Tax incidence in the fuel market: Evidence from station-level data

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Abstract

This paper examines heterogeneity in the pass-through of a substantial diesel tax increase in Finland using station- and daily-level microdata. The estimated average pass-through rate is approximately 80% of the nominal tax increase. The pass-through rates differ across income groups, ranging from 90% in the lowest income septile to 76% in the highest income septile. These results suggest that fuel taxes are regressive. We also find evidence that the pass-through rate is larger in the most sparsely populated rural areas than in the most urban areas. Finally, we find evidence that the supply side anticipated the reform and filled up storage diesel tanks in the last months preceding the large diesel tax increase.

Keywords: Excise tax, fuel taxation, diesel, gasoline, tax-incidence, distributional effects

JEL codes: H22, H23, Q41, Q48

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1 Introduction

Many countries tax road transport fuels heavily, for both fiscal and environmental reasons. In Finland, excise and value added taxes add close to one euro to the average per liter price of gasoline (Finnish Customs 2016). In the US, the excise taxes on fuel are in general lower than in Europe but in some States, for example California and Pennsylvania, the aggregated state and federal taxes for gasoline and diesel are also relatively high, at approximately 70¢ and $1 per gallon, respectively. From the environmental point of view, climate change mitigation calls for substantial reductions in CO2 emissions from road transport. In the European Union (EU), road transport accounted for nearly 21% of the total CO2 emissions in 2016, and significant emission reductions are needed to meet the overall EU target of a 40% cut in its CO2 emissions (relative to the 1990 level) by 2030.

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. Increases in fuel taxes are often opposed forcefully on the grounds that the burden is carried disproportionally by low income households. Besides differences in overall 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 has lent support to the hypothesis that fuel taxes are regressive, more recent studies utilizing richer datasets and employing more sophisticated methods suggest that fuel taxation may have different distributional implications in different countries.

Tax incidence plays a central role in the political and environmental implications of fuel taxes: The extent to which taxes are passed on to retail prices, and factors determining the pass-through rate, affect in part both the effectiveness carbon taxes as a climate policy tool, and the distributional impacts of fuel taxes. Yet rather little empirical work has addressed the extent to which taxes are passed along to retail prices in practice, as noted by Poterba (1996), Doyle and Samphantharak (2008) and Marion and Muehlegger (2011). Furthermore, previous empirical work on fuel tax incidence has focused mostly on US data that exhibit fairly small variation in tax rates.

This paper examines the pass-through of fuel taxes to retail prices in Finland following a large tax reform in 2012 that increased the excise tax on diesel by more than 10 euro cents per liter and the excise tax on gasoline by approximately 2 euro cents per liter. While diesel maintained its preferential tax treatment, the reform brought the overall excise taxes on diesel and gasoline closer to each other. We study the effect of the diesel tax change on diesel prices utilizing a detailed data set of prices at the gas-station level. We focus in particular on heterogeneity in the diesel tax pass-through and the distributional consequences of Finland's 2012 fuel tax reform. In addition to the distributional analysis, we examine the role of competition between fuel stations as a factor explaining heterogeneity in tax incidence. Finally, we investigate whether and how the supply side anticipated the large diesel tax increase.

The results indicate that approximately 80% of the diesel tax increase was passed onto consumers. The pass-through rates differ notably across income groups, ranging from 90% in the lowest income septile to 76% in the highest income septile in our base specification. A difference of similar magnitude emerges in other specifications as well, suggesting that fuel taxes are regressive in Finland. Similar results were obtained for our wealth measure, regional housing prices. We also examined heterogeneity in diesel tax pass-through across relatively sparsely and densely populated locations and found that the most densely populated locations have the lowest pass-through rates. The divergence in pass-through rates is likely to stem from demand differences in that competition does not appear to be a driver of heterogeneity. Nor do other observable fuel-station-level characteristics appear to explain the heterogeneity in price responses, at least not as much as the income and wealth differences.

In addition, we find that diesel prices increased rapidly after the reform of 2012 and that the pass-through did not continue to increase over a longer time horizon, implying that the longer-run tax incidence is similar to the shorter-run estimates summarized above. We also observe that the amount of diesel fuel taxed at the wholesale terminals and delivered to retailers' storages increased right before the reform, implying that the supply side anticipated the reform by filling up retailers' storages shortly before the tax increase went into effect. This might partly explain why our pass-through estimates are lower than most estimates in the literature.

We contribute to the empirical literature on fuel tax incidence by providing an estimate of the pass-through rate in a market with relatively high fuel taxes and by measuring heterogeneity in pass-through across income and wealth groups. Our results also highlight the importance of accounting for potential anticipatory responses by distributors and retailers before large tax changes.

Our estimates of the pass-through rate are somewhat lower than the pass-through rates estimated by Doyle and Samphanthrarak (2008) and Marion and Muehlegger (2011) on US data, and Stolper (2016) on Spanish data. Our finding that fuel taxes are regressive is contrary to the result by Stolper (2016), who found fuel taxes to be progressive in Spain. The contrasting findings could be explained by differences in fuel demand characteristics, stemming for example from the prevalence of car ownership in the different income groups or the availability of substitutes for driving. Our results also provide further evidence that anticipatory responses to tax changes by distributors and retailers may be important, as suggested by Coglianese et al. (2017) .

This paper proceeds as follows: Section 2 describes the taxes pertaining to motor vehicle use in Finland and the fuel tax reform of 2011, and reviews previous literature on fuel tax incidence. Section 5 describes the data, offers graphical evidence and methods. Section 6 offers the overall results and Section 7 analyzes the supply-side anticipation of the tax reform. Finally, Section 8 concludes the study.

2 Fuel tax incidence

The incidence of a tax is a function of the relative supply and demand elasticities. These elasticities define the slopes of the supply and demand curves and may differ accross markets. Theory suggests that under perfect competition the fraction of a tax that is passed on to consumers is

$$\frac{dp}{dt} = \frac{\eta}{\eta - \varepsilon}$$

where η and ε are the elasticities of supply and demand, p the retail price and t the tax. The pass-through rate will be at most 100%. If supply is perfectly elastic, for example, taxes will be passed through to prices fully. Under imperfect competition, both undershifting and overshifting of the tax may occur (Katz and Rosen 1985, Seade 1985, Stern 1987, Besley and Rosen 1999, Hamilton 1999). While demand and supply elasticities still affect tax incidence, pass-through also depends on the shape (convexity) of the demand and supply curves (Weyl and Fabinger 2013).

Local and regional markets may differ in terms of the degree of competition, cost structure, consumer preferences and income. These differences will translate into differences in the supply and demand elasticities and consequently pass-through rates. If pass-through differs accross socioeconomic groups or differences in market competition or cost structure are systematically related to local socioeconomic characteristics, fuel taxes may have distributional implications. Demand in a given local market is likely to be influenced by factors such as the degree of urbanization, availability of public transportation, driving preferences, and a wide variety of household characteristics. Demand may be less elastic in rural areas where distances are long and public transportation networks limited. Demand elasticity may also be related to household income. The direction of the potential relationship is an empirical question. The same holds for the relationship between market power and pass-through.

3 Previous literature

Average pass-through

Our paper contributes to the literature on fuel tax pass-through and the broader literature on tax incidence. Most previous work on fuel taxation has employed monthly panels of state-level prices for the US. Chouinard and Perloff (2004, 2007), Alm et al. (2009) and Marion and Muehlegger (2011) use state-level variation in prices and taxes to study the pass-through rate of gasoline taxes. Chouinard and Perloff (2004, 2007) find that 50% of the US federal excise tax is passed on to consumers, 75% of the state ad valorem taxes are passed on to consumers, and nearly 100% of the state excise taxes are passed on to consumers. Alm et al. (2009) find that excise taxes are fully passed onto the consumers within the first month of the tax change. They also compared rural and urban states, and found that all of the excise taxes were passed on to consumers in urban states while pass-through was lower in rural states. Marion and Muehlegger (2011) analyze how factors constraining the US gasoline and diesel supply chains – gasoline content regulations, refinery capacity constraints, inventory constraints, and variation in demand of diesel for heating – affect the incidence of diesel and gasoline taxes. They find that in periods when the supply chain is constrained, for reasons unrelated to demand, the pass-through rate of fuel taxes declines. Otherwise, their results suggest at least full, and potentially more than full pass-through of federal and state diesel and gasoline taxes, although the null hypothesis of merely full pass-through could not be rejected.

Doyle and Samphantharak (2008) use gas station level data for the states of Illinois and Indiana. They estimate pass-through rates for both tax decreases and tax increases, and study whether the pass-through rate varies across markets described by their distance to the state border and their levels of brand concentration. They find that about 70% of a tax suspension is passed through to consumers, while the pass-through rates are 80-100% for tax reinstatement. Furthermore, they find that brands earn a premium, and some evidence that greater concentration and greater distance to the state border are associated with higher pass-through. Kopczuk, Marion, Muehlegger and Slemrod (2016) find similar pass-through rates for state diesel taxes, on average over 90%.

Stolper (2016) analyzes gas station and week level data for Spain and exploits variation in excise taxes across Spanish states to examine fuel tax pass-through. His average pass-through estimates are 95%, which is consistent with the estimates for the United States.

Heterogeneity in pass-through

Chouinard and Perloff (2004, 2007) find that differences in taxes and market power have a substantial effect on geographic price differentials. They 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.

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%, diesel tax pass-through was only 41%; however, no similar relationship was identified for gasoline tax pass-through. 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.

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%, 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%; 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 pro-portion 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%. 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 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.

Our paper is also closely related to a recent paper by Coglianese et al. (2017) on anticipatory behavior by gasoline buyers before tax increases. Coglianese et al. 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. Our data indicate increases in diesel and gasoline prices already in the months preceding the tax increases, and we account for anticipatory behavior by several alternative specifications excluding months just before- and after the tax change.

4 Fuel taxes and the 2012 fuel tax reform

Private motoring is taxed in several ways in Finland. New vehicles and imported used vehicles are subject to a vehicle first registration tax (car tax), and all vehicles which are to be used in traffic must pay an annual vehicle tax. Both the level of car taxes and vehicle taxes depend on the CO2 emission levels of vehicles such that more polluting vehicles are taxed more. Therefore, the taxation of vehicles is heavily based on environmental grounds incentivizing the use of less polluting vehicles. On top of these taxes, fuels are also subject to an excise tax and a value added tax. The excise taxes are defined as euro cents per liter, and the tax level varies across fuel products. The value-added tax (VAT) is charged as a standard percentage of the excise tax-inclusive price of fuel. The tax rate is currently 24% but has changed over the years and was 23% before and after the tax reform in 2011 and 2012. Altogether the different taxes on motoring contributed approximately 9% of the total tax revenue in Finland in 2014.

Table 1 displays a decomposition of average fuel prices in 2017 in euro cents per liter. The price data were provided by Statistics Finland. The total taxes amounted to 98.6 cents per liter on gasoline and 78 cents per liter on diesel.[1] With average market prices of 1.46 euros per liter for a gasoline blend called 95E10[2] and 1.29 euros per liter for diesel, taxes formed approximately 67.5% of the gasoline price and 60.5% of the diesel price.[3]

[1] Here we simplify the calculation by assuming that the fuel blends only include pure fossil-based gasoline and diesel and ignore the different tax rates on biofuels and other additives.

