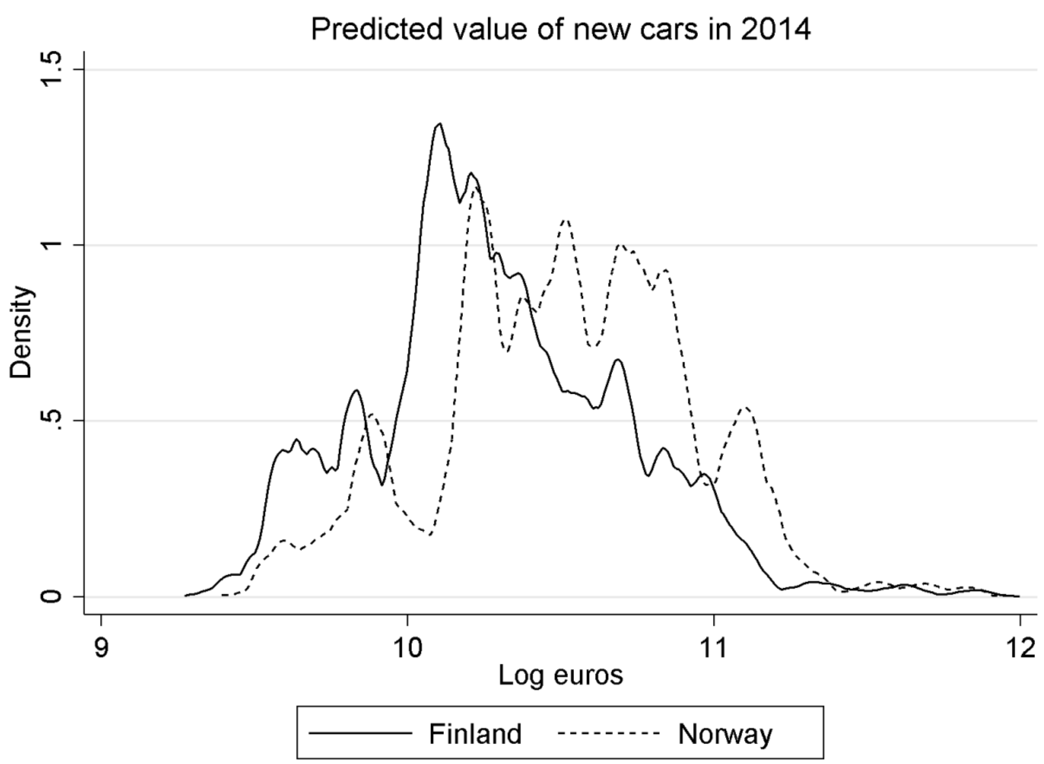


Figure 11 shows the log distributions of new car values in different countries comparing Finland to Sweden in the upper panel, and Finland to Norway in the lower panel. Evidence is quite clear: the value of new cars is clearly higher in both of the comparison countries than in Finland. The average values of new cars using our predicted measures are 29,400 in Finland, 34,900 in Sweden and 36,800 if Norway. The mode of the density distribution is only a bit above log value 10 (22000 euros) in Finland and declines rapidly after that value.

On the contrary, the Swedish and Norwegian distributions show much more density around log values 10.8 (close to 50000 euros) than the Finnish distribution. Many reasons could explain the fact that cars are more valuable and higher quality in the comparison countries compared to Finland: the makes and models of cars are different in these countries or the cars have attributes of higher quality, e.g. higher engine power, or for other similar reasons.

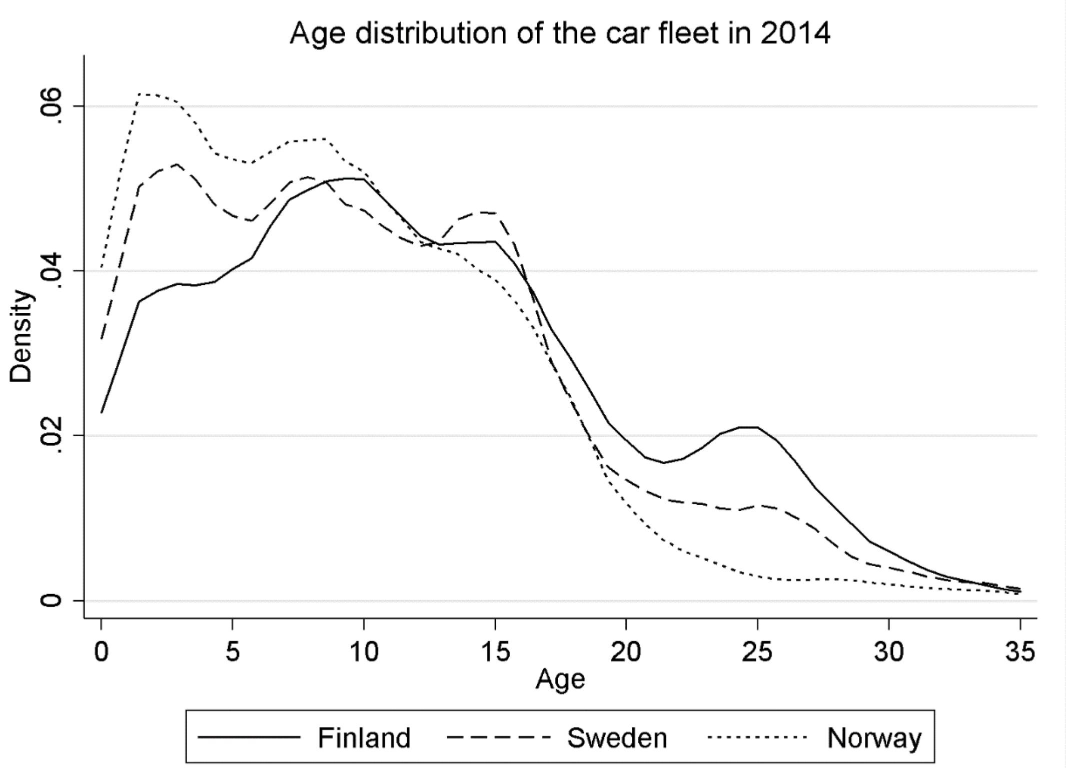
Figure 11. Predicted values of new cars by country in 2014





Until now we have only focused on new cars registered in each country. One interesting additional margin is to examine the characteristics of the whole car fleet. One additional difference across countries could be the average age of the car fleet. This further affects the quality (or value) of car fleet, but also the emissions of average cars in the fleet. As we have data on the whole car fleet in each of these countries, we can examine the age distribution of car fleets. Figure 12 below clearly shows that the whole car age distribution is higher in Finland than in comparison countries. This suggests that the car fleet in Finland is even less valuable than the distribution of new cars would suggest. Also, a very recent evidence by Jacobsen et al. 2018 suggests that the emission levels increase rapidly with the age of cars (CO and NO_x), which would imply that the Finnish car fleet would be much more pollutive compared to comparison countries. CO and NO_x are local pollutants and their effect on climate change is not as great as that of CO_2 emissions.

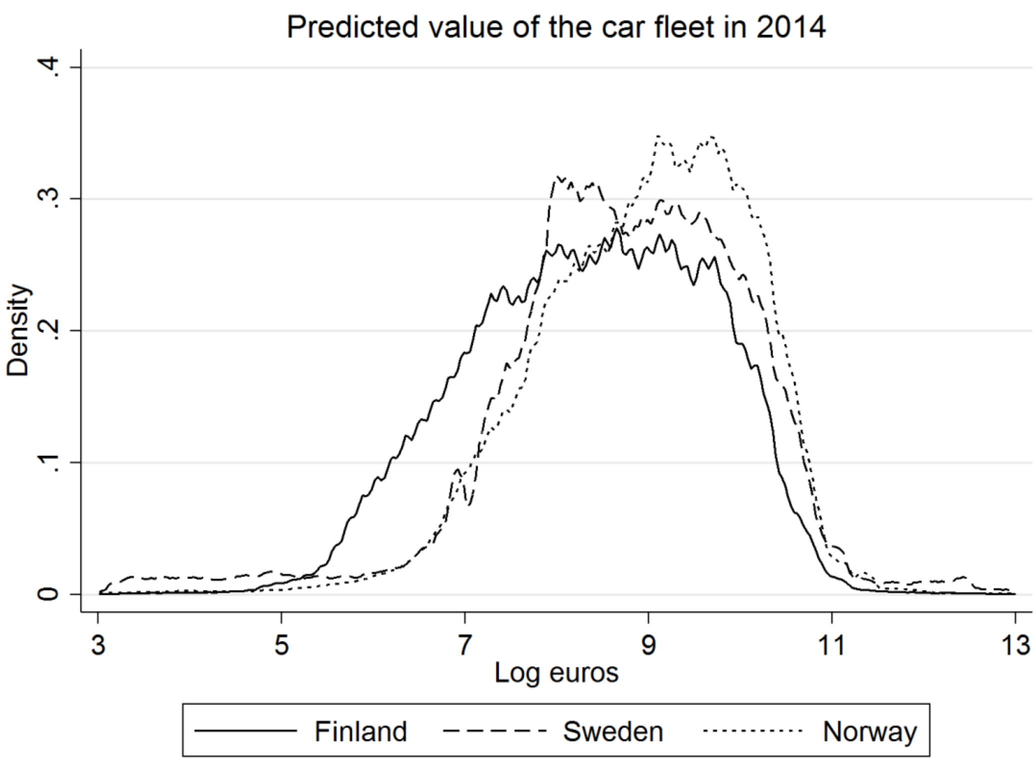
Figure 12. Age distribution of registered cars by country in 2014



Combining the analysis of the value of new cars and age of the cars in the car fleet, we predict the value of all cars in the car fleet using data on asking prices of used cars in Finland. These asking prices could be slightly higher than the actual realized sales prices but for our purposes this is not a huge concern, as we use these prices to make the prediction for all countries similarly as above for new cars. Therefore, the predicted measure is used to illustrate the value differences of the whole car fleets across countries. Figure 13 shows the predicted value distributions for Finland, Sweden and Norway using data in 2014. The figure shows that the value of Finnish car fleet is even less valuable compared to the other countries and compared to the analysis of new cars, when we take into account also all used cars in the car fleet. This is expected given that the Finnish car fleet is on average older than the car fleets in the comparison countries. It seems that the largest difference across countries is that in Finland there is relatively large number of very low value cars that almost do not exist in Norway and Sweden. Also, the share of very expensive cars is smaller in Finland than in the comparison countries.

