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A free rider problem?
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Abstract

Several cities around the world try to internalise congestion costs from road traffic by instituting charges for entering their city centres. The revenues collected from these charges are often redistributed to improve conditions for motorists, cyclists, pedestrians and public transport. At the same time, many schemes allow for exemption of cleaner vehicles, which might offset the reduction in congestion and reduce revenue. In this paper, I assess the effects of exempting electric vehicles from charge on the charge level. Using panel data of Norwegian cities with urban toll rings, I exploit regional variation, and find that a higher share of electric vehicles increase toll charges. The results imply that owners of conventional cars pay 2.5 NOK (0.3 USD) more per passing because of the exemption. The estimates are robust to variations in estimation method and sample. As the majority of electric vehicle owners have above-average income, exempting electric cars from toll charges suggests a distribution effect that have implications for social welfare.

JEL Classification: H230, R40, R42
Keywords: Electric vehicles, Toll road, Distributional effects

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1 Introduction

Growing air pollution and congestion from road traffic is a challenge faced by many cities. This has led to several schemes aimed at curbing private vehicle usage, where the motivation has been to alleviate congestion externalities (Pigou, 2017; Vickrey, 1963). In some cities, such as Stockholm, London, Singapore and Milan, commuters have to pay to enter a pre-defined congestion area. These schemes often exempt less polluting vehicles from payment, in part to incentivise the use of cleaner vehicles. Along these lines, a number of cities in Norway have implemented “city packages”, which include projects aimed for improving roads and public transport funded by revenues from urban toll rings.[1] Concurrently, the Norwegian government allow several generous tax exemptions in order to spur the uptake of cleaner vehicles, including exemption of electric vehicles from all toll road charges. The cost of this exemption scheme is significant, and it’s application is frequently debated. For example, the toll charge exemption amounted to a loss in revenue of 550 million NOK (approximately 63 million USD) in 2016 (The Norwegian Public Roads Administration, 2018).

Even though exempting cleaner vehicles from charges is common, the literature has paid little attention to the consequences of this. Leape (2006) describes the process and effects of the London congestion charge and mention a higher-than-expected number of passings by exempt or discounted vehicles. In addition, Stockholm saw an increase from 2 to 14 percent share of exempt cars entering the charging zone during a two year period. In evaluating the effect of the congestion charge, Börjesson, Eliasson, Hugosson, and Brundell-Freij (2012) argue that this simply contributed to a minor increase in traffic volumes across the cordon. However, the exemption for cleaner cars in Stockholm was gradually phased out from 2009 and onwards. Evidence from Milan suggests that the reduced traffic, as a consequence of the congestion charge, was partially offset by an increase in the number of vehicles exempt from payment (Rotaris, Danielis, Marcucci, & Massiani, 2010).

Road pricing schemes can be viewed as serving two purposes. First, it changes the cost of private vehicle use in congested areas. Second, it provides funding for transport infrastructure improvements. However, commuters progressively switching to exempt vehicles implies, among other things, reduced revenue from urban toll rings. There has been a substantial and rapid rise of electric cars in Norway, going from one percent to one-third of new car sales between 2011 and 2018. This unexpectedly big increase in exempted vehicles creates tension between the ability of local governments to raise funds and congestion externalities.

This paper explores how the share of electric vehicles affects urban toll ring charges in Norwegian cities. The huge increase in uptake of electric vehicles represents a sudden income loss for local governments and their road infrastructure projects. The question of interest is whether urban toll ring charges are raised in order to compensate for this income loss. Furthermore, several cities in Norway have urban toll rings, which allows an

[1] An urban toll ring is comprised of tolls placed on all roads leading into the central points of a city. Usually, driving into the city is charged, whereas leaving the city is not.

unique analysis of several toll rings over time, whereas earlier work mostly focuses on one city.

An important aspect of exempting electric vehicles from charge is the question of who the owners of electric vehicles are. In the paper by Borenstein and Davis (2016), the authors find a strong correlation between income and electric vehicle take-up. Offering income tax credit to all vehicle buyers in the US led to the top income quintile receiving 90 percent of all credits. In the case of Norway, electric vehicle owners often have above-average income and belong to a two-car household (Institute of Transport Economics, 2016). Thus, the toll charge exemption may result in a distributional effect where motorists who can afford it, buy themselves out of the charge.

I utilise data on the number of electric vehicles in cities with urban toll rings and their adjacent municipalities from 2010 to 2017. A possible econometric concern is that higher toll charges can increase the uptake of electric vehicles, in which case standard OLS estimates may overstate the true impact of electric vehicle share on toll charges. To address this empirical challenge, I treat different commuting zones as submarkets of electric vehicle usage, which are exposed to separate tolls, parking prices and road infrastructure. Further, I exploit the Norwegian government's national electric vehicle policy, and instrument for one commuting zone's electric vehicle share by using the share of electric vehicles in other commuting zones. The baseline instrument variable estimate implies that one percentage point higher electric vehicle share in a city leads to a toll charge increase between 2.9 and 4.8 percent. A crude back of the envelope calculation based on estimates retrieved from this paper suggest that a conventional vehicle owner pays 2.5 NOK (0.3 USD) more every time she crosses an urban toll ring, compared to the counterfactual case where electric vehicles are not exempt from charge.