[2] 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%.

[3] Figure 8 in the Appendix A illustrates the development of different price components around the reform of 2012 using the average monthly consumer price levels. The Figure shows the average levels of monthly consumer prices for diesel (above) and gasoline (below) from January 2010 to December 2014 such that the horizontal axis describes the months from the first observation after the tax reform (0 is for January 2012). We divide the consumer prices to different components for both types of fuels over time similarly as in Table 1. The darkest area in the Figures show tax-exclusive prices for diesel and gasoline, the lightest area is for the fuel taxes and the are between these represents the amount of VAT. The top edge of the darkest area illustrates the average consumer prices for diesel and gasoline. The above Figure shows clearly that the level of diesel tax increased sharply right after the tax reform. Also, it is evident that the consumer prices increased at the same time. The Figure below illustrates also a small increase in the fuel tax of gasoline in January 2012. However, this change is much smaller than that for diesel. In addition, Figure 9 in the Appendix A shows the development of taxable fossile- and bio-components of diesel over time by months. These amounts are used to weight the level of taxes to obtain more accurate tax levels for diesel.

	Diesel	Gasoline (95E10)
Market price	129.0	146.0
VAT	25.0	28.3
Energy content tax	32.8	52.2
CO2 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%

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

Finally, it is important to note that the supply chain consists of refinery and imports of gasoline and diesel fuel, terminal storage, and retail delivery. Approximately 63% of petroleum products sold to Finnish consumers were refined in Finland in 2014 (Petroleum and Biofuels Association Finland). In terms of tax collection, the value added tax is remitted to the state by the retailer, while the excise tax is remitted by the wholesale terminal. The price posted by gasoline stations includes any taxes.

The reform of 2012

The excise taxes on diesel and gasoline have been increased six times during the last 20 years.[4] The six reforms took place between 2003 and 2017 and five of them featured a moderate 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, however, that the tax increases faced by consumers differed from the

[4]There were two other tax reforms during this prediod. First, in September 2004 the number of different fuel types recognized in the legislation was reduced and the existing types were redefined. However, the taxes for the most common types of diesel and gasoline fuels sold in the market were unchanged. Second, in January 2011 the taxes on fossil-based fuels, biofuels and other fuel components were differentiated but the first retained their previous levels.

diesel and gasoline tax increases stated above. Gas stations sell fuel blends that contain biofuels and other additives, rather than pure fossil-based diesel and gasoline. As these biofuels and additives are generally taxed at a lower rate, the excise taxes per liter at the retail stage slightly differ from the taxes on pure diesel and gasoline.[5] Unfortunately, data on the composition of the various fuel blends sold at gas stations around Finland are not available. However, we have aggregate data provided by Finnish Customs on the annual taxable amounts of various fuel products that are used in making the market fuel blends. Using these data, we constructed estimates of the average taxes on the market blends of diesel and gasoline in 2011 and 2012 by weighting the taxes on the different fuel products by their taxable amounts.

Table 2 shows that the estimated tax increases on the market blends are lower than those for the pure fossil-based fuels. The lower taxes on biofuels reduced the magnitudes of the excise tax increases at the retail stage by nearly 10%. However, to calculate the actual sizes of these tax increases, we still have take into account the VAT. As VAT is also paid on the excise tax component of the fuel price, an excise tax increase contributes to the overall tax increase also through the VAT component. With a VAT rate of 23%, the overall tax increases were approximately 11.80 cents per liter on diesel and 2.66 cents per liter for gasoline.

Excise tax	Diesel			Gasoline (95E10)		
	2011	2012	Change	2011	2012	Change
Pure fossil-based fuel	36.40	46.95	10.55	62.70	65.04	2.34
Market blend	36.06	45.65	9.59	60.14	62.30	2.16
Market blend×(1+VAT)	44.36	56.15	11.80	73.97	76.63	2.66

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

[5] Table 10 in the Appendix A collects the excise tax levels in 2012 for all the different fuel products. Product numbers 10 and 50 are the pure fossil-based gasoline and diesel respectively. The gasoline blends sold at gas stations contain product numbers 20–40 while product numbers 51–57 are used in making different diesel blends.

5 Data and methods

5.1 Price 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 a user-reported 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 names and addresses reported by the website users, some stations are listed multiple times because of reporting under slightly different names or because they are reported on both websites. We drew a random sample of about 50% 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

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 12 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 at each station was calculated as the average of the fuel-specific prices reported for the station within a day. Table 3 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.

	Diesel price		Gasoline (95E10) price	
	2011	2012	2011	2012
Number of day-and-station obs.	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

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

A potential concern when using these data in econometric analysis is the possibility that individuals systematically report 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

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.

serious the threat of misreporting might be by comparing the average monthly price levels calculated from the microdata to average gasoline and diesel fuel prices reported by Statistics Finland. The evolution of diesel prices in these two data sets is shown in Figure 1. The station-day microdata and Statistics Finland 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 Statistics Finland data on gasoline prices exhibit a similar trend (Figure 13 in the Appendix). A caveat is that the price series in Figures 1 and 13 were calculated from six municipalities that are among the largest in Finland, as Statistics Finland data on fuel prices are only available for these locations. However, considering the accuracy of the microdata in the Statistics Finland sample municipalities and virtually identical trends in the microdata for other locations, we conclude that misreporting is not a significant concern.

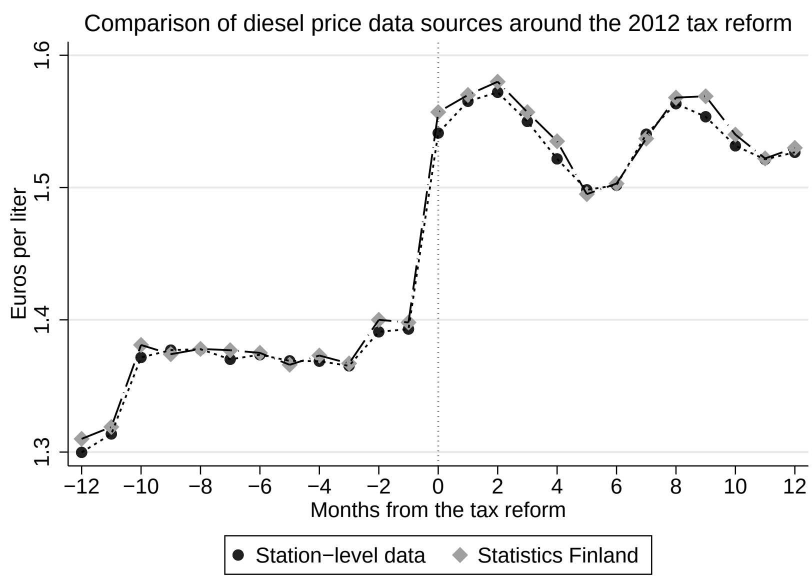

Figure 1: Comparison of average monthly consumer prices of diesel (euros per liter): Consumer-reported microdata vs. data from Statistics Finland

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 and housing price data are available at the postal code level only from 2012 onward. 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.[7] 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 postal code areas 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 between 2011 and 2012 represent altogether 257 municipalities, 446 three-digit postal code areas and 670 five-digit postal code areas. Housing prices are available for only 509 of the five-digit areas. Urban-rural classes 2, 6 and 7 each include 140–160 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 code areas is equal across the septiles for income, housing prices and population density, there are more price observations in the higher

[7] 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.

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.[8] 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.

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	135	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	917	219,034	1117	218,993	1114

Table 4: Number of observations and filling stations between 2011 and 2012

5.2 Methods

Identification in our econometric analysis is based on comparing diesel and gasoline prices around the 2012 reform. 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 group 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.

We estimate the following equation:

$$P_{sft} = \gamma_1 + \gamma_2 D_f + \gamma_3 A_t + \gamma_4 D_f A_t + \varepsilon_{sft} \tag{1}$$

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

[8]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.

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, γ_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 2 plots the price changes of diesel and gasoline between 2011 and 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. The difference between the fuel prices is also smaller around six months after the reform than right after it or another six months later.

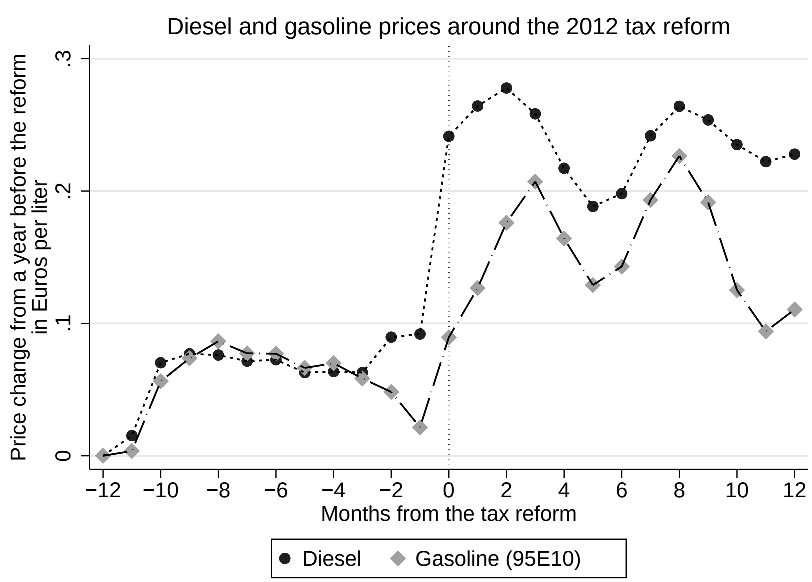

Figure 2: Changes in consumer prices of diesel and gasoline (including VAT) from January 2011 to January 2013

There are two plausible explanations for the divergence before the reform. First, the divergence may be due to anticipation effects. The amount of diesel taxed in Finland nearly doubled in late 2011 only to return to its previous level immediately after the turn of the year (see Figure 6 below), suggesting a clear supply-side anticipation effect. The potential impact of anticipation on market prices is unclear, though, as there might have been anticipation on the demand-side as well.

Second, it might be that diesel prices always rise more quickly relative to gasoline prices before the winter. This is because gas stations switch to offering a more expensive type of winter diesel that prevents the fuel from freezing in use in cold temperatures. Based on monthly price data from Statistics Finland over the period 2000–2018, diesel and gasoline prices indeed exhibit clear seasonality that lends support to this hypothesis. The price of diesel is always lower than the price of gasoline on average but the difference between the prices is always at its largest during summer months and at its smallest during winter months. This cyclicality can be seen in Figure 10 in Appendix A which shows the calendar montly average price differences between 2000 and 2018.