One reason why the Finnish car fleet is much less valuable than in the neighboring comparison countries could be the value-based car taxation. Finland has had this tax system in place for a long time, and in the comparison countries there is either no taxes for new cars (Sweden), or the tax system where taxes are on a high level but does not target the value of cars rather than other attributes (Norway). Other potential reasons for car fleet being less valuable in Finland include the lower average income level in Finland compared especially to Norway.

Figure 13. Predicted value of registered cars by country in 2014

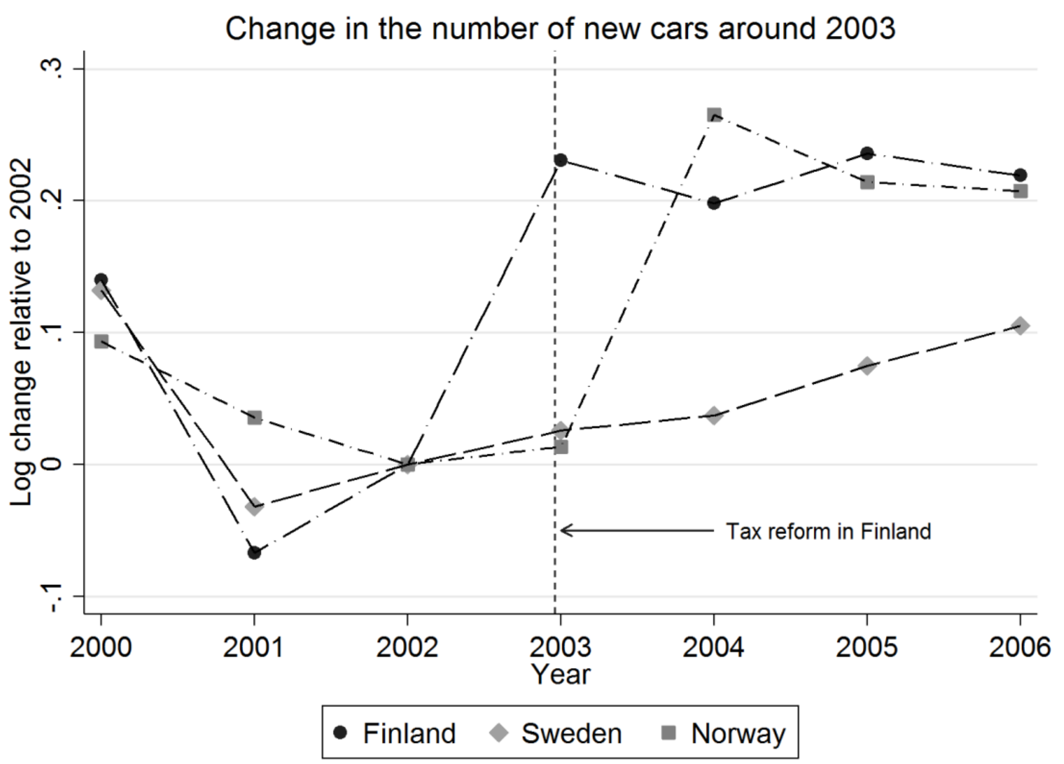


The effects of the recent reforms

Next we focus more specifically on the effects of the recent Finnish car tax reforms, and also offer descriptive analysis of how car or vehicle tax changes affect the car fleet in Norway and Sweden.

The 2003 reform uniformly reduced car tax rates for new cars. Figure 14 shows the number of new cars introduced in Finland, Sweden and Norway, focusing on the time period around 2003. Finland and Sweden seem to develop on a similar trend before the reform and there is a sharp increase in the number of new cars in Finland at the time of the reform. However, there is also an increase in Norway in 2004. The data quality from Norway for the earlier years is not ideal, reflected in the trends prior to the reform that are not very similar to Finland and Sweden. Thus, we cannot be completely sure whether Norway in this period represents a good counterfactual for Finland or not. We also have no clear institutional reasons for such behavior, e.g. in terms of policy reforms, that could associate with these changes in the time series. Nevertheless, the fact that the number of new cars increases also in Norway one year after the reform in Finland make it hard to interpret the increase in Finland straightforwardly as the causal effect of the reform in 2003. However, an increase in the number of new cars is expected as the average car tax rates for new cars decreased sharply 2003 onward.

Figure 14. Number of new cars around the 2003 reform



The 2008 reform introduced CO2 dependent car tax rates, favored purchases of less emitting cars and decreased car taxes slightly on average. Figure 15 shows that there was a jump in the number of cars relative to Sweden and Norway in 2008. The anticipatory effects of the reform were extensive as we showed in Figure 7 (on page 30), making it a rather difficult to evaluate the changes in annual numbers surrounding the reform. Also, the economic downturn started to have an effect from 2008 onward. This creates challenges for interpreting the changes in trends as a response to the reform. For these reasons the analysis of 2008 reform is challenging. We conclude that if the 2008 reform had any effect on the number of new cars it seems to have been anticipatory effects and some increase post reform, but any potential longer-term effects seem rather small.

Figure 15. Number of new cars in the 2008 reform

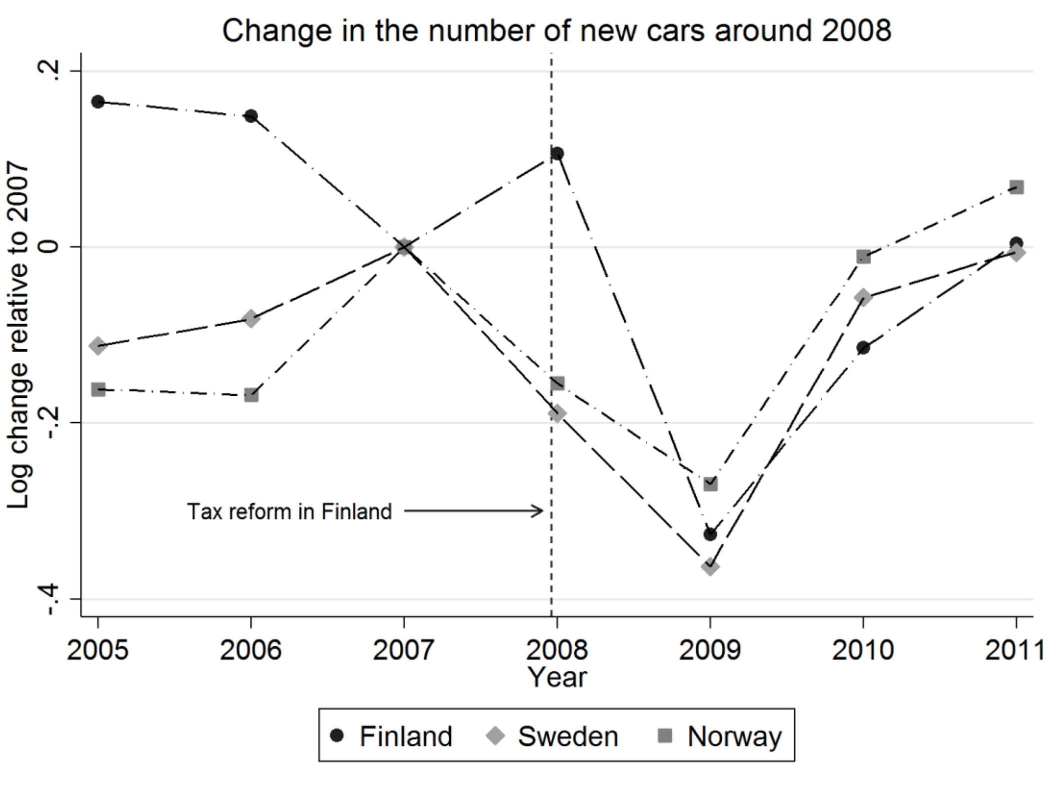
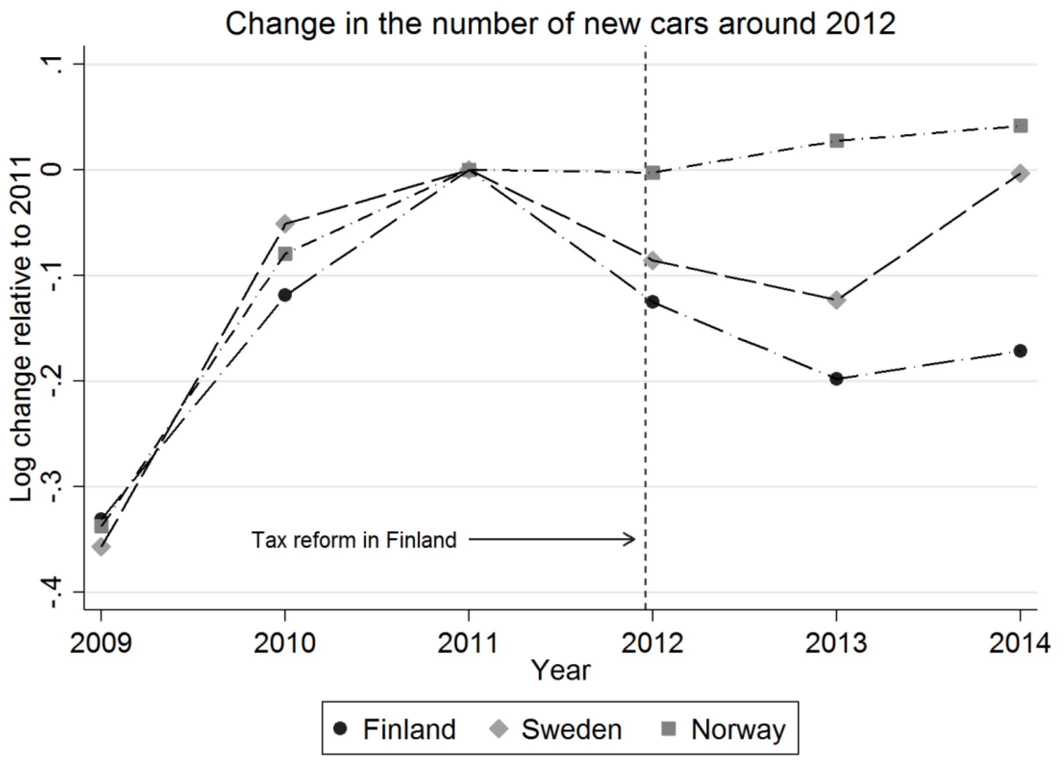