In addition to performing a range of robustness tests, I extend the analysis to examine heterogeneous effects of electric vehicle take-up on urban toll ring prices. Performing a jackknife analysis where cities in turn are excluded from the main regression produces results consistent with the baseline estimations. However, a pattern worth noting is that effect of electric vehicle shares on toll charges is slightly stronger in bigger cities. Lastly, I investigate whether different political ideologies of the municipal government, with different attitudes towards using urban toll rings as a means of financing road investment, react differently when faced with this sudden income loss. Separate regressions for local governments with left and right wing majority reveals that left wing local governments react to a higher share of electric vehicles by raising the toll price. Municipalities with a right wing majority do not react to an increased share of electric vehicles. Interestingly, left-wing parties, which are supporters of social equality, might therefore contribute to an unintended distributional effect.

This paper contributes to the knowledge of the interaction between electric vehicles and road pricing schemes. First, I show that incentives aimed at spurring electric vehicle adoption can have unintended distributional effects. These findings will influence how welfare effects of pricing schemes are assessed, and additionally contribute to a long literature on incidence. Moreover, this paper is the first to examine multiple cities with urban road pricing over several years. Lastly, using the estimates from this paper, I am able to offer a unique estimate of the extent that electric vehicle exemption have increased the price for owners of conventional vehicles. This contributes to policy debates likely to appear in many cities around the world dealing with challenges related to congestion and pollution.

The remainder of the paper is structured as follows. Section 2 presents the institutional background. Section 3 presents the data and the empirical method. Sections 4 and 6 presents the main findings and heterogeneity analyses, respectively. In section 7, I conclude and discuss the findings.

2 Institutional background

2.1 The electric vehicle policy in Norway

Norway has a long history with electric vehicles. From the 1970s and onward, the desire to establish a Norwegian electric vehicle production was strong, and attempts at commercialisation were carried out.[2] In the 1990s, an electric vehicle association was established, whose lobbying activities focused on removing barriers to electric vehicle adoption (Figenbaum, Assum, & Kolbenstvedt, 2015). These activities resulted in many exemptions implemented in the late 90s and early 2000s, which are still in place today.

[Table 1 around here]

Table 1 provides an overview of the advantages of buying and owning an electric vehicle and when the policy was put into force. First, there is no registration or value added tax, leading to a nontrivial reduction in the purchasing price. Second, the annual road tax is reduced compared to conventional cars. Further, owners of electric vehicles can recharge and park their cars at no cost at public parking spaces,[3] drive in public transport lanes and pass through road tolls free of charge. Virtually all of the policy changes were carried out between the mid 1990s and beginning of the 2000s. Nevertheless, the demand for electric vehicles did not change notably after the implementation of these incentives.

[Figure 1 around here]

Figure 1 provides an overview of the share of electric vehicles in cities within commuting distance to a toll ring in Norway, between 2010 and 2017. The share of electric vehicles was essentially zero until 2010, when ownership started to grow at an exponential rate. Figenbaum et al. (2015) explains this by pointing to an increased international focus on greenhouse gas mitigation and improved battery technology. From 2010 and onwards, many of the large international car companies introduced their electric vehicles to the Norwegian market. The vast increase in availability of electric cars led to a rapid expansion in sales and increased price competition among the different manufacturers,

[2]The firm PIVCO (later Think) was established in 1990 and produced the first prototypes in Oslo.

[3]In the later years, some municipalities have started charging a full or reduced price for electric vehicles compared to conventional cars due to overcrowding of electric vehicles.

which further fuelled the acquisition of electric vehicles.[4] At the end of 2017, five percent of the car fleet were battery-only driven, and by August 2018, almost 30 percent of new cars sale consisted of electric vehicles (Information Council for the Road Traffic, 2018).

2.2 Urban toll rings

The first urban toll ring in Norway opened at the end of the 1980s, and the number of rings have been steadily increasing ever since. Historically, the aim of an urban toll ring was not to reduce traffic flows or pollution. Rather, it provided a means of financing new road projects and improving already-existing roads in order to handle growing traffic flows (Ramjerdi, Minken, & Østmoe, 2004). This manifested through low toll rates and little or no variation on rates according to the degree of congestion or time of day.

Today, urban toll rings still serve as a way to raise revenue for road infrastructure investments. The rationales for using this type of revenue raising are several. First, city infrastructure is improved at a faster rate than if municipalities were to wait for the national government's funding. Second, there exists a principle of fairness based on a user-pay concept. The driving population in and around the city pays the road tolls, but also benefits from the revenue in the form of investment in local road infrastructure. Third, municipalities often contract a revenue matching scheme with the central government. Every NOK revenue raised in the toll ring is matched with the equal amount of government funding, which provide additional incentives for toll ring implementation (Larsen & Østmoe, 2001).