Because of the cyclicality, our identifying assumption in the DID model simplifies to assuming that diesel and gasoline prices have parallel trends only at the annual level. Examining the trends in average annual fuel prices between 2000–2018 in Figure 11 in Appendix A, the prices do seem to behave nearly identically in the absence of tax reforms and the financial crisis. We thus think that the assumption of parallel annual trends is reasonable and define the pre and post-reform periods in our main DID specification as the full calendar years 2011 and 2012 respectively. An alternative model excluding six months around the reform is also estimated to account for potential anticipation. Additionally, an indicator variable for the winter months from October to March is included as a covariate in the main specification to further control for the potential winter diesel effect.

Differences in the average pass-through rates between the seven income 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 least squares takes the form

$$\begin{aligned} P_{sgft} = \beta_1 + \beta_2 D_f + \beta_3 A_t + \beta_4 G_g + \beta_5 D_f A_t + \beta_6 D_f G_g \\ + \beta_7 A_t G_g + \beta_8 D_f A_t G_g + \beta_9 X_{sgft} + \varepsilon_{sgft} \end{aligned} \tag{2}$$

where G_g is a vector of indicator variables representing each group g (septile or class), and X_{sgft} is a vector of covariates that include the daily price of Brent crude oil, the daily EU ETS CO2 emission permit price, the daily EUR/USD exchange rate, the winter diesel indicator and its interaction with D_f, an indicator for unmanned stations[9]. Vector X_{sgft} also includes indicators for station chains representing station chain fixed effects. Both the covariates, which represent fuel demand and supply shifters, as well as the station chain fixed effects are included to increase estimation precision.

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 Equations (1) and (2). In the absence of a gasoline tax increase, coefficient γ_4 in (1) would identify the causal effect of the diesel tax increase on diesel prices on average and β_5 in (2) would identify the same effect in the baseline group. The coefficients in vector β_8 in (2) in turn would indicate how the price changed in each group relative to the baseline group. Pass-through on average would be calculated as $\gamma_4/\Delta t_d$ and pass-through in the baseline group 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 in both models 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. Our preferred and the simplest way to implement this is to divide 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} and P_{sgft} are the VAT-inclusive retail prices, 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 the price variables as the VAT-exclusive prices and ignore the VAT component in Δt_d and Δt_g.

Calculating the diesel tax pass-through rates by dividing the regression co-

[9]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.

efficients by the difference in tax increases only recovers the true pass-through rates if the true unobserved pass-through rates of the gasoline and diesel tax increases were equal to each other (in addition to the assumption of parallel trends).[10]The holds true for the average pass-through estimate in Equation (1) as well as all the group-specific estimates in Equation (2). We discuss the potential bias in the pass-through estimates induced by the violation of this additional assumption in Section 6.3.

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} and ε_{sgft}, 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 regressions on municipalities. The number of clusters could be increased by clustering on individual stations or 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

[10]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 $\hat{\gamma}_4$ in Equation (1) can be expressed as follows:

$$\hat{\gamma}_4 = \Delta p_d - \Delta p_g = \Delta t_d PT_d + \Delta p_{t,d} - (\Delta t_g PT_g + \Delta p_{t,g})$$

where PT_d and PT_g are the true unobserved 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 $\hat{\gamma}_4 = \Delta t_d PT_d - \Delta t_g PT_g$. Hence, assuming that the trends were in fact parallel, and dividing $\hat{\gamma}_4$ by $\Delta t_d - \Delta t_g$, the estimated diesel tax pass-through, $\widehat{PT}_d$, is:

$$\widehat{PT}_d = \frac{\hat{\gamma}_4}{\Delta t_d - \Delta t_g} = \frac{\Delta t_d PT_d - \Delta t_g PT_g}{\Delta t_d - \Delta t_g} \tag{3}$$

From Equation (3) we then get that $\widehat{PT}_d = PT_d$ if and only if $PT_d = PT_g$. All of the above holds true for coefficient $\hat{\beta}_5$ in Equation (2) as well if we define Δp_d and Δp_g as the average price changes in the baseline group.

level on which errors are likely to be correlated, as long as the number of clusters remains sufficiently large. In this sense we argue that the municipality level is the most appropriate level of clustering in our study.[11]

6 Results

6.1 Overall pass-through

Table 5 presents results from estimation of Equation (1), the average pass-through for the data on the whole. Columns (1) and (2) show the results for regressions using data for the entire period 2011-2012 and columns (3) and (4) for regressions excluding three months before and after the tax reform. Columns (1) and (3) show estimates from bivariate regressions of prices on indicators for diesel and the post-reform period. Columns (2) and (4) contain estimates from separate regressions that add station chain fixed effects and cost, exchange rate and quality controls (the daily Brent crude oil price, the European emission allowance price, the EUR/USD exchange rate, an indicator for automated stations and an indicator for winter diesel). The estimated pass-through is the proportion of the difference in the diesel and gasoline tax increases, 9.14 euro cents per liter, that was passed on to diesel price. We find undershifting of taxes to consumer prices. In column (1), a 9.14 euro cent increase in diesel tax per liter, beyond a concurrent 2.66 euro cent increase in both diesel and gasoline taxes, results in a 7.3 cent increase in diesel price per liter. This implies a pass-through rate of about **80%** for the diesel tax increase. In column (2), we add station chain fixed effects and the cost, exchange rate and quality controls described above. Adding these controls has virtually no effect on the pass-through estimate, as seen from column (2). Both estimates are statistically different from a full pass-through rate of 100% at the 0.1% level.

The estimated average pass-through rate is at the lower end of the pass-through rates estimated in most previous studies which have documented rates ranging from 80% to 100% or even above.[12] There are several explanations for

[11] 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).

[12] Results based on US micro-data suggest pass-through rates of 80% to 120% for tax in-

the difference. Apart from Stolper (2018), previous analyses with micro-data have focused on the United States. Local and regional markets may differ in terms of the degree of competition, cost structure, consumer preferences and income. Fuel demand may, for instance, be more elastic in Europe than in the United States because of wider availability of public transportation or markedly higher fuel taxes and prices. These differences likely lead to different pass-through estimates for different markets.

The relatively low pass-through rate could also be the result of anticipatory effects discussed in Section 5.2. As seen in Figure 2, the prices of diesel and gasoline diverged in the months preceding the tax reform, which could indicate anticipatory behavior in the market prior to the reform, or simply reflect the annual transition to winter diesel. In columns (3) and (4), we exclude the three months immediately before and after the tax reform from the estimation in order to understand whether potential anticipation affects our estimates. The model in column 3 only includes indicators for diesel and the post-reform period. The estimated pass-through rate falls to approximately 73%. Again, adding controls has virtually no effect on the pass-through estimate, as shown in column (4). While the estimates in columns (3) and (4) differ from the estimates for the full 24 month period, the differences are not dramatic.

creases (Doyle and Samphantharak (2008), Marion and Muehlegger (2011)). A recent study on Spanish micro-data found station-specific pass-through rates of 70% to 115%, with a central tendency around 90% to 95% (Stolper 2018).

	Whole period		Six months excluded	
	(1)	(2)	(3)	(4)
	Fuel price	Fuel price	Fuel price	Fuel price
D	-0.192***	-0.216***	-0.202***	-0.213***
	(0.001)	(0.001)	(0.001)	(0.001)
A	0.103***	0.079***	0.108***	0.111***
	(0.001)	(0.003)	(0.002)	(0.003)
D×A	0.073***	0.073***	0.066***	0.067***
	(0.001)	(0.002)	(0.002)	(0.002)
Constant	1.551***	1.370***	1.555***	1.258***
	(0.002)	(0.010)	(0.002)	(0.013)
Controls	No	Yes	No	Yes
Pass-through	79.5%	79.9%	72.6%	73.3%
N	219,034	219,034	163,693	163,693
R^2	0.81	0.87	0.82	0.89

Table 5: Overall effect of diesel excise tax increase on consumer prices

The dependent variable is fuel price in euros per liter. The controls include the daily Brent crude oil price, the EU ETS emission allowance price, the EUR/USD exchange rate, as well as dummies for winter diesel, automated gas stations and station chains. Pass-through is calculated by dividing the estimated coefficient on D×A by the difference between the VAT-inclusive increases in diesel and gasoline taxes, amounting to 0.0914 euro cents per liter. Standard errors (in parentheses) are clustered at the municipality level. *, ** and *** indicate significance at the 5%, 1% and 0.1% level.

6.2 Pass-through by income group and rural-urban classification

An important distributional question pertaining to fuel taxes is whether and how the incidence of taxation varies across socioeconomic groups and the rural-urban continuum. Table 6 presents estimates of how fuel taxes affect the prices paid in areas with different income levels and in rural versus urban areas. The estimates in Table 6 come from models comparable to columns (1) and (2) of Table 5. Again, the estimated pass-through is the proportion of the difference in diesel and gasoline tax increases, 9.14 euro cents per liter, that was passed on to diesel prices.

The effect of the tax increase on fuel prices decreases across the income distribution. The tax increase was passed through the most to prices in the lowest income areas, where individuals earned less than €19,170 per year on average. The pass-through is still only partial, at about 90%. In the highest income areas with average annual incomes of at least €23,810, the tax increase was passed through to prices to a notably lesser degree, with an estimated pass-through rate of 76%. The pass-through estimates are virtually unaffected by the inclusion of control variables in column (2), but estimation precision improves slightly. Figure 3 illustrates the differences in pass-through between income groups, with the differences measured relative to the pass-through estimate for the lowest income areas. The differences were obtained by dividing the coefficents for the diesel, post-reform period and income group interactions (DxAxG) from column (2) in Table 6 by the difference in diesel and gasoline tax increases. The figure demonstrates a monotonic decrease in pass-through with respect to income across the income distribution. Although the estimated coefficients for the diesel, post-reform period and income group interactions are statistically significant at conventional levels only for the three highest income groups, the results suggest heterogeneity in pass-through. The joint significance tests for the diesel, post-reform period and income group indicator interactions also support this conclusion. Results for how the tax increase affected the prices paid in areas with different housing prices, a proxy for lifetime wealth, are qualitatively very similar (results not reported at the interest of space).

That the tax increase is passed through more to prices in low income areas relative to high income areas has important distributional implications. The results resonate the concerns brought forth by the "yellow vests" movement, for instance, of fuel taxes disproportionately affecting lower impact groups. The expenditure shares of fuels are higher in middle income groups than in low income groups in Finland though[13], which serves to attenuate the regressive nature of fuel taxes.

[13] Official Statistics of Finland (2019)

	Whole period		Six months excluded	
	(1)	(2)	(3)	(4)
	Fuel price	Fuel price	Fuel price	Fuel price
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	79.5%	79.9%	72.6%	73.3%
1st septile	89.9%	90.7%	84.4%	86.3%
2nd septile	87.2%	88.3%	80.1%	81.6%
3rd septile	83.1%	84.6%	73.4%	76.5%
4th septile	79.9%	83.7%	74.1%	77.6%
5th septile	82.0%	80.6%	76.5%	75.3%
6th septile	77.1%	77.5%	69.7%	70.1%
7th septile	76.0%	75.7%	69.3%	69.0%
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

Table 6: Pass-through results by income septiles

The dependent variable is fuel price in euros per liter. The controls include the daily Brent crude oil price, the EU ETS CO2 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×A and D×A×G_s divided by the difference between the VAT-inclusive diesel and gasoline tax changes, or 0.0914. 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.