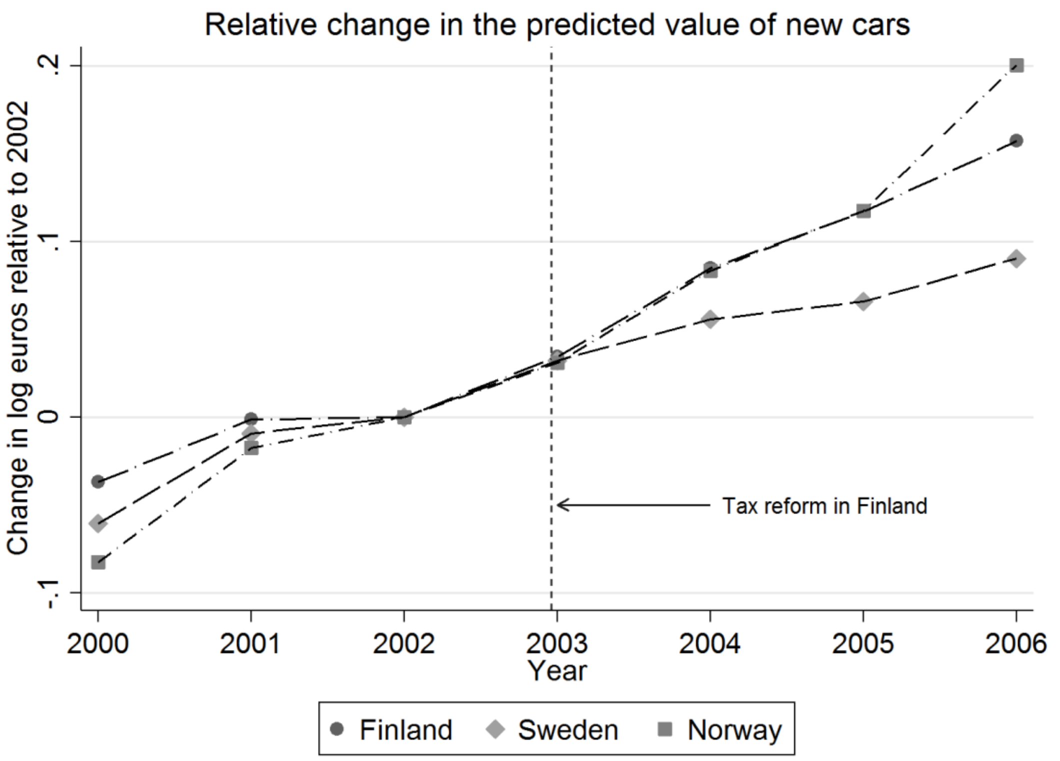
Figure 16 shows the number of new cars in the three countries around the 2012 reform. The 2012 reform made the car tax rate schedule steeper so that high CO2-emitting cars were taxed at even higher rates, and on average increased the car tax rates. In Norway there were no large reforms around the 2012 reform but there were some minor changes to the annual vehicle tax policy during that time in Sweden. The changes included the Green Car Rebate that gave exemptions to low-emission cars from the vehicle tax policy. That is why these might have created substitution effects within new cars rather than average effects. Figure 17 shows that the number of new cars follow each other in all three countries reasonably well prior to the 2012 reform. After the reform, the number of new cars drops the most in Finland, but there is also a decline in the number of cars in Sweden. This again creates challenges for interpreting what part of the decline is due to higher car taxes in Finland and what part is due to other reasons. For example, the economic conditions did not develop completely similarly across the countries, and the changes in the number of new cars might well reflect those differences. However, the fact that the number of new cars stays lower in Finland relative to Sweden and Norway in subsequent years suggests that some of the decline in the number of new cars in Finland might have been induced by an increase of average car tax rates for new cars.

Figure 16. Number of new cars in the 2012 reform



Next, we examine the effects on the taxable value of new cars of the 2003 reform in Finland. We use the same predicted measure for the taxable value across countries that we described above. Figure 17 shows the development of this measure over time for three years before and after the reform. It seems that the value of cars increased in Finland after the reform, but whether this can be attributed to the tax reform is questionable given that the taxable values increase in Norway to the same extent. When we compare Finland to Sweden, there seems to be a positive effect of decreasing car taxes on the taxable value of cars. However, when we compare to Norway, the effect looks quite neglible. As noted above we have some reservations regarding to the quality of Norwegian data from this period. One indicator of problems in the data is that when we include some controls the predicted Norwegian car values vary the most. Thus, suggestively there is an effect of the 2003 reform increasing the value of cars, but the suggestive effect is not super robust on different cross-country comparisons.

Figure 17. Changes in the average predicted taxable value before and after the 2003 reform by country



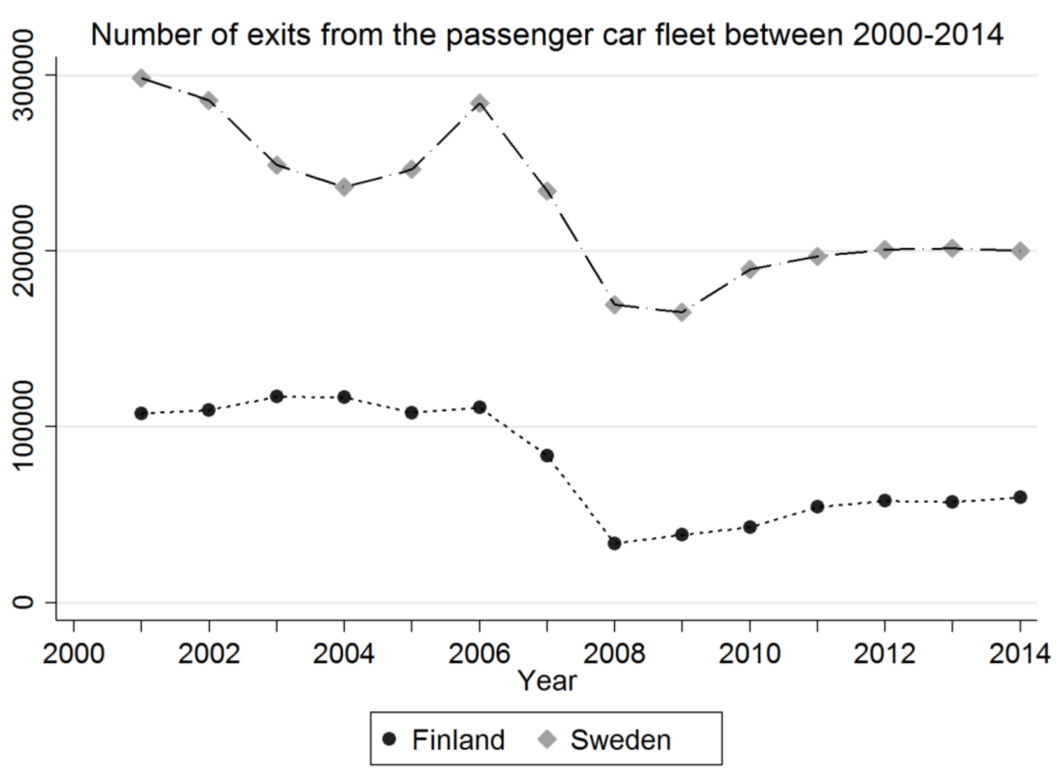
By analyzing the effects of the recent Finnish reforms on purchasing decisions of new cars, we have learned that there could be an effect on the total number of new cars, but we could not find clear longer-term results on the number of new cars. The taxable value results are even less clear, but they suggest that lower average tax rates that depend on taxable value of cars could induce individuals to buy more valuable cars. This could induce (among other things) higher CO2 emissions if the more valuable cars have higher engine power or other emissions-related attributes.

As we explained in the mechanisms section, individuals might substitute new cars with used cars. Given that we found a suggestive evidence that some of the tax reforms might have influenced the number of new cars, it is interesting to look at whether we find a corresponding evidence on the scrappage of used cars. In the mechanisms section we explained that if individuals substitute used cars for pricier new cars, in theory such effects could exist.