The process of instituting an urban toll ring begins with the affected municipalities and counties initiating a project. The purpose of the project could be to enhance a road or the public transport system or improve safety for cyclists and pedestrians, and finance it by the use of toll road revenue. If a majority is obtained, the Norwegian Public Roads Administration (NPRA) is asked to assess the feasibility of the proposed project. This process is repeated a couple of times, where the NPRA reports extends in detail for every round. In order for the project to progress, each updated report must win the majority's vote. Finally, the Parliament vote in order to approve the introduction of the toll ring and use of revenues, which usually is passed. After an urban toll ring has been passed, an independent public company is established. The company's responsibility is managing the finances, including loan raising related to the planned projects, administering the toll collection and managing revenue. After paying for operating costs, the profits are limited to expenditure on the pre-defined projects.

The initial toll charge is computed based on the predicted costs of the planned projects and the expected revenues over the collection period. For example, a city package might include upgrading a certain stretch of highway and investing a certain amount to public transport improvement. After establishing the financial contribution of the central government, as mentioned usually about 50 percent, local governments are left with an expected cost. The toll charge is computed based on expected future interest rate, the

[4]The price competition following the entry of international car companies to the Norwegian market led to the end of the Norwegian electric vehicle production.

number of paying cars in the urban area and the duration of the collection period, which cannot exceed 15 years.

Two types of price increases are possible during the urban toll ring's operation period. The first type is price adjustment changes. In example, charges are raised in order to adjust for general price increase. These price changes are managed by the toll road company. Some companies choose to do this annually, while others have fewer and bigger price changes. In addition, every year during the collection period, toll rates are assessed dependent on the economy of the company. In projects where the economy is bad, NPRA has the authority to raise the toll charge up to 20 percent, or extend the collecting period with up to five years (The Norwegian Public Roads Administration, 2014). However, this is less common in urban toll ring projects. The second type of price change is politically decided, and often involves bigger price changes. There are two reasons for local municipalities to consider raising the urban toll ring charge. Either, politicians wish to add a road infrastructure to the project, and thus need to raise additional revenue. Alternatively, the planned projects are underfinanced. In this case, politicians choose to raise the charge in order to increase revenue, and also to avoid extending the collection period. All of these changes must win the local majority's vote in order for the price change to be implemented. Consequently, the political composition of parties and their attitude towards the use of urban toll rings as a means of financing is important for whether and when toll prices are changed.

[Table 2 around here]

In 2018, eleven cities have urban toll rings, and a doubling is expected over the next decade.[5] An overview of cities with toll rings, the year of implementation, prices and population is provided in Table 2. The number of urban toll rings have been growing steadily during the last three decades. The share of electric vehicles varies between cities, a variation that is not fully explained by population levels. The prices given in column two and three in table 2 are twenty-four hour averages, stated in 2017 prices. The averaging is done in order to ensure that any changes in ring operation hours or rush hour charges is reflected in the price. In general, real prices have increased most prominently in the biggest cities, whereas smaller and more recent rings have moderate price developments.

Ever since the urban toll rings opened, toll companies have offered subscriptions to toll ring passers. The discounts were implemented in order to incentivise prepayment, and to give a perception that the toll ring cost were held at reasonable levels for frequent passers, which likely contributed to lower public resistance (Larsen & Østmoe, 2001). The discount schemes have varied between cities and over time. Earlier, discounts ranged

[5] Cities with toll rings in 2017 are Bergen, Bodø, Bærum/Oslo, Førde, Haugesund area, Harstad, Namsos, Kristiansand, Trondheim, Skien/Porsgrunn and Stavanger area. I am keeping the toll rings in Bodø, Førde, Harstad and Skien/Porsgrunn out of the analysis because they all opened late in the observation period (2015). Thus, these toll companies have more information about the relationship between toll price and electric vehicle share and can set a high initial price in order to prepare for a high electric vehicle share. However, I do include the toll ring in Tønsberg, which closed down in 2016 because the collection period ended.

between 30 and 50 percent per passing, whereas most toll companies today offer 10 or 20 percent rebate. As a result of the discounts, around 80 percent of crossings is done by vehicles with a subscription (The Norwegian Public Roads Administration, 2018). This has at least three implications. First, the majority of the vehicle owners face a lower price in practice than the stated prices. Thus, the incentive for switching to an electric vehicle or an alternative transport mode is reduced. Second, in some cases the toll companies reduced the maximum discount instead of increasing the toll price. Such changes will not be visible in the stated prices, whereas a majority of commuters in reality experience a price increase. Third, the discounted price represents the true income of the toll companies. Rebated prices is therefore a more accurate measure of revenue than the stated prices. Thus, I estimate the effect of electric vehicle share on urban toll ring price, assuming that the price commuters face is the one that gives maximal discount.

In 2018, the Norwegian government passed a law stating that individuals driving electric vehicles can be charged up to 50 percent of the rebated price a conventional vehicle pays when passing a road toll. The final charge for electric vehicles is set by the relevant local governments. From mid-2019, the toll ring in Oslo will be the first to charge electric vehicles to enter the city centre.[6] A charge for electric vehicles is also expected to be imposed in Bergen in the next couple of years.