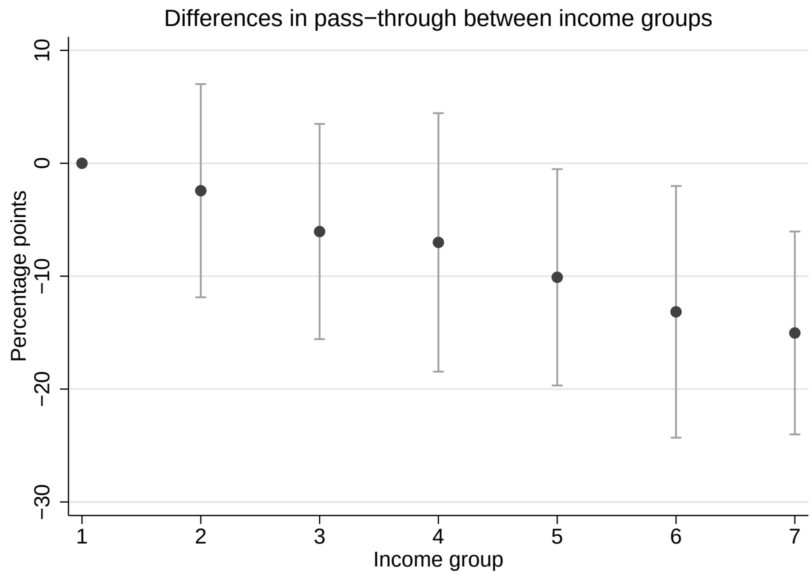

Figure 3: Differences in pass-through between income groups. Difference is measured relative to the pass-through in lowest income areas. Bars represent 95% confidence intervals.

The pass-through estimates for urban and rural areas also differ in terms of the point estimates (Table 7 and Figure 4[14]). With seven rural-urban classes, the difference in pass-through relative to the most rural class is only statistically significant for the most urban class, at the 5% level of significance. For the most sparsely populated rural areas, the pass-through rate is 91% and for the most urban areas (inner urban locations) 77%. The joint significance tests for the diesel, post-reform period and rural-urban class interactions also indicate pass-through differences between rural and urban areas.

Some of the differences in pass-through may be driven by the availablity of public transportation as a substitute for driving, which might affect the price elasticity of fuel demand, and by market competition, both plausibly greater

[14]The differences in Figure 4were obtained by dividing the coefficents for the diesel, post-reform period and rural-urban class interactions (DxAxG) from column (2) in Table 7by the difference in diesel and gasoline tax increases.

in the most urban areas than in sparsely populated areas. Part of the the differences may also be explained by the lower average income levels in rural areas if fuel demand is more inelastic among lower-income individuals. Section 6.4tests the hypothesis of competition as a driver of heterogenous tax incidence; we are unable to directly test the other hypotheses with our data.

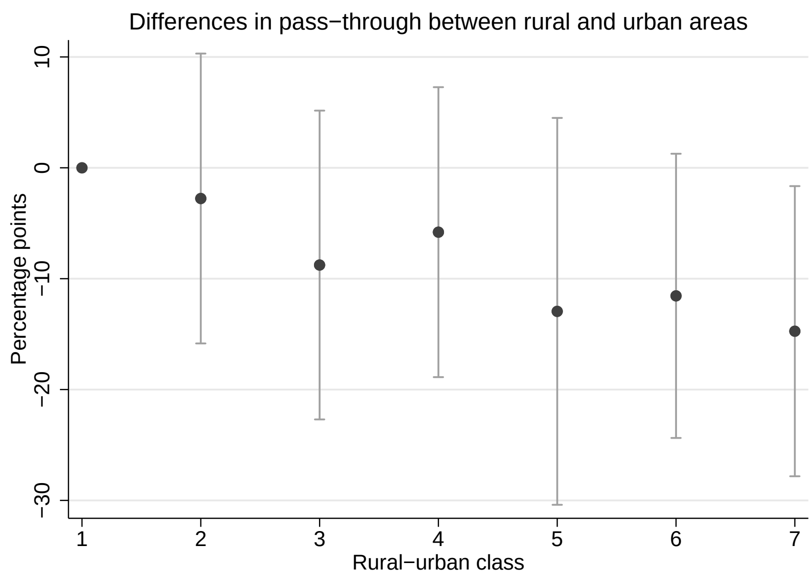

Figure 4: Differences in pass-through between rural and urban areas. Difference is measured relative to the pass-through in the most sparsely populated areas. Bars represent 95% confidence intervals.

	Whole period		Six months excluded	
	(1)	(2)	(3)	(4)
	Fuel price	Fuel price	Fuel price	Fuel price
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				
Average	79.5%	79.9%	72.6%	73.3%
1st class	91.2%	91.3%	86.2%	87.3%
2nd class	87.1%	88.5%	82.7%	84.6%
3rd class	84.6%	82.5%	81.9%	78.5%
4th class	87.1%	85.5%	81.9%	81.5%
5th class	77.5%	78.4%	71.7%	73.4%
6th class	78.3%	79.8%	71.1%	72.7%
7th class	76.5%	76.6%	68.4%	68.6%
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

Table 7: Pass-through results by urban-rural classes

The dependent variable is fuel price in euros per liter. The controls include the daily Brent crude oil price, the EU ETS CO2 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×A and D×A×G_s divided by the difference between the VAT-inclusive diesel and gasoline tax changes, or 0.0914. 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.

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

As pointed out in Section 5.2, 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, Δt_d, was much larger than the simultaneous gasoline tax change, Δt_g, at $\Delta t_d = 11.80$ and $\Delta t_g = 2.66$ in euro cents per liter. Suppose that that the assumption of parallel trends holds. We then have from Equation (3) that

$$\frac{\partial \widehat{PT}_d}{\partial PT_g} = -\frac{\Delta t_g}{\Delta t_d - \Delta t_g} \approx -0.29 \tag{4}$$

That is, given the true unobserved diesel tax pass-through rate, PT_d, a 10-percentage point difference between the true unobserved gasoline pass-through rate, PT_g, and the true unobserved diesel tax pass-through rate produces a 2.9 percentage point error in the opposite direction in the estimated diesel tax pass-through rate, $\widehat{PT}_d$. The estimated diesel tax pass-through rates are thus not overly sensitive to differences between the underlying diesel and gasoline tax pass-through rates. Another way to see this is to consider the following modified version of Equation (3):

$$PT_d = \frac{\hat{\gamma}_4 + \Delta t_g PT_g}{\Delta t_d} \tag{5}$$

If the assumption of parallel trends holds, the Equation (5) tells us how large the true unobserved diesel tax pass-through rate, PT_d, had to have been given our estimated DID coefficient, $\hat{\gamma}_4$, and an assumption about the true unobserved gasoline tax pass-through rate, PT_g. Based on our country-wide DID estimate in column (1) of Table 5 and various assumptions for the gasoline tax pass-through rate ranging from 70% up to 110%, possible values for the true unobserved diesel tax pass-through fall between approximately 77% and 86%. These rates deviate relatively little from our estimate of 80% in column (1) of Table 5.

Potential differences between the true unobserved diesel and gasoline pass-through rates are perhaps more of a concern if we wish to compare diesel tax pass-through rates across regions. Applying Equation (3) separately to each group g in the model in (2) shows how these comparisons can be misleading if the assumption of equal diesel and gasoline tax pass-through rates does not hold in all the groups. If, say, the true unobserved gasoline tax pass-through was higher in richer regions while the true unobserved diesel tax pass-through was constant across all regions, the diesel tax pass-through estimates would be downward biased in the richer regions. This would suggest that the diesel tax increase was regressive when in fact it was proportional and the gasoline tax increase was actually progressive.

However, the differences in the estimated pass-through rates between the highest and lowest septiles or classes, for all the grouping variables, are relatively large at about 15 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.

6.4 Competition

One obvious explanation for heterogeneity in tax incidence suggested by the theory is competition. The degree of competition could affect the average pass-through such that we would, for example, observe much higher pass-through in areas where there is no or only little competition compared to areas of close to full competition. To offer a complete view of what are the reasons behind the observed price responses at the time of 2012 reform, we also examine the role of competition.

We use two different measures of competition: the number of gas stations within a specific driving distance from each gas station and the Herfindahl–Hirschman Index (HHI). The latter is a measure of market concentration and is defined here as the sum of the squares of the market shares of station chains within postal code areas or municipalities. HHI gets values between 0 and 1, with 0 indicating perfect competition and 1 a station chain monopoly. Both measures have been used in the literature to study heterogeneity in fuel tax pass-through. The distance measure is employed for example by Stolper (2016) while HHI is used by Doyle and Samphantharak (2008).

When we measure competitiveness by the number of competing gas stations in the proximity of each station, we limit our scope to a maximum driving distance of five kilometers. The driving distance data used in the analysis were first obtained from Google Maps by using the coordinates of the gas stations in our sample. We then calculated for each station the number of competing stations within driving distances ranging from one to five kilometers. To complement the more aggregate-level HHI-based analysis, we also calculated the average number of nearby stations for each three-digit postal code area and municipality. It should be noted that because we only have a random sample of the stations, the numbers of competing stations calculated from our sample are necessarily too low on average. This could induce bias in our estimated regression coefficients.

Table 11 in Appendix A displays descriptive statistics for a subset of our competition measures: the number of nearby stations within one and five kilometers at the individual station, postal code and municipality levels and HHI at the postal code and municipality levels. The median station in our sample has no nearby stations within one kilometer and only two within five kilometers but the distributions have long right tails. Postal code and municipality-level averages exhibit a similar pattern. The median postal code area has a median HHI value of 0.6 while for municipalities it is 0.5. However, the HHI values are very unevenly distributed with 44% of the postal code areas and 32% of the municipalities having a value of exactly 1 and the rest values between about 0.2 and 0.6.We use one year before and after the reform of 2012 as our pre and post-reform periods in all the regressions.

A comparison of the average values of our measures across housing price groups and rural and urban areas suggests that competition might indeed explain part of the estimated pass-through differences. On the one hand, Figure 14 in Appendix A shows that stations in higher income areas and in more urban areas have more nearby stations on average within a five kilometer driving distance. There are, however, no clear differences between the average numbers within shorter distances. On the other hand, market concentration as measured by HHI is decreasing in three-digit postal code area income, as seen from Figure 15 in Appendix A. These two patterns are also evident when we look at regional groupings based on housing prices and population density.

To analyze the connection between pass-through and competition more rigorously, we estimate models similar to Equation (2) and replace the indicator variables in G_g with our measures of competition. We use the full calendar years of 2011 and 2012 as our pre and post-reform periods in all the regressions. Rather than producing causal estimates of the effect of competition on pass-through, these DID regressions merely compare the pass-through rates between regions with varying degrees of competition. This is because regional competitiveness might be correlated with other factors that explain the differences in pass-through. To potentially control for some of these factors, we also include as covariates various station, postal code area and municipality-specific factors that might be correlated with competition and explain pass-through. These include indicators for unmanned stations, stations along highways and station chains, the urban-rural classification and population density. Finally, the skewedness and unevenness of the competition measures discussed above are potential sources for problems in our estimation. To minimize these problems and to allow for more flexibility in the estimation, we calculate tertiles for all the competition measures.