To study whether the used car market responded to the reforms, we first examine the number of car-exits over our sample period in Figure 18.[25] Any change in the number of exits from the car fleet could be important in itself given that the oldest cars typically pollute the most. Figure 18 compares the number of car-exits from the car fleet over time in Finland and Sweden. The number of car-exists in Finland is quite unchanged over the reform of 2003, suggesting no large response to the large tax decrease. The number of exists drop sharply in 2008 suggesting that the economic downturn is a major factor explaining the overall trend in car exists. Therefore, it is challenging to evaluate the effect of the 2008 reform in Finland given that the car exits start to decline already in 2007 in Finland, and that the Swedish exits follow roughly a similar pattern. According to the Figure, there seems to be no responses to the reform of 2012. In sum, our results suggest that car taxes create only rather small effects on car scrappage, if any.

[25] Figure 4B in the Appendix also shows the number of exiting cars from the car fleet *per capita* by years in Finland and Sweden from 2001 to 2014.

Figure 18. Car exits in Finland and Sweden over time

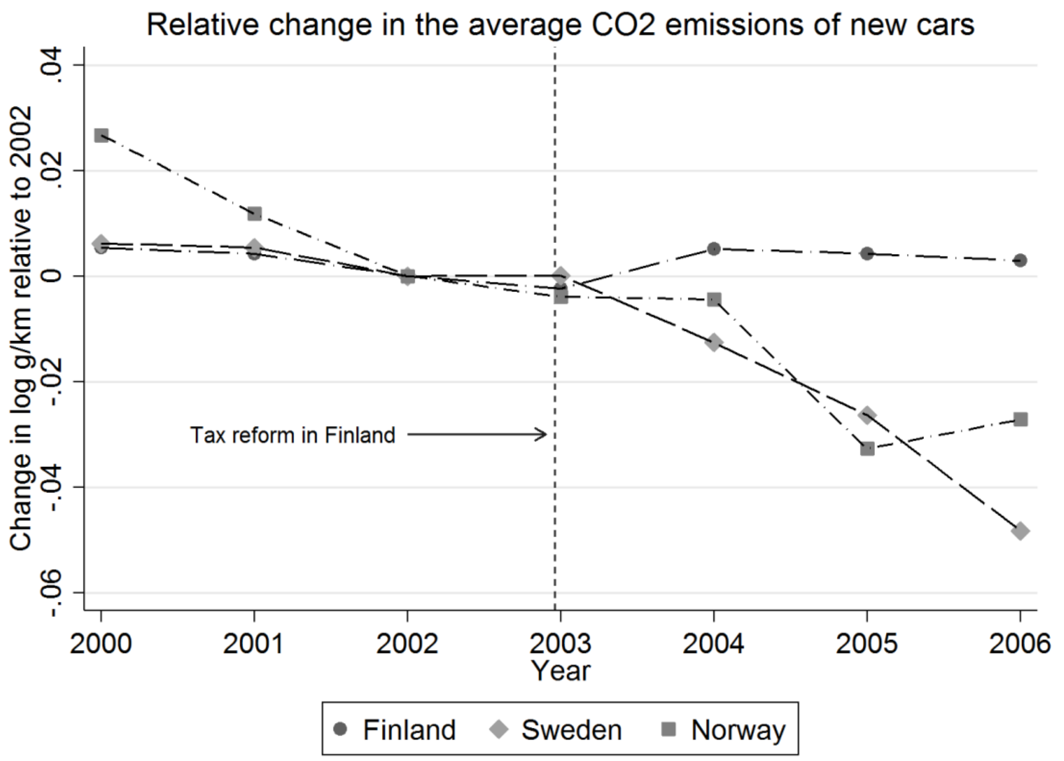


Analyzing the fuel-economy related car tax policies

In this Section, we analyze the fuel-economy aspects of car and vehicle tax policies in Finland, Sweden and Norway. We are interested in the overall development of CO2 emissions and related attributes. More importantly, we focus on finding evidence of how country specific changes in policies could explain the observed patterns in the data.

We start with the 2003 reform in Finland. This reform did not introduce fuel-economy standard or any other environmental aspect to the tax code, but only decreased car taxes related to the value of cars. As noted above, this kind of attribute-based policy could create secondary effects by incentivizing the purchases of cars with higher engine power that in turn could lead to higher CO_2 emissions of new cars. Figure 19 shows that CO_2 emissions seem to have stayed on similar levels in Finland from 2000 to 2006, or increased slightly, after the reform in Finland. In Sweden and Norway, the emissions have decreased during this period, and this development represents a counterfactual of what would have happened to the emissions on Finland in the absence of the 2003 reform, the total effect of the policy is an increase in CO_2 emissions. Although this evidence is again only suggestive, it illustrates that even non-CO_2 related car tax policy can create fuel-economy effects, because the value of a car is associated with the fuel-economy of a car.

Figure 19. Change in the CO2 emission levels of new cars before and after the 2003 reform by country



We continue our analysis by focusing on average CO_2 emissions during the time-period between years 2006 and 2008. During this period all three countries in our analysis reformed their vehicle-related tax policies. In October 2006 Sweden introduced CO_2 emissions to its annual vehicle taxation. In 2007 Norway introduced fuel-economy standards to its car taxes. In 2008 Finland introduced CO_2 dependent car tax rates. During this period car producers also started introducing cars with better fuel economy in all countries, probably as a response to average fuel economy standards and changes in consumer preferences.

A challenge in our data is that we do not observe detailed CO_2 emissions for Swedish cars. Also, CO_2 emissions are missing for large parts of the data. However, we have data of CO_2 emissions from Finland for the whole time period and we use these CO_2 values to predict CO_2 emissions for other countries. We use make and model of cars, engine power and weight of a car to make the prediction, which should be fairly accurate given that CO_2 emissions should not vary within these car attributes.

Figure 20 shows the average CO_2 emissions of new cars over time in the three countries using the predicted CO_2 measures. In all countries, there is a clear decreasing trend in average CO_2 emissions, consistent with the international trends explained above. Moreover, there seems to be drops in CO_2 emission in each country associated precisely with fuel-economy related car tax reform in each country. The change in CO_2 emissions related tax incentives were especially strong in Norway and Finland, because these changes were particularly targeted for new cars. The largest drops in the average CO_2 emissions of new cars are visible associated with these reforms. Given the strong decreasing overall trend and the fact that the reforms happened close to each other makes it difficult to estimate a precise effect on CO_2 emissions from the overall decreasing trend.

Figure 20. Average CO2 emission levels for new registered cars

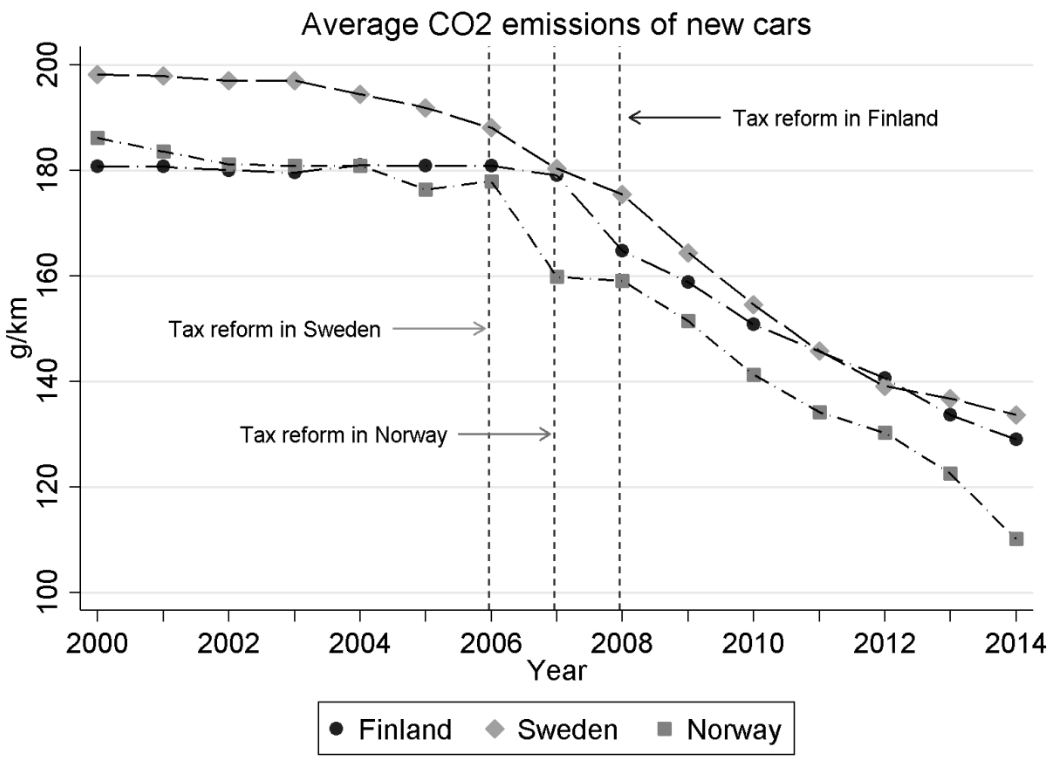


Figure 21 further analyses the CO2 emissions of new cars by dividing the sample to the share of new cars in a low emission group relative to all new cars in that country and year. The low emission group is the group of new cars with lower than median emission levels (CO2 emissions less than 165 g/km). The share of low emission cars increases rapidly over time, and also after the tax changes in all countries. The immediate jump in the share in low emission group seems to be more pronounce in Norway in 2007 and in Finland in 2008 than in Sweden in 2006. However, the reform in Sweden was only in October 2006 and the share of diesel cars increases clearly in 2007 compared to previous year that is also consistent with a response to the Swedish reform that at least partly explains the modest effect for Sweden in 2006.