3 Data and methodology

I use information about toll prices from 2010 to 2017 of all urban toll rings in Norway, which have been provided by the respective toll companies. Data about the number and type of vehicles registered, population, income, share of urban population and education for all 419 municipalities in Norway is acquired from Statistics Norway (SSB).[7] Since data is provided on an annual basis, the price of the toll rings are weighted annual averages, where the weights are the number of days a given price is in operation. This is done in order to capture price changes that happen during a calendar year.

The main hypothesis to be tested is whether a higher share of electric vehicles increases the price of the toll ring as a consequence of the government's electric vehicle policy. The empirical specification is:

$$ln(realprice)_{it} = \alpha_1 shareEV_{it} + \alpha_2 X_{it} + \alpha_i + \varepsilon_{it} \tag{1}$$

where $ln(realprice)_{it}$ is the natural logarithm of the real price of a toll ring in municipality i in year t, $shareEV_{it}$ is the number of electric vehicles over all vehicle types[8] in municipality i at time t, X_{it} is a vector of observed covariates for municipality i as observed at time t, α_i is unobserved time-constant effects in municipality i and ε_{it} are the

[6] The charge will be 30 percent of rebated conventional vehicle charge.

[7] I will use municipalities as per 2017, which was 426. There have been several splits and mergers of municipalities during the last decade in Norway and the seven missing municipalities in my data is a consequence of this.

[8] The vehicles included are passenger cars, divided in five fuel categories: Petrol, diesel, gas, electric and other.

time-varying idiosyncratic errors. The key parameter of interest is α_1, which provides an estimate of the effect of an increase in the share of electric vehicles on the price of the toll ring.

Several econometric challenges arise when identifying the effect of the electric vehicle share on the toll rates. First, the main explanatory variable is the number of registered vehicles and thus, a proxy for the actual usage of a certain vehicle type. It is a fair assumption that newer vehicles will be more frequently used than older vehicles because of improvements in fuel efficiency, safety and appearance. This might especially be true for electric vehicles in areas where an urban toll ring exists. According to the toll company in Oslo, the share of electric vehicles passing the toll ring in 2017 was 10.41 percent (Fjellinjen, 2018), while the share of registered electric vehicles was approximately 8.4 percent. This is a measurement error, implying that true effect of the electric vehicle share on toll charges possibly will be underestimated when using the number of registered vehicles. On the other hand, the crossing of electric vehicles in toll rings is a more responsive measurement, in the sense that the toll price will affect car use to a higher degree than it will affect the acquisition of a car. Thus, using the stock of cars can be advantageous in this particular analysis.

Furthermore, it is more likely that the most frequent toll passers are not the people living in Oslo. Rather, it is the people living in the adjacent municipalities, commuting to Oslo for work, that face the toll charge. In example, the neighbouring municipality Bærum had an electric vehicle share of 11.5 percent in 2017, which seems to be closer to the crossing share observed in the toll ring. This emphasises the importance of including close-by municipalities in the analysis, and utilising the stock of electric vehicles allows for some additional insight regarding commuting patterns across municipalities. In the analysis, I will group municipalities that have strong proximity, economic and labour market attachment to the municipality where the toll ring is located. For example, if one city has an urban toll ring, the inhabitants in neighbouring municipalities will be assumed to face the same price as the inhabitants in the ring city. This will be done in two different ways, where the sample of included municipalities varies.

The first grouping will include only adjacent municipalities. The second grouping will capture municipalities that are close to but does not necessarily border a toll ring municipality.[9] The proposed groups of Bhuller (2009) are applied, where the main grouping criterion is the commuting patterns in the municipality. An objection to this approach is that in some cases the labour market connection can be relatively weak, which might increase measurement error. Nevertheless, weak links are assumed a less serious challenge than omitting relevant municipalities. All regressions are estimated using both groupings, in order to identify how the effect differs between samples.

A second challenge is that the number of planned projects, and thus the cost of the projects, will vary between city packages. In addition, topography and car culture may

[9] A natural grouping would be to follow the structure of Statistics Norway's economic regions, based on labour and commodity market flows, and population (Statistics Norway, 2001). One major drawback of this division is that groups cannot cross county boarders, which contradicts commuting streams in practice. In example, Oslo is both a county and a municipality, thus workers outside Oslo cannot be coupled with Oslo. Accordingly, I omit this grouping from the analysis.

influence both car use, toll cordon placement and the number of cordons required in order to form a ring around the city. These time invariant variables effect both the share of electric vehicles and toll price. Failing to control for them will thus result in a biased estimate of β. In order to lower the risk of this bias, all regressions are estimated with municipality fixed effects. In addition, a number of time-varying variables such as population size, share of urban population, average income and unemployment are included.

Third, one might expect that higher toll prices incentivise consumers to buy electric vehicles, as passing the tolls with an electric vehicle is free of charge. Likewise, changes in toll prices might come at the same time as other policy changes. For example, changing the price or number of parking spaces in the city centre, or altering the public transport system, can either strengthen or dampen the acquisition of electric vehicles. These instances will lead to reverse causality bias, where toll prices influence the share of electric vehicles. Failing to adjust for these challenges could lead to a biased estimate of β. One possible strategy for obtaining consistent estimates is applying an instrument variable approach. In this paper, I will use the yearly average share of electric vehicles in other municipalities as an instrument for the share of electric vehicles in a given municipality. The instrument is described in detail in the following subsection.