Pass-through results using the distance measures are presented in Table 8. We only report the coefficients for the diesel–post reform interaction terms and the three-way interaction terms between diesel, post-reform period and the competition measures. The first coefficient in each column is an estimate of the causal effect of the diesel tax increase on diesel prices in the baseline group. The coefficients below it measure the difference in pass-through between the other groups and the baseline group. All the results reported here come from models that include all the covariates because including them had no effect on the estimated coefficients but resulted in higher estimation precision.

	Station level		Postal code level		Municipality level	
	(1)	(2)	(3)	(4)	(5)	(6)
	Fuel price	Fuel price	Fuel price	Fuel price	Fuel price	Fuel price
D×A	0.073***	0.075***	0.074***	0.077***	0.076***	0.081***
	(0.002)	(0.002)	(0.002)	(0.004)	(0.003)	(0.004)
D×A×# of stations	-0.002		0.001		-0.004	
w/i 1 km 2nd tertile	(0.002)		(0.004)		(0.004)	
D×A×# of stations	0.000		-0.002		-0.001	
w/i 1 km 3rd tertile	(0.003)		(0.002)		(0.003)	
D×A×# of stations		-0.001		0.001		-0.003
w/i 5 km 2nd tertile		(0.003)		(0.004)		(0.005)
D×A×# of stations		-0.005		-0.006		-0.009*
w/i 5 km 3rd tertile		(0.003)		(0.004)		(0.005)
N	218,993	218,993	218,993	218,993	218,993	218,993
R^2	0.83	0.83	0.83	0.83	0.83	0.83

Table 8: Pass-through results by the number of competitors

The dependent variable is fuel price in euros per liter. The controls include indicators for unmanned stations, stations along highways and station chains, the urban-rural classification and population density. Standard errors (in parentheses) are clustered at the municipality level. *, ** and *** denote significance at the 5%, 1% and 0.1% level respectively.

Based on the results there seems to be no relationship between pass-through and the number of nearby stations within one kilometer at any level of aggregation. The coefficients on the interaction terms are very close to zero in all three models. One possible explanation for this is that there is not enough variation in our data: the absolute numbers of nearby stations are on average very low and most stations have no neighboring stations. When the driving distance is increased to five kilometers, the numbers of neighboring stations increase and so do the sizes of the estimated coefficients at least in the highest tertiles. The negative signs of the estimates imply that pass-through might decrease with the number of nearby stations, but the station and postal code-level estimates are not statistically significant at any traditional level. However, at the municipality level the coefficient on the highest tertile is relatively large at -0.009 and statistically significant at the 5% level. This translates to a pass-through rate that is approximately 10 percentage points lower in municipalities with stations that have the highest number of nearby stations on average. The average pass-through rate among municipalities with the least competition was nearly 89% which is relatively high compared to the national average of 80%.

One reason we only observe differences in pass-through at the municipality level might be because of a potentially higher number of confounding factors at lower levels of aggregation. That is, stations in the same tertile calculated at lower levels of regional aggregation do have similar numbers of nearby stations but may be vastly different from each other in terms of other factors that might influence the pass-through rates more.

Table 9 presents the pass-through results using HHI as a measure of market concentration. Because of the large share of HHI values of exactly 1, we could not uniquely form tertiles for the measure. Instead, we use an indicator that takes on the value of one when HHI is above 0.5. This is reasonable because of the almost complete lack of observations with HHI values over 0.5 but under 1. We again only report estimates from models that include all the covariates due to the covariates not having any effect on the estimates but lowering standard errors.

	Postal code level	Municipality level
	(1)	(2)
	Fuel price	Fuel price
D×A	0.071***	0.072***
	(0.002)	(0.002)
D×A×1{HHI > 0.5}	0.007**	0.008*
	(0.002)	(0.004)
N	218,993	218,993
R^2	0.83	0.83

Table 9: Pass-through results by the degree of market concentration

The dependent variable is fuel price in euros per liter. The controls include indicators for unmanned stations, stations along highways and station chains, the urban-rural classification and population density. Standard errors (in parentheses) are clustered at the municipality level. *, ** and *** denote significance at the 5%, 1% and 0.1% level respectively. No estimate is reported for D×A×HHI 3rd tertile at the postal code level because the second and third tertiles of HHI are not uniquely defined but identical to each other.

The results indicate that pass-through increases with the degree of market concentration both at the postal code level and the municipality level. Coefficient estimates from both models are statistically significant at the 1% or 5% level. The three-way interaction coefficient estimate implies that the average pass-through rate among postal code areas with maximal or near maximal market concentration was more than 7 percentage points higher compared to other areas. The difference between high and low market concentration municipalitites, on the other hand, was approximately 9 percentage points.

Both of our measures of competition suggest that pass-through might be decreasing in the degree of competition. The results are less clear when we use the number of nearby stations as a proxy for competition than when we measure market concentration by calculating HHI values. Our estimates may also be biased due to not having all the gas stations in Finland in our sample, and thus not being able to calculate the competition measures accurately. Finally, our DID estimates of the effect of competition on fuel tax pass-through are necessarily not causal in nature.

6.5 Robustness checks

We test the validity of our DID identification strategy and the assumption of parallel trends in diesel and gasoline prices in two ways. First, as a placebo test we compare price changes between diesel and gasoline in times of no fuel tax changes, which should produce null results. Second, we use Swedish diesel prices as an alternative control group to see whether we obtain results similar to those in our comparison of diesel and gasoline prices in Finland.

In the placebo DID regressions we consider two time periods, 2009 vs 2010 and 2012 vs 2013, when there were no excise tax changes.[15] We estimate models identical to Equation (1) with the full calendar years as pre and post-periods.[16] The results are presented in Table 12 in Appendix A. The estimated interaction coefficients of 0.002 and -0.002 confirm that there were no differences in the time trends of the two fuels. While the first of these coefficients is statistically significant at the 1% level, it is so close to zero that is has no economic significance. These results provide further evidence that the comparison between fuel types over time is an appropriate method to study the incidence of fuel taxes.

As a robustness check, we use price data from Sweden as an alternative control group for Finnish diesel prices and compare the prices changes in the two

[15] However, the standard VAT rate in Finland increased by 1 percentage point in both 2010 and 2013, first from 22% to 23% and then from 23% to 24%. Assuming that these small increases were passed through to diesel and gasoline prices at the same rate, our placebo estimates are valid.

[16] When we compare years 2009 and 2010, the post-turn-of-the-year period we use actually only extends until November 30, 2010. This is because diesel and gasoline prices seemed to diverge a bit right at the end of 2010 and we suspect that this is due to potential anticipation effects of two events that occured simultaneously in January 2011: fuel taxes were changed and gas stations stopped selling gasoline type 95E5 and switched to type 95E10 with a higher ethanol concentration. Including December 2010 in the estimation increases the size of the estimated interaction coefficient by about 0.5 Euro cents per liter.

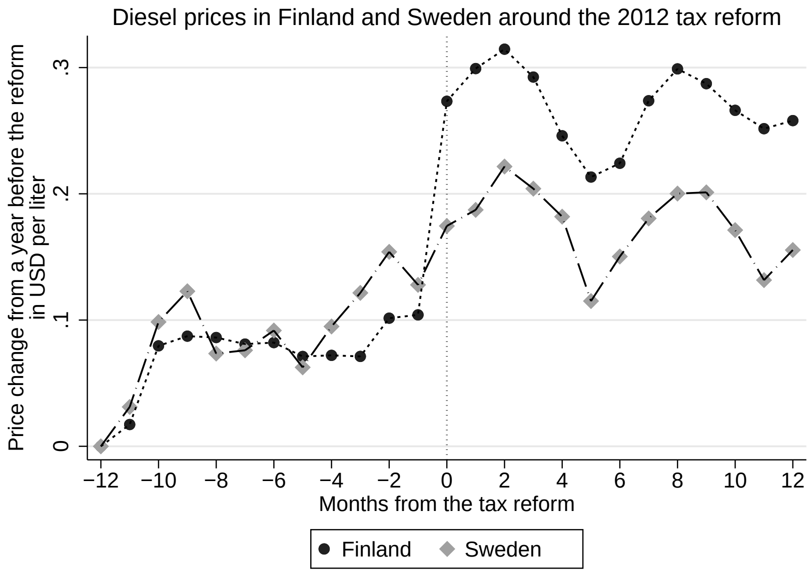

Figure 5: Diesel price changes in USD per liter in Finland and Sweden around the 2012 tax reform

countries around the 2012 reform. Our Swedish data are average daily prices from all manned stations operating unde the Circle K name. The monthly averages of these prices are identical to monthly averages reported by Svenska Petroleum & Biodrivmedel Institutet, a Swedish fuel trade association that collects price data all around Sweden. We thus view the data as being well-representative of the whole country.

The assumption of parallel trends in diesel prices between Finland and Sweden seems plausible because Finland and Sweden are neighboring countries with very similar fuel tax policies, institutions and weather conditions. Diesel prices in the two countries are, however, in different currencies so the price levels are not directly comparable. Because the prices of diesel largely follow changes in the price of crude oil which is always traded in US dollars, we transform the price data into dollars in both countries. We use fixed annual average exchange rates from 2011 so that the comparison is not confounded by short term exchange rate volatility and so that we can also consistently calculate the size of the tax change in US dollars.

Changes in the monthly average diesel in Finland and Sweden around the Finnish tax reform in 2012 are plotted in Figure 5. Here the prices are VAT exclusive because of different VAT rates in the two countries. The assumption of parallel trends seems reasonably valid judging by the very similar price movements in both countries during the whole period between 2011 and 2012. Diesel price in Sweden were, however, more volatile in 2011 and increased faster in the fall of 2011 than in Finland.

Despite the similar trends in Finnish and Swedish diesel prices, a concurrent tax increase in the control group complicates this cross-country comparison as well. The excise tax on diesel was raised by 12.5 öre by liter in 2012 which is equal to about 1.92 US dollar cents at the 2011 rate. However, because biocomponents in fuels were not subject to an excise tax in Sweden during 2011 and 2012 and their shares in the market blend of diesel increased from 2011 to 2012, the estimated tax increase faced by consumers was only about 1.1 öre per liter or 0.17 US dollar cents per liter.[17]Compared to the Finnish diesel tax change of 9.59 Euro cents per liter in Table 2, or 13.36 US dollar cents per liter at the 2011 exchange rate, the Swedish tax increase is negligible and has practically no effect on our estimated pass-through rate in Finland.