Figure 21. Share of new cars in low emission group – below median (<165 g/km) – by country

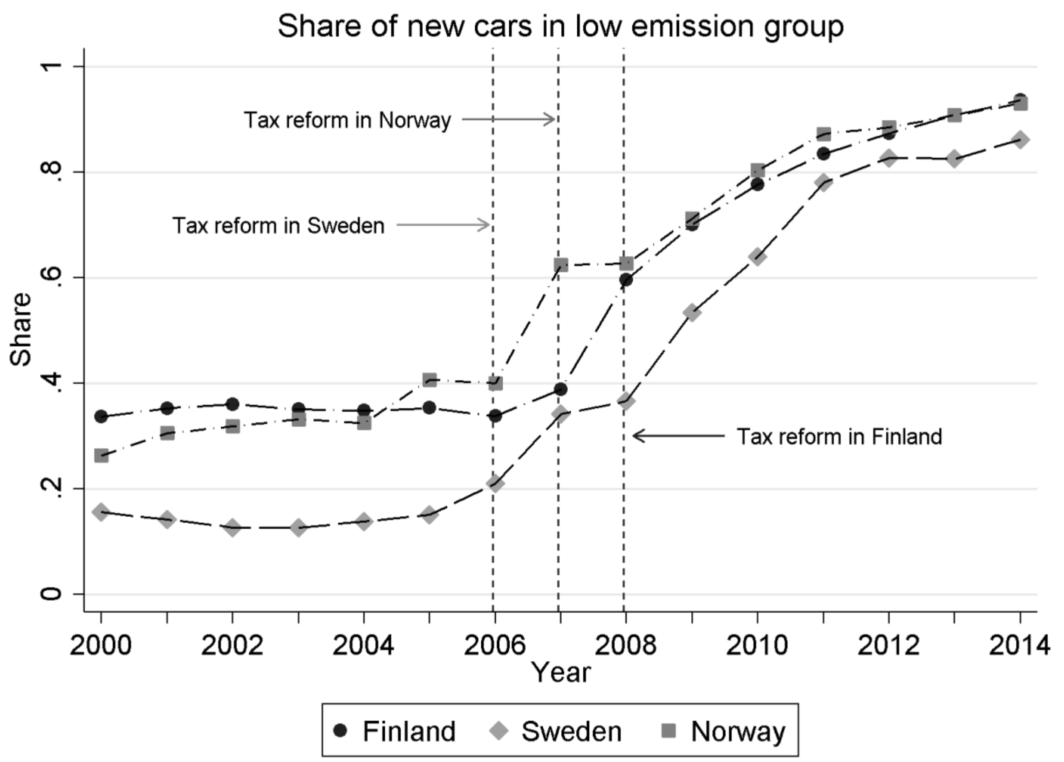
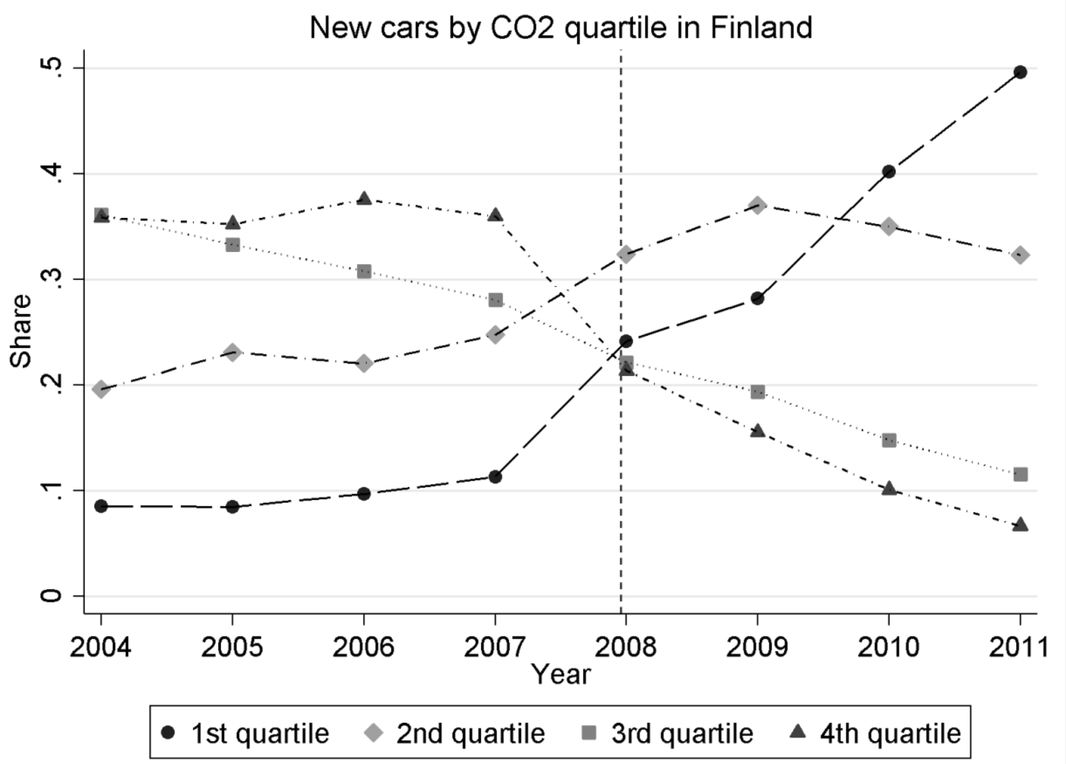


Figure 22 shows the same division only for Finland, but instead dividing new cars into quartiles according to their CO_2 emissions. This figure further shows that the changes around the 2008 reform are the most pronounced in the lowest and highest CO_2 emission quartiles. This division further shows that the sharp increase among the lowest quartile vehicles could be associated with the 2008 reform.

In summary, the 2008 reform only slightly decreased car tax rates on average, and the analysis above shows that there were not very large changes in the average number of new cars. Instead, the 2008 reform introduced CO_2 emissions-based car tax rates that reduced the taxes for some cars while increased them for others. This change in the slope of car tax rates seems to have created quite strong substitution effects within new car purchases, where car buyers substituted away from cars with worse fuel economies that had become more expensive. These substitution effects seem to be much stronger than any effects on the average number of new cars.

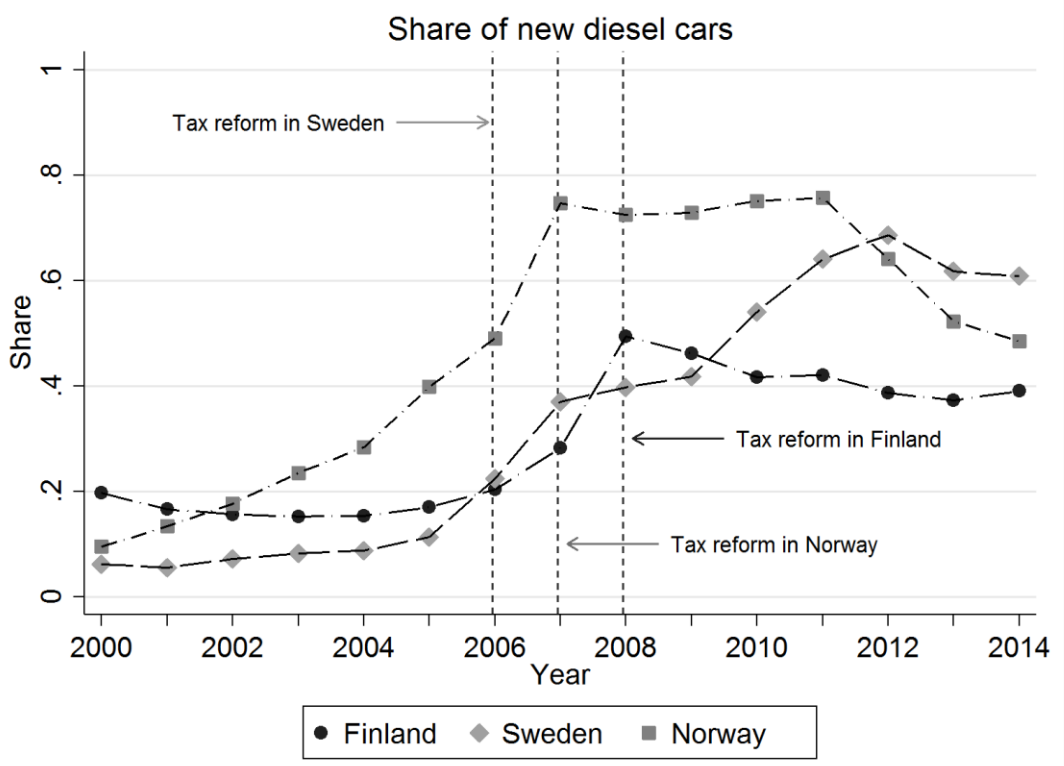
Figure 22. Share of new cars in emission quartile groups in Finland



One additional channel of response to the car related taxes (car tax, vehicle tax or fuel tax) is the motive power of cars. In general, after the mid-2000s the changes in vehicle related taxes in all Nordic countries incentivized the purchases of diesel cars. This is because a diesel car tends to have lower CO_2 emissions compared to otherwise similar petrol car, and the tax changes introduced or made stricter the CO_2 related tax incentives. Figure 23 shows the share of new diesel cars by country from 2000 to 2014. The Figure clearly depicts the increase in the shares of diesel cars after the changes in vehicle and car taxes in each country, marked with vertical dashed lines, respectively. Noticeably the share of diesel cars from all new cars purchased has been over 70 percent in Norway during many years, over 60 percent in Sweden and over 40 percent in Finland.