3.1 The instrument

The Norwegian government's electric vehicle policy, as well as supply and technological progress of electric vehicles, is homogeneous within the country. Consequently, changes to any of these components causes analogous effects across municipalities. For example, exemptions from VAT or advances in battery technology is likely to have a positive effect on electric vehicle adoption, irrespective of which city one lives in. This correlation can be exploited to instrument for the endogenous electric vehicle share in a city. A similar approach has been applied by Autor, Dorn, and Hanson (2013) and Hausman and Ros (2013), where imports from China in the US and mobile prices in Mexico, respectively, are instrumented for by similar countries' levels of the interest variable. Hausman, Leonard, and Zona (1994) and Nevo (2001) use cities within a country to instrument for product prices. In the previous applications, the underlying marginal product cost is assumed to be similar across countries and cities, which causes correlation in prices between cities and countries, whereas market-specific changes provides exogenous variation.

In this paper, the identifying strategy is that the share of electric vehicles in one geographical area can instrument the electric vehicle share in another geographical area. Municipality or urban toll ring specific changes over time, for example infrastructure changes, will provide exogenous variation. In order for an instrument to be valid, two criteria needs to be satisfied. First, it must be correlated with the instrumented variable. The national government's electric vehicle policy and technology conditions will provide relevancy between the instrument and the endogenous variable. Second, the instrument must be uncorrelated with the error term in the structure equation. It is important to note that I use the share of electric vehicles in all municipalities except for Oslo and it's nearby municipalities, as an instrument for electric vehicle share in Oslo and nearby municipalities. It seems unlikely that the electric vehicle share in one municipality, affects the price in a geographically distanced toll ring. Thus, the instrument is arguably in line with the exclusion restriction. The new empirical specification is as follows:

$$ln(realprice)_{it} = \alpha_1 shareEV_{it} + \alpha_2 X_{it} + \alpha_i + \varepsilon_{it} \tag{2}$$

where

$$shareEV_{it} = \beta_1 shareEV_{-it} + \beta_2 X_{it} + \beta_i + \epsilon_{it} \tag{3}$$

There might be circumstances where the share of electric vehicles municipality -i correlates with the error term ε_{it} in equation 2. One can imagine a shock that affects the number of electric vehicles in one municipality, which other municipalities can learn from, and in turn alter the price of their toll ring in order to prepare for a similar shock. This learning effect, if present, will occur between cities with urban toll rings. In order to approach this possible challenge, I construct a second instrument, which include only average share of electric vehicles in municipalities without, and not in commuting distance to, urban toll rings.

4 Results

4.1 Fixed effects estimates

Table 3 reports estimates of the effect of electric vehicle share, in municipalities with or adjacent to an urban toll ring, on the price of the toll ring. This includes 62 municipalities observed from 2010 to 2017. In all regressions, the standard errors are clustered at municipality level, which is motivated by the concern that the error terms might be correlated within municipalities across years.[10]

[Table 3 around here]

In column (1), I present the model estimated using ordinary least squares for comparison reasons. In column (2), I add municipality time-fixed effects to the model. The difference in the two columns demonstrates a slight upward bias in the OLS estimates. The results from the fixed effects model in column (2) suggests that an increase in the share of electric vehicles of one percentage point will increase the toll ring price with approximately 4.2 percent. Thus, a toll charge at 20 NOK (2.35 USD) will increase to 20.84 NOK (2.45 USD) if the share of electric vehicles increases by one percentage point. In column (3), I control for population and the share of urban population, which leads

[10]The cluster level is not straightforward in this case. One could argue that standard errors should be clustered at urban toll ring level, i.e. including all municipalities that commute through a particular toll ring, or county level. However, there are only 8 toll rings and 13 counties in the analysis, and clustering in few numbers is advised against (Cameron & Miller, 2015). An alternative is clustering at lower levels, i.e. municipalities, where a greater number of clusters are available. The level of clustering will be further discussed at the end of this chapter.

to reduction in the point estimate of the effect of electric vehicles on the urban toll ring price. The positive estimates indicate that the bigger the population and the higher the degree of urbanisation, the higher the toll ring price. The direction of the estimate seems reasonable as congestion and pollution is associated with a dense and populated city, which in turn might drive the toll ring prices up. Adding income level, unemployment rate and education level decreases the estimated effect in column (4). In general, many of the controls have weak or insignificant estimates, which is likely due to limited time variation.

In order to estimate the distinct effect of electric vehicles and conventional vehicles on the toll ring price, I estimate a model where they enter as separate variables. The results are presented in column (5). Indeed, separating the variables suggests that a higher number of electric vehicles increases toll prices, whereas higher number of paying conventional vehicles has a negative effect on toll price, keeping all else constant. More specifically, an increase of a thousand electric cars will increase the price by 0.46 percent, whereas a thousand more conventional vehicles will decrease the price by 0.2 percent. This asymmetry suggest that toll prices are more easily increased in the case of lost income than decreased in the case of increased income. In column (6), I re-estimate the main model and add year dummies in order to control for national factors changing each year that effect toll prices. The coefficient for electric vehicle share increases somewhat compared to column (4), and in less precisely estimated. However, the estimate is significant at the 10 percent level.