Using the VAT-exclusive USD per liter prices and taxes, we estimate cross-country DID models identical to Equation (1) with the indicator variable for diesel replaced with an indicator for Finland. The results are presented in Table 13 in Appendix A. When we use the full calendar years of 2011 and 2012 as pre and post-periods our results show that diesel prices in Finland increased by approximately 11.1 US dollar cents more than in Sweden. Dividing this by the difference in the tax changes between the two countries in dollars gives us a pass-through estimate of about 84%. This is very similar to the estimate of 80% in our main specification using Finnish gasoline prices as a control group. To make our results directly comparable to those in Table 5, we also estimate the model excluding six months around the tax reform and obtain a pass-through estimate of 76%. Again, the estimate is close to the estimate of about 73% in the gasoline comparison. The similarity betweenall of the results lends support to the assumption of parallel trends between diesel and gasoline prices and the

[17]The Swedish Energy Agency estimated that the share of biofuels in diesel increased from 5.2% in 2011 to 7.5% in 2012 (Swedish Energy Agency 2013). This means that on average only 94.8% and 92.5% of every liter of the market blend of diesel was taxable in 2011 and 2012 respectively. Thus, while the excise tax on pure diesel increased from 454.1 öre per liter to 466.6 öre per liter, the tax on the market blend only increased from 430.5 öre per liter to 431.6 öre per liter, a 1.1 öre per liter increase.

validity of our main identification strategy.

7 Supply side and anticipation

One additional and often unstudied aspect that might affect both the size and validity of our pass-through estimates is the possibility of supply side anticipation of large reforms. On the one hand, if the observed divergence in the prices of diesel and gasoline was directly caused by anticipatory behavior, it would be a violation of the assumption of parallel trends and induce bias in our estimates. On the other hand, anticipation could have affected the actual pass-through rate through changes in the elasticity of supply or the possibility of evading a part of the tax by shifting production costs to the future or incurring them sooner.

We find evidence of supply side anticipation by looking at data on the aggregate taxed amounts of diesel and gasoline in Finland. Figure 6 shows that there was a notable increase in the amount of taxed diesel right before the large diesel tax increase in January 2012. The amount of taxed diesel appears to be almost twice as large as the amount in the preceeding months. No such jump in the amounts of taxed diesel and gasoline precedes the smaller diesel and gasoline tax increases that went into effect in January 2008 or January 2014 marked with vertical dashed lines in Figure 6. Such anticipatory pattern at the time of 2012 reform is consistent with the findings by Kopczuk et al. (2016) that the incidence of a quantity tax depends on the point of tax collection and that this behavior is driven by tax evasion. While we cannot test tax evasion responses, the pattern in Figure 6 indicates that distributors are actively avoiding some of the additional tax burden brought along by a large tax increase.

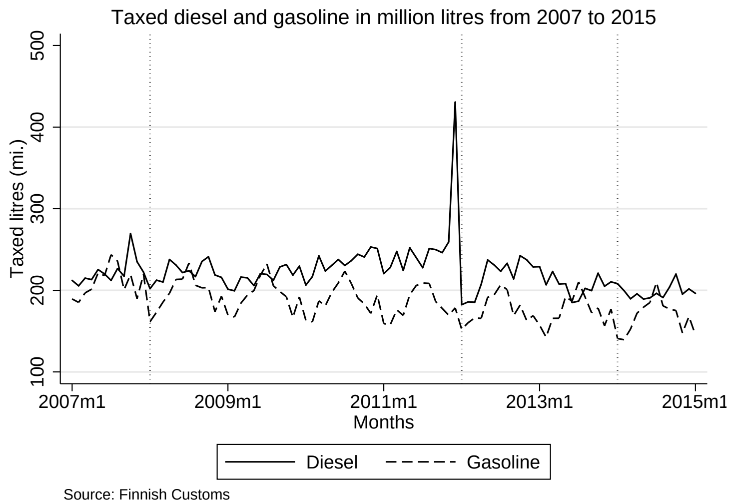

Figure 6: Taxed amounts of diesel and gasoline in million litres from January 2007 to December 2015

In order to quantify the supply-side anticipation response, we use the recently developed bunching method. We adopt the same approach as Kleven and Waseem (2013) in their study of income tax notches in Pakistan.[18] However, in our application the tax notch is situated at the time of the tax teform, not the level of taxable income as in the Kleven and Waseem study.

The magnitude of the bunching response is often referred to as excess mass in the bunching literature as it is represented by an additional mass in the observed distribution exactly at the kink/notch point, relative to a counterfactual distribution that would correspond to a world without the notch. Measuring the excess mass, of course, requires first approximating the counterfactual distribution – in our case, the empirical density distribution of taxed diesel (in million liters) in the absence of the tax reform. The counterfactual density is estimated by fitting a flexible polynomial to the empirical density where observations in a range before and after the tax reform are excluded. The excluded range should correspond the area where the bunching responses occur. The lower limit of the excluded area is commonly determined by visual observation indicating where the behavioral responses – in our case anticipatory behavior – begins. The upper

[18] More about the bunching method can be found from Kleven (2015).

limit instead cannot be determined visually. To fix the upper limit, we follow Kleven and Waseem (2013) and use the excess liters in the distribution that constitute the bunching response (that is, appear between the lower limit and the notch point) to match the taxed liters that are 'missing' after the reform. We iterate by starting with a low initial value of the upper limit, which we then increase it in small increments. The counterfactual is re-estimated for each increment until a point of convergence is achieved such that all the excess liters that were taxed before the reform have been added to the observed distribution after the reform.

Figure 7 groups the taxed diesel quantities into to bins of one month. Value zero on the horizontal axis corresponds to the time of the tax reform. We estimated the counterfactual distribution with two alternative lower limits for the excluded area: we first set the lower limit at November 2011 (indicated by the vertical line at -2 months in Figure 7 top panel) and then at January 2010 (vertical line at -24 months in Figure 7 bottom panel). The first choice reflects the assumption that the supply side anticipated the reform only two months in advance while latter choice corresponds to the assumption that anticipation began right when the reform was made public. The upper limits were determined using the convergence rule described above.

The top panel of Figure 7 suggests that as much as 90% more diesel was taxed in the last two months preceeding the reform than what the estimated counterfactual would have suggested. The bottom panel of Figure 7suggests even larger anticipation during the two-year period when the upcoming reform was publicly known (January 2010 through December 2011), with approximately 170% excess liters taxed relative to the counterfactual distribution. The bunching estimates imply that the supply side anticipated the reform. The anticipatory behavior may have taken several routes: distributors may have transferring their old untaxed storages to taxed storages, refineries may have refined more diesel, and importers may have imported more ready-to-use diesel from abroad. As bunching behavior is so apparent in the last months before the reform, transferring diesel from untaxed storages to taxed storages may be the most likely explanation.

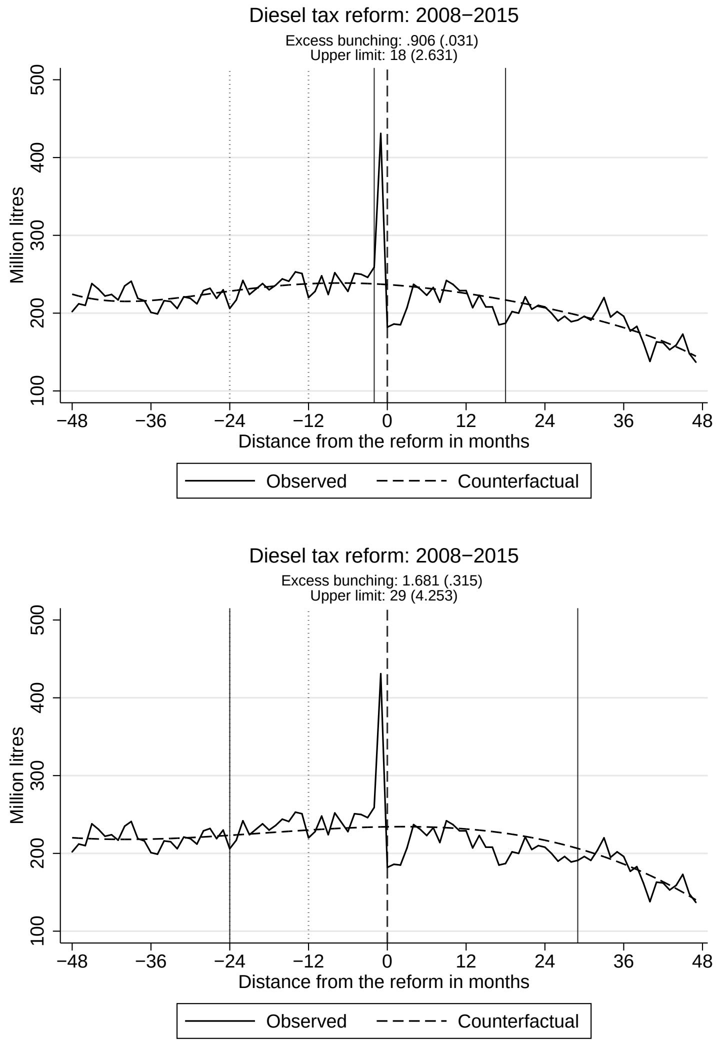

Figure 7: Excess mass of the taxed amount of diesel (million liters) at the time of the 2012 reform

We have also estimated the excess bunching for the diesel tax reform of 2014 similarly as in the upper panel of Figure 7 using data for two years and after the reform. We find no statistically significant bunching before that small reform (0.070 (0.046)). Unfortunately, we have data on taxed diesel litres only from January 2007 onwards which makes it difficult to estimate the excess bunching before the 2008 diesel tax reform. However, using only 12 months before the reform and 12 months after, the estimated excess mass is 0.146 (0.192).

8 Conclusions

Despite a large literature on the theory of tax incidence, few empirical studies have addressed the distributional and regional heterogeneity in pass-through rates of excise taxes. Moreover, most of the existing empirical studies have examined tax changes in the US, where fuel taxes are markedly lower compared to Europe. Thus, pass-through estimates based on US data may not be very informative of fuel tax incidence in countries with relatively high tax levels. In addition to fiscal reasons, fuel taxes are used in Europe increasingly also as an attempt to curtail CO2 emissions from traffic and to encourage the use of biofuels. Tax incidence plays an important role in the political and environmental implications of fuel taxes, both because of distributional reasons and because it may affect the effectiveness of carbon taxes to reduce CO2 emissions from traffic.

We examine the effect of a substantial diesel tax increase of 10.55 euro cents per liter on the retail prices of diesel. We use a detailed data set of gas station level prices. We find evidence for less than full shifting of the tax: the estimates suggest that 80% of the tax increase was passed on to consumers. The estimated pass-through rate is somewhat smaller than found for the US and Spain in earlier studies. 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 the wider availability of public transportation, it is plausible that demand may be more elastic in Europe than in the US. Previous research by Alm et al. (2009) also found less-than-full pass through in rural US states, which may also be indicative of incidence in a relatively sparsely populated country such as Finland. While our results directly measure incidence only in Finland, they suggest some difference in fuel tax incidence in the US, documented in previous empirical literature, and in the relatively high-tax context in Europe.

Our main results suggest consistently that the pass-through rate is decreasing with income and wealth measures, implying that fuel taxes are regressive. This is contrary to the findings by Stolper (2016) who finds these taxes to be progressive using a somewhat similar setting as we do. However, our tax reform is much larger than the average changes used by Stolper (2016). We find some evidence that competition might drive some of the heterogeneity in pass-through, but the results are not conclusive. However, we are not able to study whether demand-side factors give rise to the observed heterogeneity.