The increase in the share of diesel cars is not necessarily only beneficial from the environmental point of view. Diesel cars are known to emit much more small particles than petrol cars, although they have lower CO_2 emissions. Therefore, this apparent response to CO_2 based tax policies in terms of motive power shift from gasoline to diesel cars among new cars highlights that these types of environmental policies might have unexpected effects that also can be opposite of the stated policy aims.

Figure 23. Share of new diesel cars by country



4.6. Need for future research

The vehicle related taxes create different types of incentives for individuals to respond to them. The existing literature offers some but definitely not conclusive evidence of the effects on various behavioral margins. In this report, we offer descriptive analysis of how the car fleet in Finland is different from the car fleets in its neighboring countries. We also try to focus more on using various reforms, changing the incentives for vehicle purchases and driving habits, to be able to offer more credible evidence. However, in many cases the comparisons between countries are not very straightforward, and therefore our observations and results should be interpreted cautiously. Surely, more detailed analysis of these reforms is needed to be able to offer better understanding of the effectiveness of current policies.

Also, this report ignores many important behavioral margins. For example, the mileage changes caused by relative price changes are very important topic for future research. This is related to all tax instruments, obviously including fuel taxes but also car taxes as higher car taxes for high emitting cars could make the car fleet more fuel efficient but at the same time it could increase the aggregate mileage driven as the cost of kilometer driven with more fuel-efficient cars is lower. Additional and important behavioral margin is also the incidence of car taxes and especially the effects of car taxes on used car prices and thus on the whole car fleet that could also have important distributional implications. Also, strictly from the point of view of pollution due to traffic, it would be important to have a measure for the total emissions. To be able to approximate this, we should have a clear view of various behavioral margins mentioned in this report. This is the most relevant measure to have to be able to assess how well different policies succeed in reducing emission. On top of all above mentioned behavioral margins, it would be also important to know local emission levels and their implications. In terms of CO_2 emissions, it does not matter if most of the aggregate kilometers are driven in densely populated regions or in rural areas but, for example, for the health of individuals it could matter a lot if the emissions are heavily concentrated on certain geographical areas.

5. DISCUSSION AND CONCLUSIONS

We study fuel and car tax policies in Finland, Sweden and Norway using microdata. We use several tax reforms in the period 2003-2012 as plausibly exogenous sources of variation. In terms of the fuel tax, we focus on the diesel tax increase that took place in January 2012. In terms of the car taxes we analyze the 2003, 2008 and 2012 reforms in Finland and car and annual vehicle tax changes in Sweden and Norway around the year 2008.

The 2012 diesel tax increase was substantially larger than the concurrent gasoline tax increase, and the trends of diesel and gasoline prices appear parallel both prior to and after the reform. Under the assumption of parallel trends, heterogeneity in diesel tax pass-through can be studied by comparing diesel price changes to gasoline price changes around the tax reform in a difference-in-differences framework.

Results from the difference-in-differences regression with gasoline prices as a control suggested that diesel price responses to the diesel tax increase were asymmetric: pass-through rates fell with income, housing prices, population density and the degree of urbanization, as measured by the urban-rural classification. The estimated pass-through rates in the first income, housing price and population density septiles, as well as in the most rural areas, were approximately 80 percent, while pass-through rates in the highest septiles were up to 15 percentage points lower.

Two caveats are in order to mention. As the excise tax on gasoline was also increased slightly in January 2012, the estimated pass-through rates measure how much of the difference in the diesel and gasoline tax increases was passed through to diesel prices. Interpreting the estimated pass-through as applicable to the overall diesel tax increase presupposes that the true unobserved pass-through rates of the gasoline and diesel tax increases were equal to each other in all septile groups. Another crucial assumption is that of parallel trends in diesel and gasoline prices. The main result on heterogeneity, pass-through differences of about 15 percentage points between the first and last septiles, is driven by observed variation in diesel price responses. A substantial divergence between the true diesel pass-through rates from the estimated pass-through rates would be needed to invalidate the finding of heterogeneity and regressivity in the pass-through of diesel taxes.

The estimated average pass-through rates are below 70 percent and thus fall short of full pass-through. While less than full pass-through is consistent with economic theory, the estimated values are somewhat smaller than what previous studies have found for the United States and Spain. There may be many explanations for the difference. To the extend that short-run tax or price elasticities for fuel demand may differ with tax and price levels, income levels, and substitution possibilities offered by availability of public transportation, it is plausible that demand may be more elastic in Europe than in the United States. Stolper (2016b) obtained an estimate of 95 percent for the average pass-through in Spain, while Stolper (2016a) found pass-through estimates for locations close to the state border, facing more potential competition, to be about 73 percent. Our results for Finland provide some further indication of differences in fuel tax incidence in the US, documented most extensively in previous empirical literature, and in the relatively high-tax context in Europe.

The second part of this report offers an academic glance on the association between car taxes and characteristics of car fleet during this millennium. We provide descriptive comparative evidence across car fleets of Finland, Norway and Sweden. We believe the comparisons are not reported before with side by side and with the same methodology for different countries, and that for this reason these results are of interest. We also attempt to analyze the impact of various car tax policies, but due to some caveats mentioned in detail below, assert that these results are suggestive at this point.

Our descriptive results relate to the over time trends of car fleet and to the differences in the car fleets of the three countries. Over time the average new cars have seen very significant improvements in their fuel-economy in all three countries. The average number of new cars introduced each year has developed more steadily. Descriptively the European economic crisis is visible as a slump in the number of new cars at least in Finland and Sweden starting from 2008. Also, number of exits from the new car fleet decreased in Finland and Sweden in 2008. These descriptive changes are consistent with some individuals getting poorer, possibly because of becoming unemployed, and this could be related to the economic crisis.

A very interesting descriptive difference across car fleets is that the average value of new car fleet is lower in Finland in 2014 than in the other countries. Also, the average age of the Finnish car fleet is greater in 2014 than in the other countries. And as a combination of the two mentioned statistics, the total estimated value of the Finnish car fleet is much lower than in the other two countries. We cannot provide a clear causal evidence on what causes the Finnish car fleet to be that much less valuable (or lower quality), but tentatively some of the reasons might relate to the Finnish car taxes that depend on the value of the car and have been in some form in place from the introduction of the first car to Finland in year 1900, while in Sweden there has been no car taxes for new consumer cars since 1996, and the car tax in Norway depends only on CO_2 emission and weight of the cars, but not on the value of cars. Other potential explanations include the fact that average income level in Finland is lower than in the other two countries, especially in Norway.

Descriptively it seems that prior to 2006 the average CO_2 emissions of new cars were on a similar level for number of years. In Sweden the average emissions were on a higher level than in Finland and Norway. This could be explained by the fact that Sweden did not have a tax for new cars, but Finland and Norway had, but the difference could be caused by other (unobserved) factors as well. Although the car tax policies were not tied to the CO_2 emissions in this era, the lower valued or lighter-weight cars could be have on average also lower CO_2 emissions. After 2006 both the EU-level emissions standards and CO_2 based car and vehicle tax policies were introduced. We see a clear change in the average CO_2 emissions trend: in all countries the average CO_2 emissions of new cars started to decline, and this continued until the end of our data period, 2014.

When estimating causal impacts of car tax policies, we take seriously the challenge of finding a credible counterfactual. If one analyzes the effect of car tax policies within one country, it could be challenging to develop a credible control group as all control groups within the country might be subject to the policy through substitution patterns and general equilibrium price effects. This is why we utilize the comparison of Finland, Sweden and Norway, that as small open economies are similarly affected by changes in fuel-economy standards for car producers and changes in the state of the European economy. We believe there are not that much substitution effects across countries. However, because the analysis shows that we are not always able to take into account concurrent changes in the other countries or differential economic development across countries, we highlight that the results of this part of the report are preliminary and a full conclusion of the effectiveness of different policy measures requires more work. The challenge is created by three changes in trends mentioned above; the average CO_2 emissions has declined since about year 2008 in all countries quite dramatically, and this is at least partly caused by changes in global trends and emission standards for manufacturers. The second trend is that the European economic crisis might have altered the trends related to consumption patterns of new and used cars, and used car scrappage, in all countries. A third caveat is that all three countries have made changes to car related policies in 2006 to 2008, and Sweden also some changes to Green Car policies around 2012. We note that these caveats apply to all studies, not just to this one, because concurrent changes in economic conditions and other policies are not possible to separate out from the analysis in principle. An improvement is not to ignore global trends and/or substitution patterns within countries and analyze, for example, cars solely within Finnish data.

Having stated all the caveats, we believe we have improved our understanding on car tax policies from our analysis of car tax reforms. When analyzing the monthly data for Finland, large spikes are visible right before or after car tax changes, especially the 2008 and 2012 reforms. These are consistent with anticipatory effects, where individuals intertemporally change the timing of car purchase decisions in an attempt to buy the same car when it is cheaper before/after a tax change. Thus, car taxes do affect car buying choices. This is also symptomatic that the most likely substitution occurs to the same or very similar car in different point of time rather than different kind of car at the same time. For policy perspective the longer-term car buying choices are more important than anticipatory effects, because the effect of car taxes on car choices, for example, in a 10-year period are potentially much larger than a two-month anticipatory effect. We did not find as strong evidence on longer term impacts of new-car purchases on average. The 2003 reform that on average reduced car tax rates seemed to slightly increase the number of new cars, although the evidence compared to Norway is not clear. We did not find much clear evidence from 2008 reform and there might have been a decrease in the number of new cars associated with the 2012 reform, which on average increased car tax rates.