In order to examine whether the coefficient of the interest variable is sensitive to estimation method, I estimate the model using a first-difference approach. If the first differences estimator provides very different results compared to estimate acquired from the fixed effects model, this can indicate misspecification of the model, which in turn can produce inconsistent estimates. The results of the first difference estimation is presented in column (7). The outcome exhibits virtually no change in the estimated coefficient of electric vehicle share, providing some robustness to the main result.[11]

As discussed in section 3, it is important to consider municipalities that do not share a border but belong to the same economic or labour market as a municipality with an urban toll ring. Table 4 presents the results of the grouping suggested by Bhuller (2009) where the group classification emphasises commuting patterns and is not restricted by county boarders. Utilising this classification, a total of 161 municipalities are within commuting distance to a toll ring in my sample.

[Table 4 around here]

In general, the estimates in column (1) to (3) are somewhat higher compared to the previous table. The estimate of the effect of electric vehicles in column (4) is nearly identical to the regression based on the adjacent sample. I also repeat the exercise of

[11]The model has also been estimated using the one-step Arellano-Bond estimator, with two lags on the dependent real price variable and share of electric vehicles. There was no considerable change in either significance or magnitude of the effect of electric vehicles on toll prices.

separating the effect of electric vehicles and conventional vehicles. The result is presented in column (5). Once again, the effect of the number of electric vehicles is positive, whereas the effect of conventional vehicles is negative. However, the effect of the number of conventional vehicles is not significantly different from zero. When adding year dummies to the regression, the effect of electric vehicle share is reduced. However, it remains positive and statistically significant at five percent critical value. Similar to adjacent sample, the first differenced model in column (7) reveals no notable change in the effect of electric vehicle share on toll prices compared to the fixed effects counterpart in column (6).

4.2 Instrumental variable estimates

The prior analysis indicates that a one-percentage point higher electric vehicle share increases the price in urban toll rings by approximately 3.3 percent, as indicated by column (4) in table 3. However, these estimates may differ from the true influence of electric vehicle share on toll charges. A concern is that the price in a toll ring may affect commuter behaviour. Commuters can respond to a higher toll charge by substituting car driving with public transport, cycling or walking. If this includes disposing of a conventional car, the share of electric vehicles will increase, keeping all else equal. Further, a higher toll price can also induce commuters to go from a conventional to an electric vehicle. This will result in a higher electric vehicle share, irrespective of whether the electric vehicle is complementing or substituting a conventional car. As a consequence of this reverse causality, the estimates in tables 3 and 4 may overstate the effect of electric vehicle share on toll price. To address this concern, I instrument the share of electric vehicles in municipalities commuting to a given toll ring by electric vehicle share in all other municipalities. Electric vehicle share across municipalities should be correlated over time due to common national electric vehicle policy and technological progress. At the same time, electric vehicle share in other cities should be independent of the stochastic error term as long as there are no shocks that effect both the national share of electric vehicles and the toll ring price in a given city.

[Table 5 around here]

Table 5 provides estimation results after instrumenting the share of electric vehicles. In the first two columns, the instrument is as described in section 3, where one city's electric vehicle share is instrumented by all other cities' electric vehicle share. The estimates in column (1) is the IV counterpart of the fully specified fixed effects model in column (4) in table 3, where the sample includes cities with urban toll rings and it's adjacent municipalities. As presented in column (1), the estimated effect in the new regression using the adjacent municipalities sample is reduced. This result indicates that endogeneity in the share of electric vehicles variable is a plausible concern in the fixed effects estimation in table 3 and 4, and indeed, the reduction in the point estimates suggests a positive bias produced by the reverse causality. Results from the IV estimation using the commuting sample are presented in column (2). The estimation exhibits the opposite pattern of the adjacent sample, where the point estimate somewhat increases in magnitude compared to the fixed effect model. This suggest a small negative bias, implying that a higher toll price might have some negative effect on the acquisition of electric vehicle for people living further from the toll ring. Nevertheless, the two coefficients on the effect of electric vehicle share are reasonably similar in magnitude and statistically significant.

A possible cause of concern is that a learning effect might exist between cities and their urban toll ring companies. For example, if altering the toll charge in one city creates a change in the number of crossing vehicles, toll companies in other cities can learn from this outcome and adjust the toll charge in order to avoid or obtain the same effect. If this is the case, the electric vehicle share in one city is influencing the toll charge in another city, which violates the exclusion restriction required for a valid instrument. In order to explore whether a learning effect is present, I re-estimate main model using average electric vehicle share in all toll ring remote municipalities as instrument. More precisely, I utilise only municipalities that are not within commuting distance of a city with a toll ring. If the change in the estimated coefficients is small compared to the results in column (1) and (2) in table 5, this indicates that a learning effect is not present in the data. The results using the alternative instrument is presented in column (3) and (4) in table 5. The effect of electric vehicle share on urban toll ring price is negligibly higher than their respective counterparts in column (1) and (2), and the effects are still positive and statistically significant.