In addition, we show that the diesel prices increase rapidly after the reform of 2012 and that the pass-through does not increase over longer time span, implying that the longer-run incidence is similar to the short-run estimates presented above. We also observe that the amount of taxed diesel liters increased right before the 2012 reform, implying that the supply side clearly anticipated the reform by loading their storages with diesel and moving diesel from untaxed storages to taxed storage tanks. The anticipatory behavior might potentially also explain why our pass-through estimates are lower compared to other estimates in the literature.

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Appendix A

Traffic fuel taxes: 2012					
Product	Pr. No.	Energy content tax	CO2 tax	Strategic stockpile fee	Total
Motor gasoline c/l	10	50.36	14	0.68	65.04
Small engine gasoline c/l	11	30.36	14	0.68	45.04
Bioethanol c/l	20	33.05	9.19	0.68	42.92
Bioethanol R c/l	21	33.05	4.59	0.68	38.32
Bioethanol T c/l	22	33.05	0.00	0.68	33.73
MTBE c/l	23	40.91	11.37	0.68	52.96
MTBE R c/l	24	40.91	10.12	0.68	51.71
MTBE T c/l	25	40.91	8.87	0.68	50.46
TAME c/l	26	44.06	12.25	0.68	56.99
TAME R c/l	27	44.06	11.14	0.68	55.88
TAME T c/l	28	44.06	10.04	0.68	54.78
ETBE c/l	29	42.49	11.81	0.68	54.98
ETBE R c/l	30	42.49	9.62	0.68	52.79
ETBE T c/l	31	42.49	7.44	0.68	50.61
TAEE c/l	32	45.64	12.68	0.68	59
TAEE R c/l	33	45.64	10.85	0.68	57.17
TAEE T c/l	34	45.64	9.01	0.68	55.33
Biogasoline c/l	38	50.36	14	0.68	65.04
Biogasoline R c/l	39	50.36	7.00	0.68	58.04
Biogasoline T c/l	40	50.36	0.00	0.68	51.04
Diesel c/l	50	30.7	15.9	0.35	46.95
Diesel para c/l	51	24	15.01	0.35	39.36
Biodiesel oil c/l	52	28.14	14.57	0.35	43.06
Biodiesel oil R c/l	53	28.14	7.29	0.35	35.78
Biodiesel oil T c/l	54	28.14	0.00	0.35	28.49
Biodiesel oil P c/l	55	24	15.01	0.35	39.36
Biodiesel oil P R c/l	56	24	7.51	0.35	31.86
Biodiesel oil P T c/l	57	24	0.00	0.35	24.35

Table 10: Excise tax rates on liquid fuels in 2012

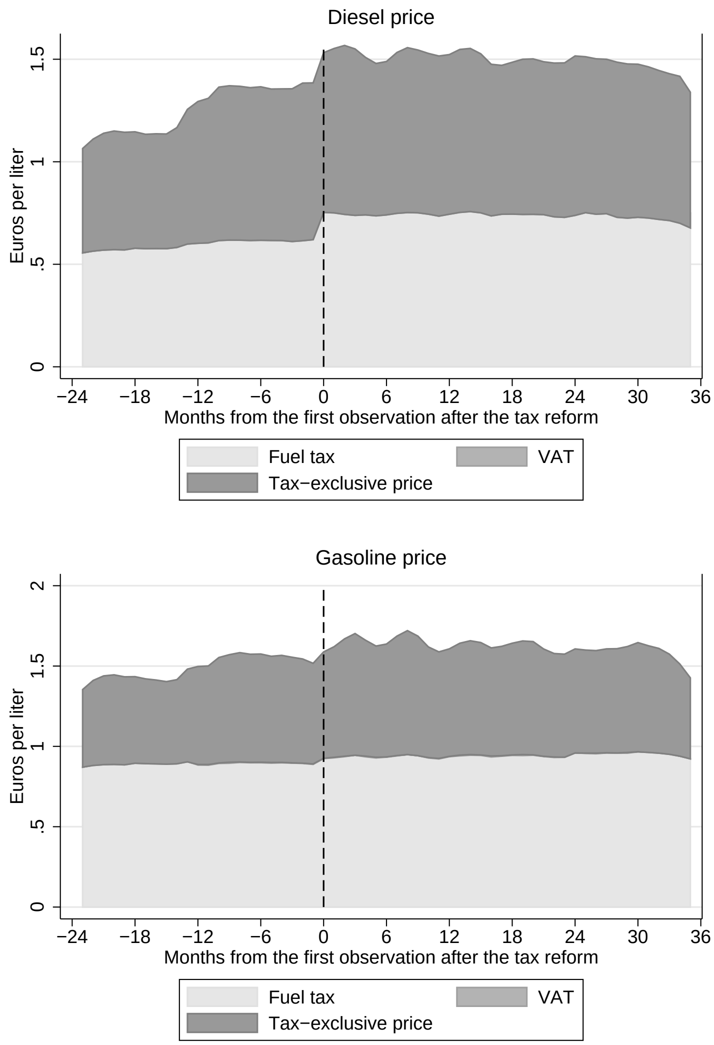

Figure 8: Composition of fuel price over time: diesel and gasoline

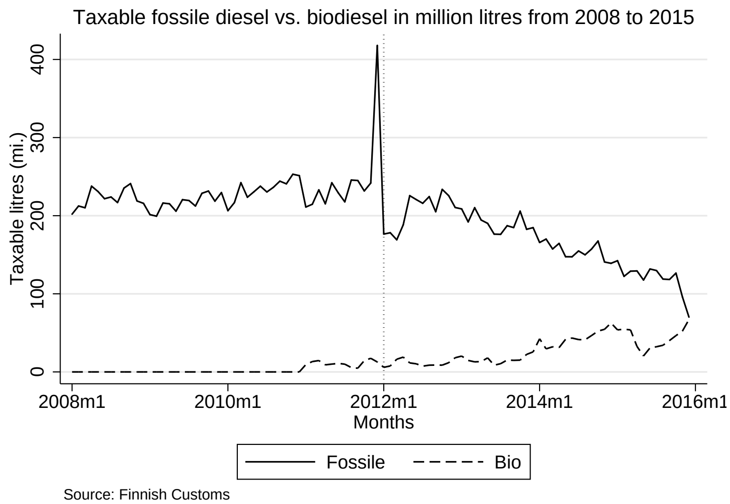

Figure 9: Taxed amount of fossile- and biodiesel in Finland from January 2008 to December 2015

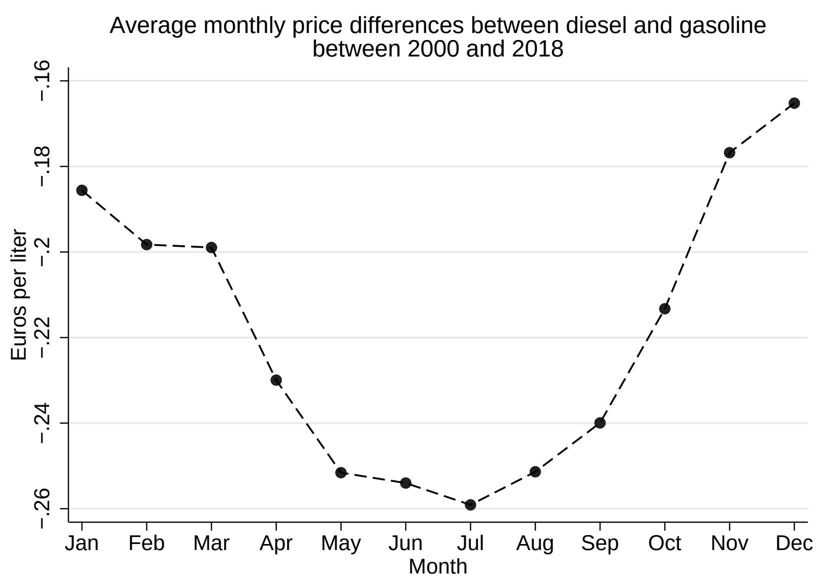

Figure 10: Seasonal cyclicality in the difference between diesel and gasoline prices between 2000 and 2018

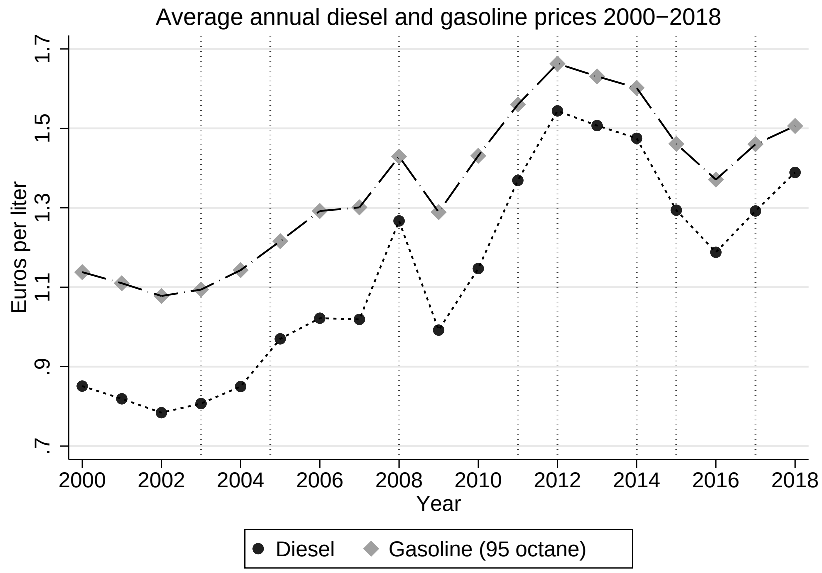

Figure 11: Average annual prices of diesel and 95 octane gasoline (95E5 until 2010 and 95E10 from 2011 onwards) between 2000 and 2018. Vertical lines indicate tax reforms.