The effects of car tax policies on distribution of new cars seem much clearer. The 2008 reform introduced progressive car tax rates in CO_2 emissions to Finnish car tax schedule. Around the same time there were similar changes to car tax policies in Norway and vehicle tax policies in Sweden. Associated with each of the changes there is a jump downwards in the average CO_2 emissions of new cars of the country in question. It is difficult to purify the longer-term effects from the global trends in all countries, but the jumps precisely at the time of the policy are evidence that the policy changes had something to do with this. We also had a distribution of new cars in Finland over time by dividing new cars into quintiles by CO_2 emissions. The share of lowest emitting cars jumps up precisely at the time of the 2008 policy while the share of highest emitting cars declines. The drastic change in the trend is hard to explain without a policy effect. We think that the distributional effects are stronger than average effects because consumers are more likely to respond to environmental policies by substituting to a less polluting new car than to a cheaper used car.

Also related to distributional effects of environmental car tax policies, the share of diesel cars increases in all countries sharply at the time of the changes towards more environmental car tax policies. Diesel cars have on average lower CO_2 emissions than similar gasoline cars. The share of diesel cars from all new cars reaches over 70 percent in Norway and over 50 percent in Finland, these are no small changes. The effect is not all to the environmentally friendly direction, because diesel cars are known to emit more other pollutants, such as CO and NO_x, than CO_2 compared with gasoline cars. These are local pollutants and do not contribute to the climate change with the same extent than CO_2. The effect to diesel cars could be explained by substitution patterns among new cars; a consumer does not need to switch to much lower quality car when responding to CO_2 emissions tied policy, a switch from gasoline to diesel car might be enough to significantly reduce the tax burden.

We also analyzed scrappage of used cars in Finland and Sweden. There are some changes to scrappage in Finland associated with the 2003 reform that are at least consistent with theory. The theory says that with cheaper and thus potentially more new cars introduced some consumers are more willing to scrap their used cars. There is an increase in the scrappage of used cars in 2003. We plan to analyze the scrappage issue in the future work more precisely and across different types of cars. More generally, in the future work we want to continue analyzing the Finnish car tax policies and tackle some of the challenges in the comparison of neighboring countries.

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Appendix A

Figure A1 Filling stations in the sample between 2011 and 2012

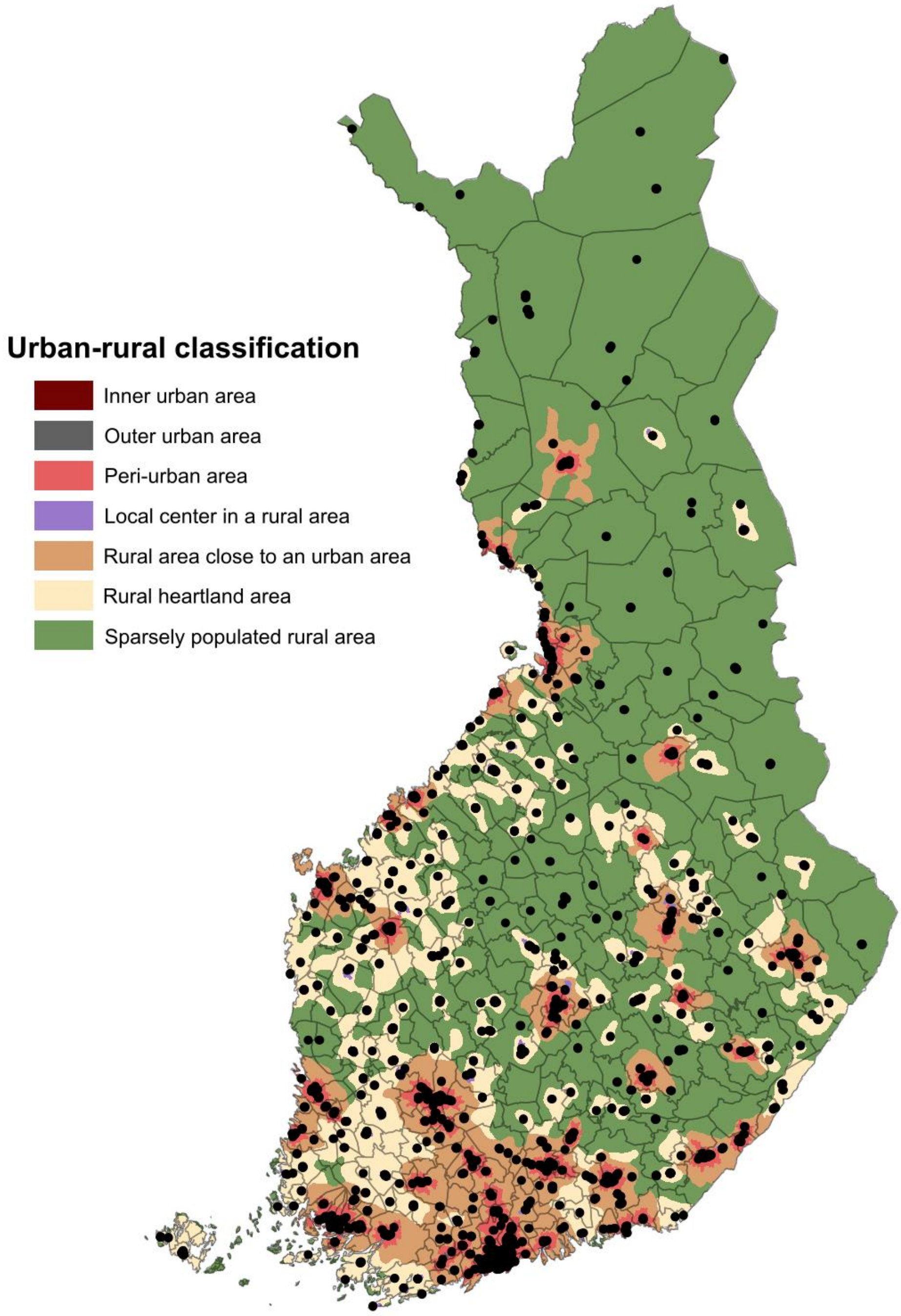
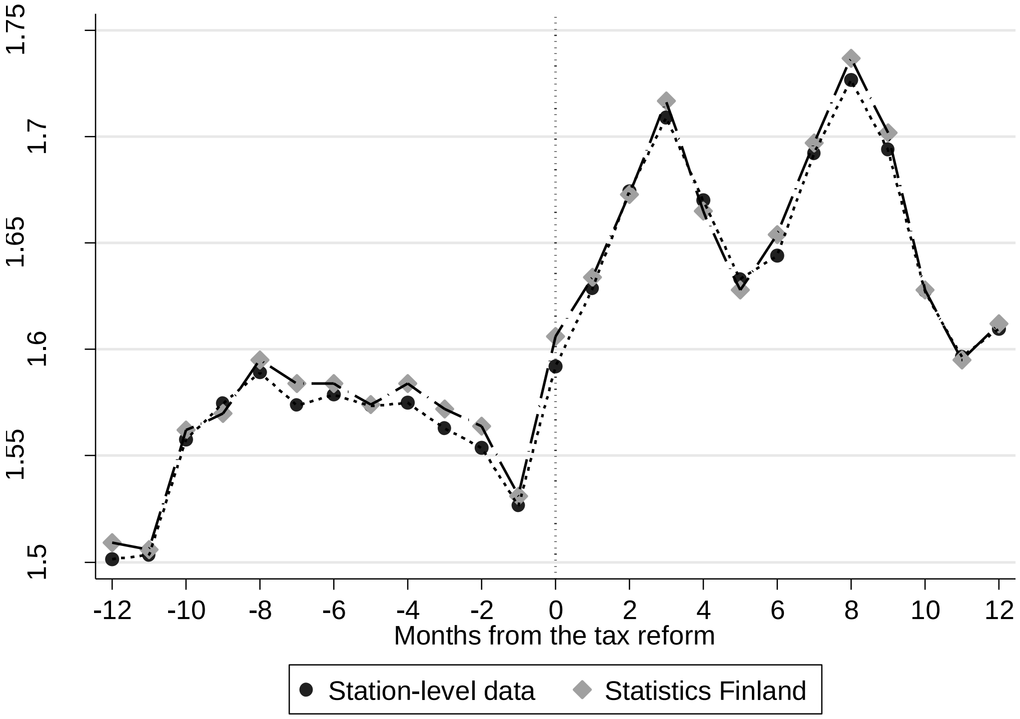
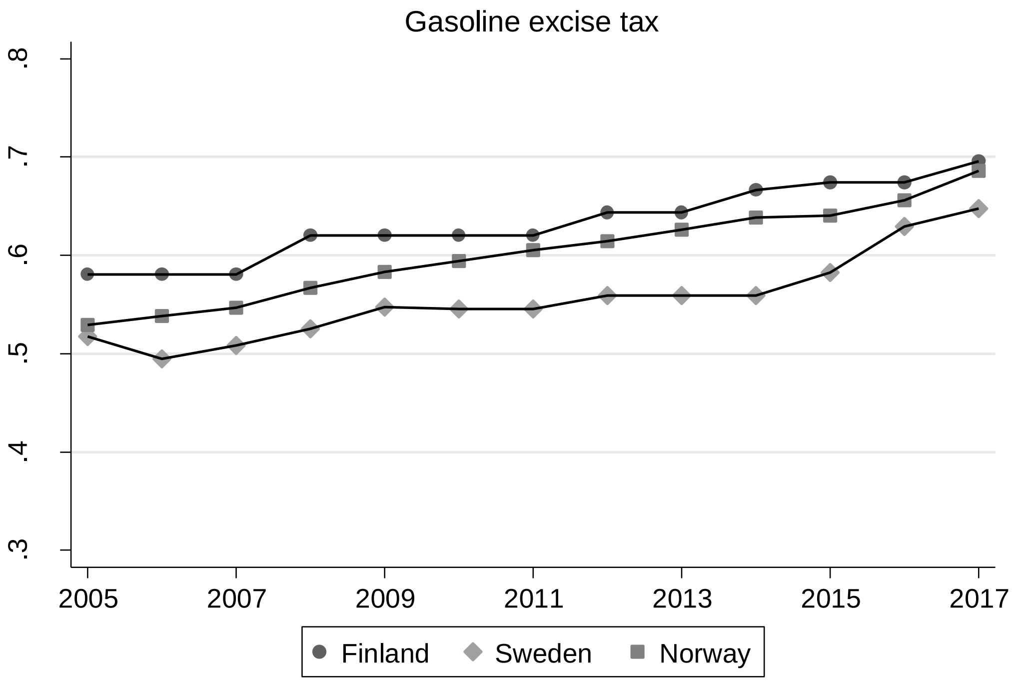