The F-statistics on excluding instruments from the first stage regressions are presented in the bottom of the table. This is a standard test of instrument strength, and following Staiger and Stock (1997), an F-statistic above 10 should provide reliable inference of the two-stage least squares estimates. Both instrument variations accordingly pass the standard thresholds for detecting weak instruments. The proximity of the results suggests that both of the two instruments are applicable, in addition to reject the concern for a learning effect between cities with urban toll rings. However, the marginally more conservative estimates provided by the instrument in column (1) and (2) will be the preferred approach and the benchmark estimate. To sum up, an increase in the share of electric vehicles of one percentage point will increase the price of urban toll rings by between 2.9 and 4.8 percent, keeping all else constant.

5 Robustness checks

5.1 Alternative cluster level

An inspection of the level of clustering of the standard errors is appropriate for this paper. The purpose of clustering is to allow model errors to be correlated within clusters (Cameron & Miller, 2015). In the main analysis, the level of clustering is set to municipal level. Because the price of the toll rings varies on the adjacent and commuting group level, one might argue that clustering on urban toll ring is the appropriate level of clustering. Table A1 in the Appendix displays the coefficients and standard errors when columns (1) and (2) in table 5 are estimated by clustering on toll ring level.

Compared with the baseline estimate, both coefficients are still significantly different from zero. However, the standard errors have increased such that the coefficient for the adjacent sample is statistically significant at 10 percent level, whereas the coefficient from the commuting sample is statistically significant at 5 percent level. The standard errors in this table should however be interpreted with caution, as it is not obvious that clustering at ring level is the correct level of cluster. The two groups, adjacent and commuting municipalities, are defined based on geography and labour market attachments. These groupings traverse county borders and enfolds different types of municipalities in the same group. Abadie, Athey, Imbens, and Wooldridge (2017) argues that clustering at too aggregate levels can have an adverse effect in the sense that standard errors can be unnecessarily conservative. Therefore, in the remaining analysis standard errors will be clustered at the municipality level.[12]

5.2 Regressing on group averages

An alternative way of handling challenges related to within group correlation is estimating a regression using group averages instead of regressing on the municipal level. The asymptotic characteristics here are also dependent on the number of groups. However, group means are normally distributed even when group size is modest. Therefore, the normal standard errors that come out of grouped estimation are presumably more reliable than clustered standard errors in samples with few clusters, such as in table A1 in the appendix (Angrist & Pischke, 2009). Consequently, I aggregate the data on toll ring level, averaging over all municipalities in commuting distance to a particular toll ring area. At this point, I have a panel consisting of one observation per eight toll ring regions per year, from 2010 to 2017.

This low number of observations makes a poor basis for instrument variable estimation, since the estimated coefficient is likely to be biased in small samples (Bound, Jaeger, & Baker, 1995). At the same time, the results found in the fixed effect analyses in table 3 and 4 in subsection 4.1 resembles the estimates found in the instrument variable estimations in table 5 in subsection 4.2. Using the adjacent sample, the obtained coefficient was 3.3, whereas the IV estimate was 2.9. The different coefficients for the commuting sample was 3.9 and 4.8, respectively. Therefore, estimating a fixed effects regression using group level averages offers an alternative test of robustness.

I estimate a fixed effect regression and control for average income, the only significant control variable in the main analysis. The result is presented in table A2 in the appendix. The results are analogous to the estimates in the main analysis. Compared to the instrument variable regression in table 5, the group of adjacent municipalities provides somewhat higher estimates. On the other hand, the group of municipalities within commuting distance of an urban toll ring deliver slightly lower estimates. In summary, estimating on group level averages produces similar results in terms of both coefficient size and significance.

[12]The subsequent analyses has all been estimated with ring number clusters, without changing the results notably.

6 Heterogeneity

6.1 Jackknifing

The effect of electric vehicle share on toll ring price most likely vary between cities and toll rings. Different toll companies might have different budgetary constraints or project duration, and therefore react dissimilarly to a reduction in revenue. If I had enough statistical power, I could run a separate regression for every urban toll ring and electric vehicle share in the associated commuting zone, and thereby identify a separate effect for every city. The second-best approach is a resampling method, often referred to as jackknifing, that involves estimating the benchmark model while excluding one urban toll ring at a time. This procedure constitutes a test on whether some toll rings are outliers that drive the general results.

[Table 6 around here]

Table 6 displays the results from the jackknifing estimation, where the first column indicates the city excluded from the regression. The general pattern from the benchmark result prevails in all regressions, and the magnitude of the estimates are similar to the main results in table 5. When omitting Oslo from the adjacent sample, as demonstrated in the first row, the effect of electric vehicle share becomes somewhat weaker and less precisely estimated. This result implies that the electric vehicle share in Oslo and its adjacent municipalities effects the toll ring price the most. The effect is also smaller in magnitude when Bergen or Trondheim is excluded from the regression.