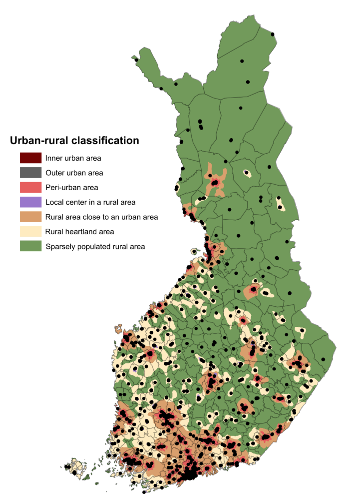

Figure 12: Filling stations in the sample between 2011 and 2012

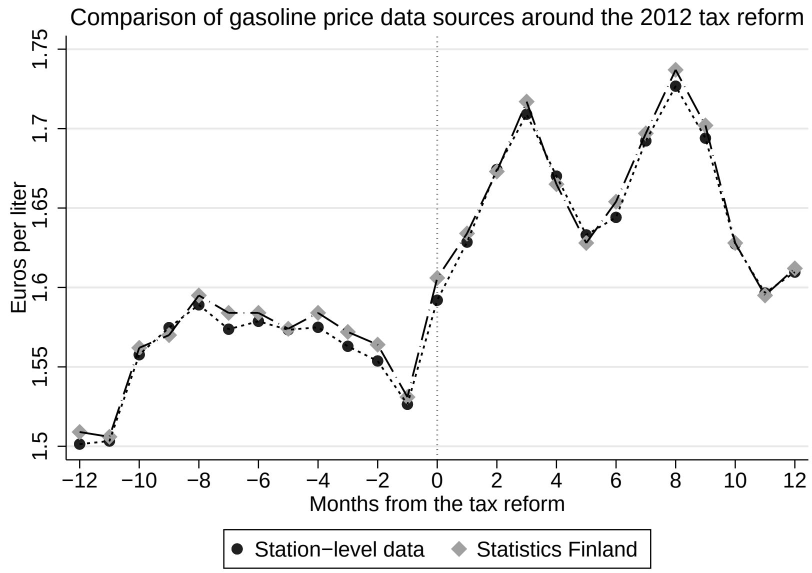

Figure 13: Comparison of average monthly consumer prices of 95E10 gasoline (euros per liter): Consumer-reported microdata vs. data from Statistics Finland

Variable		Mean	Median	Min	Max	SD
# of stations within 1 km	Station level	0.5	0	0	5	0.8
	3-digit postal code	0.3	0	0	4.3	0.5
	Municipality level	0.4	0	0	3.7	0.5
# of stations within 5 km	Station level	3.9	2	0	31	4.6
	3-digit postal code	2.5	1	0	24.5	3.5
	Municipality level	1.6	1	0	19.8	2.2
HHI	3-digit postal code	0.7	0.6	0.2	1	0.3
	Municipality level	0.6	0.5	0.2	1	0.3

Table 11: Descriptive statistics of competition measures

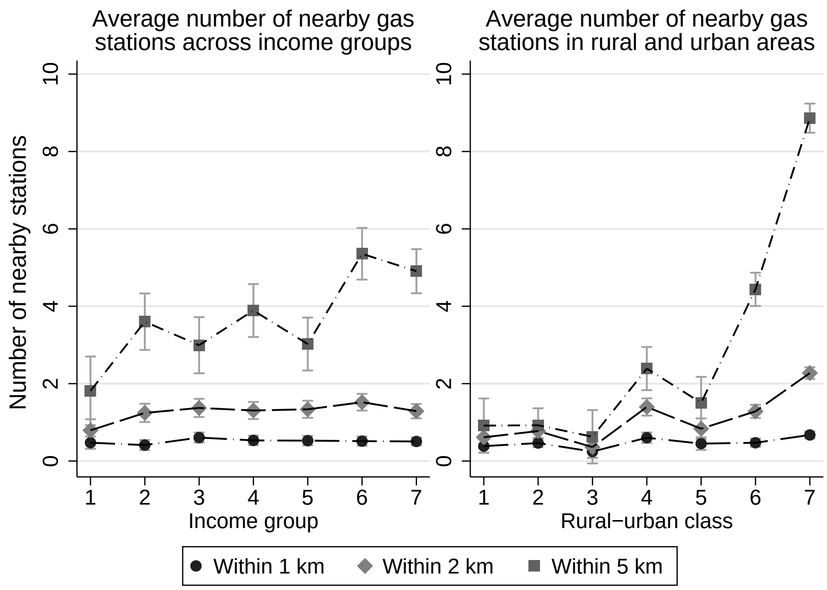

Figure 14: Average number of nearby gas stations for stations in each income group and in rural and urban areas

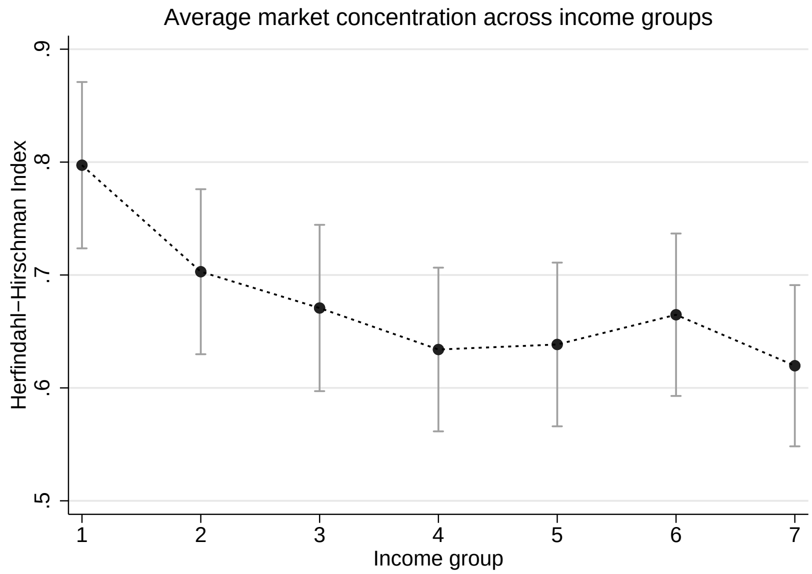

Figure 15: Average market concentration among three-digit postal code areas in each income group

	2009 vs 2010	2012 vs 2013
	(1)	(2)
	Fuel price	Fuel price
D	-0.236***	-0.097***
	(0.001)	(0.001)
A	0.107***	-0.031***
	(0.001)	(0.001)
D×A	0.002**	-0.002
	(0.001)	(0.001)
Constant	1.047***	1.345***
	(0.001)	(0.002)
N	253,313	215,169
R^2	0.89	0.59

Table 12: Placebo DID results

The dependent variable is fuel price in euros per liter excluding VAT because of VAT increases occuring in 2010 and 2013. Standard errors (in parentheses) are clustered at the municipality level. The post-turn-of-the-year period in column (1) is not the full calendar year of 2010 but extends from Janury 1, 2010 to November 30, 2010. This is due to potential anticipation effects of both a tax reform and a switch from gasoline type 95E5 to type 95E10 at fuel stations in January 2011 . *, ** and *** denote significance at the 5%, 1% and 0.1% level respectively.

	Whole period	Six months excluded
	(1)	(2)
	Fuel price	Fuel price
Finland	-0.196***	-0.187***
	(0.003)	(0.003)
After	0.089***	0.098***
	(0.004)	(0.005)
Finland×After	0.111***	0.100***
	(0.004)	(0.005)
Constant	1.734***	1.719***
	(0.003)	(0.003)
Pass-through	84.1%	75.7%
N	111,493	83,046
R^2	0.77	0.77

Table 13: Pass-through results from a comparison of Finnish and Swedish diesel prices

The dependent variable is fuel price in USD per liter excluding VAT at fixed 2011 average exchange rates. Pass-through is calculated by dividing the estimated coefficient on Finland×After by the difference between the VAT-exclusive increases in Finnish and Swedish diesel taxes, amounting to 13.19 US dollar cents per liter. *, ** and *** denote significance at the 5%, 1% and 0.1% level respectively.

Appendix B

Price dynamics around 2012 reform

The low pass-through rate around the 2012 tax jump and the anticipation apparent in the shift in taxed diesel (Figure 7) raise the question whether pass-through increases gradually over time due to menu costs or other costs related to changing prices. One reason for only partial pass-through in the short-term could be that prices are stagnant and the increase in taxes is passed through to consumers later on. However, in the case of fuels retail prices are posted electronically and can thus be easily updated easily.

We examine the pace at which prices change first by looking into very short run responses. The top panel of Figure 16 shows the development of diesel and gasoline price indexes up to 120 hours before and after the reform. Both prices are indexed to take on value one twelwe hours before the reform. It is evident in Figure 16 that the diesel price index increases right after the reform. As soon as 24 hours from the reform there is a clear difference in diesel and gasoline indexes, which implies that price responses are rapid. The bottom panel left panel of Figure 16 depicts the price responses for 30 days before and after the reform. The figure shows that a large share of fuel stations have increased their prices to a level that encompasses the average pass-through (see 6) within few days of the reform.

Finally, the bottom right panel shows the price responses by weeks before and after the reform. The Figure illustrates clearly the parallel pre-reforms time trends between diesel and gasoline before October 2011 (weeks -24 - 12). After that the time trends diverge and the gap between indexes widens three months before the turn of the year most likely due to the change in diesel quality, discussed above. This Figure also shows a quisck increase in diesel prices after the reform but again suggest smaller than full pass through to retail diesel prices.

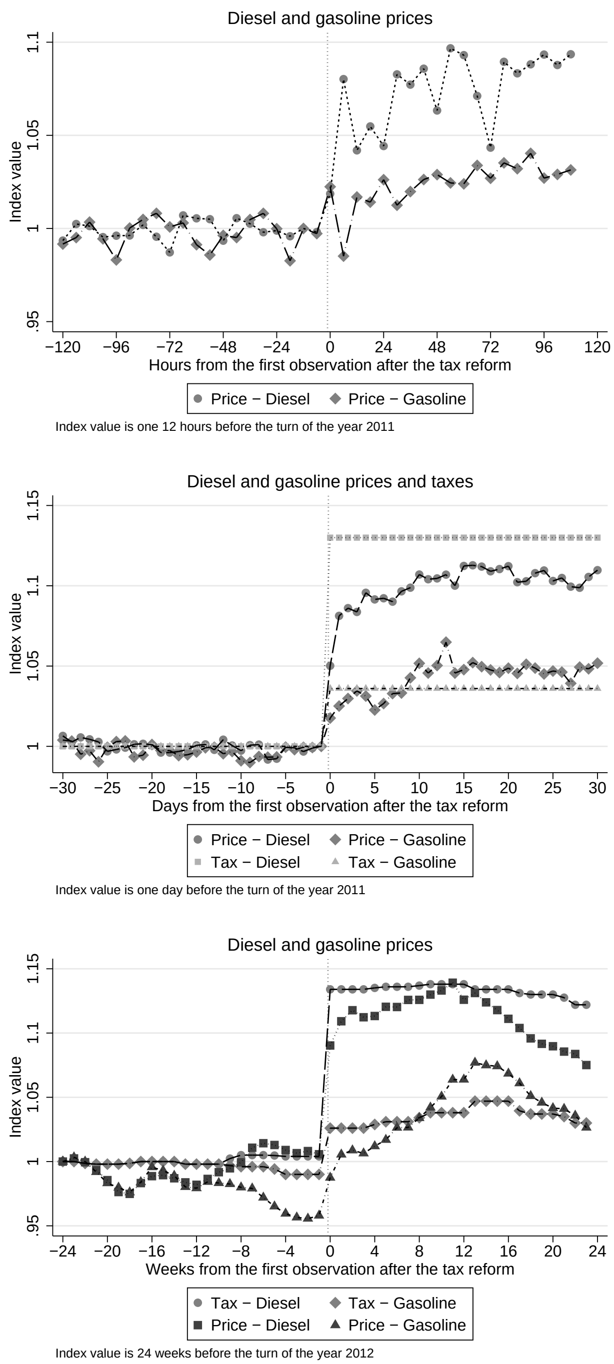

Figure 16: Prices responses hours (above), days (middle) and weeks (below) after the turn of year 2012