Figure A2 Comparison of monthly average gasoline prices



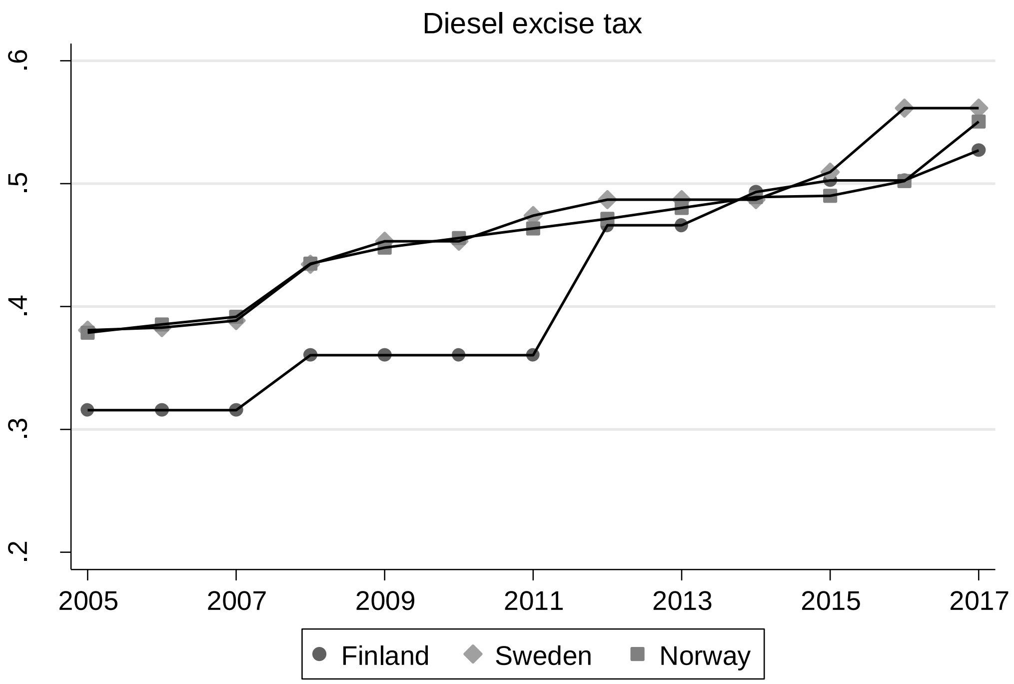
Appendix B

Figure B1. Excise taxes on gasoline in Finland, Sweden and Norway from 2005 to 2017



1 January 2017 exchange rates used to convert Norwegian and Swedish krones to euros

Figure B2. Excise taxes on diesel in Finland, Sweden and Norway from 2005 to 2017



1 January 2017 exchange rates used to convert Norwegian and Swedish krones to euros

Figure B3. Number of new cars registered per capita in Finland, Sweden and Norway from 2000 to 2014

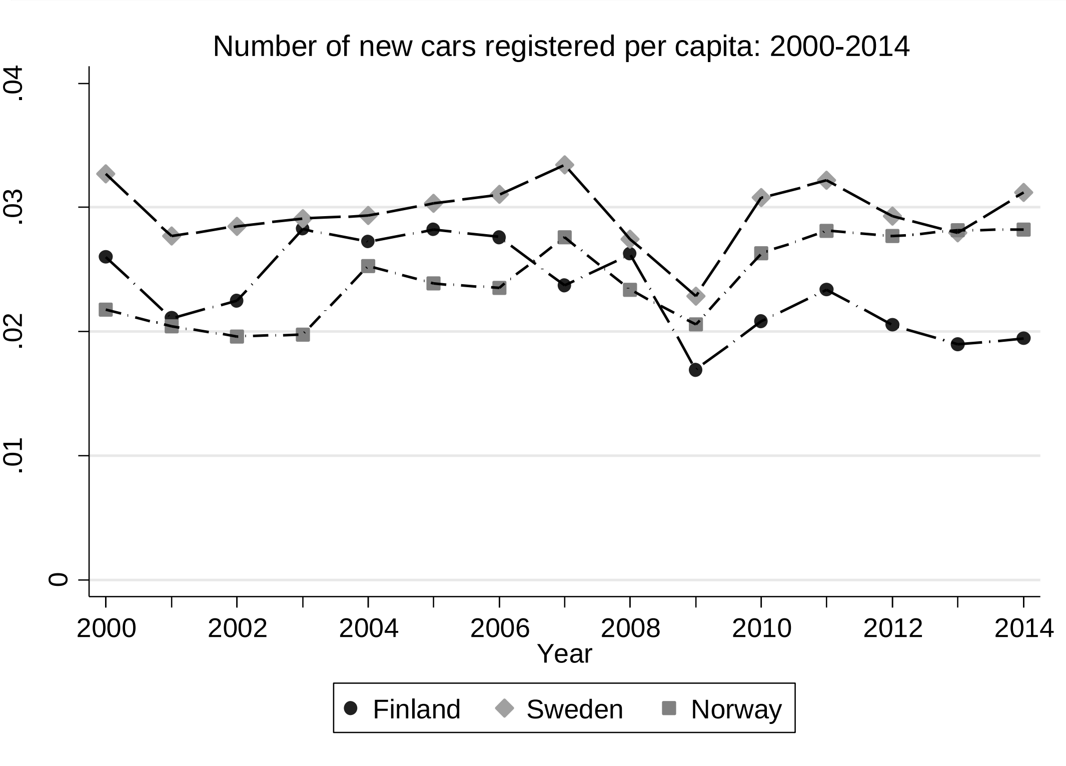
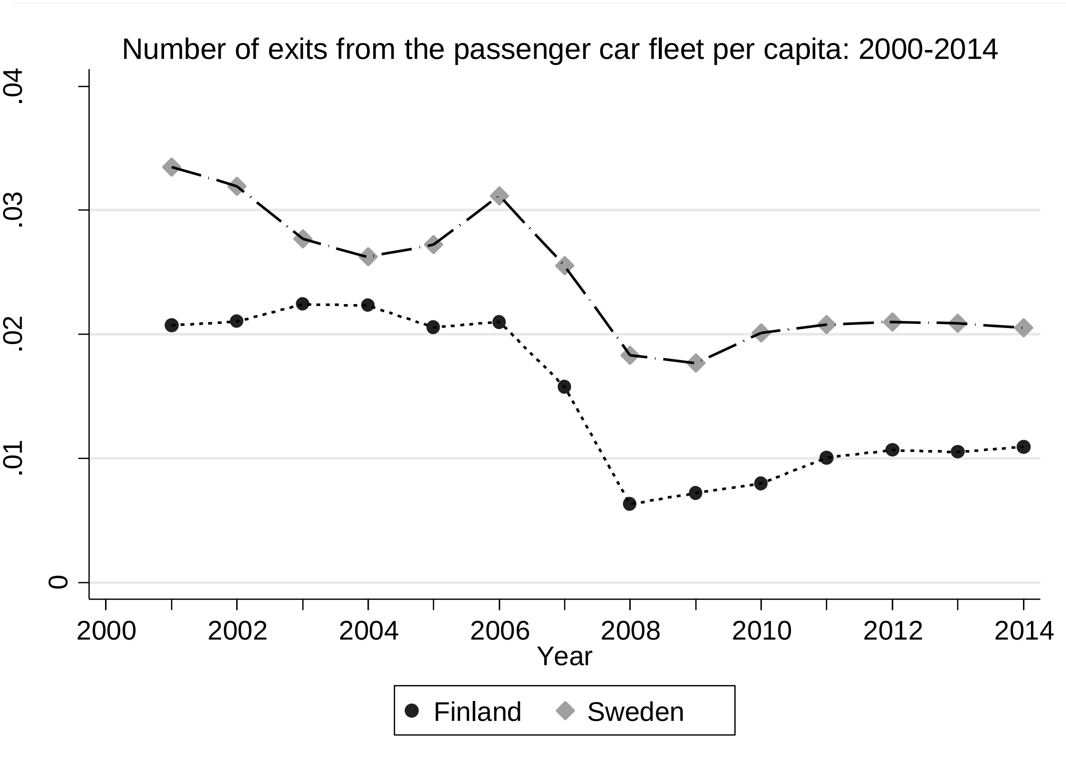


Figure B4. Number of exiting cars from the car fleet per capita in Finland and Sweden from 2000 to 2014



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