In the lower panel of table 6, I perform the jackknife analysis utilising the commuting sample. The effect of electric vehicle share is positive and significant for all models. Once again, the effect is strongest when the three biggest cities are included in the regression. In summary, there seems to be a tendency of smaller estimates when bigger cities are excluded. At most, estimates vary around 2 percentage points. This implies that toll ring prices in bigger cities have a propensity to react stronger to an increased electric vehicle share. Thus, given a one percentage point growth in electric vehicle share, a big city will increase the toll charge more than a small city. A possible explanation may be that bigger cities have higher supply of public transport. Therefore, price increases can more easily be justified. Nevertheless, the main pattern is positive and statistically significant, implying that no urban toll ring is solely responsible for the results in the main models, whereas the effect is strongest in the biggest cities in Norway.

6.2 Political heterogeneity

As explained in subsection 2.2, price setting and price changes are heavily dependent on the incumbent parties in local governments. Obtaining a majority in the municipal council is an important step on the way to introducing toll rings or granting a bigger increase of the toll charge. In general, left wing parties are positive towards using toll charges in order to collect revenue for road construction[13], including the Labour party, the biggest party in Norway. The biggest right wing party, the Conservative Party, wants to reduce the share of road building financed by toll road revenue, whereas the second biggest right wing party and the third biggest party in Norway, the Progress Party, is strongly against toll rings. This division between left wing and right wing parties' outlook on using toll roads to raise revenue serves as a basis for a heterogeneity analysis.

In this subsection, I investigate whether different political affiliations are associated with different toll charging strategies[14]. I utilise data on election results, and investigate whether having a majority and how mayor party affiliation affects how urban toll ring prices are changed when the electric vehicle share increases. Through the course of my observational period, three elections results are available (2007, 2011 and 2015). First, I re-estimate the main regressions from table 5, exploiting urban toll ring cities where left wing parties have a majority or mayor. I am basing the electoral data on the municipality where the urban toll ring is situated. Like before, I include the share of electric vehicles in the adjacent municipalities in the regression[15]. Second, I do the same for municipalities where right wing parties have majority or mayor. It is likely that if one of the wings have a majority, they will also have the mayor. However, the mayor's political affiliation does not imply majority for that wing. For instance, a wing close to obtaining a majority can collaborate with either a small party of the opposite wing or a party categorised as neither left nor right wing. A collaboration can include bargaining over the mayor position, and the mayor's wing affiliation can impact whether and how urban toll rings are discussed.

Exploring the correlation between majority and mayor reveals that, for right wing parties, holding the majority almost always leads to having the mayor. However, the correlation between majority and mayor for left wing parties is approximately 0.6. This can have two interpretations. On the one hand, left wing parties are more often forced to collaborate with other parties in order to be in government, which may weaken their salient urban toll ring policy. On the other hand, left wing parties might be imperative in order for other parties to be able to govern, which can lead to a left wing mayor influencing the discussion about urban toll rings. Thus, the estimates of left wing majority municipalities and municipalities with a left wing mayor should diverge more compared to the right wing case.

[Table 7 around here]

The results from the policy heterogeneity analysis are presented in table 7. In the first column, the regression is based on urban toll rings where left wing parties have a

[13]Except for Red Electoral Alliance, the smallest and leftmost party, arguing that toll roads are inequitable.

[14]Left-wing parties are Red Electoral Alliance, Socialist Left Party, Labour Party and joint lists of left-wing parties. Right-wing parties include the Liberal Party, Centre Party, Christian Democrats, Conservative Party, Progress party and joint lists of right-wing parties. The data on local government election is provided by Fiva, J. H., Halse A.H., and Natvik, G. J., (2017): Local Government Dataset. Available at www.jon.fiva.no/data.htm.

[15]The results for the commuting sample follows the same pattern as the main results in table 5.

majority in the municipal council. The effect of electric vehicle share is positive and statistically significant. In fact, the estimate is by and large the same as in the baseline model in column (1) in table 5. Moving on to column (2), I estimate a regression based on municipalities where the mayor belongs to a left wing party. In this case, the effect of electric vehicle share has increased compared to the first column, but is still in the range of the baseline results in table 5. Carrying out the same exercise on right wing municipalities exhibits a different result. As portrayed in columns (3) and (4), neither holding a right wing majority nor having a mayor belonging to a right wing party yields significant results on the effect of the electric vehicle share on urban toll ring price.

These results provides a simple way to decompose the heterogeneous pricing decisions dependent on different wings' politics. The baseline estimates revealed that a one percentage point higher electric vehicle share increases the toll price by 2.9 percent. Running separate regressions dependent on which political wing have majority in the municipal council shows that a left wing majority will react to an increased electric vehicle share by increasing the toll price. Interestingly, having a mayor belonging to a left wing party increases the effect of electric vehicle share on the urban toll ring price to about 3.4 percent. This increase indicates that when left wing mayors are collaborating with parties from other wings, they bring urban toll rings as a means of revenue raising to the table. Conversely, right wing majorities or mayors do not react to an increased electric vehicle share at all. Combining these results suggests that different wings react differently to a shock leading to revenue deficiency. Left wing parties tend to respond by increasing urban toll ring charges, whereas right wing parties will not. This could indicate that right wing parties balance their budgets otherwise, for example by reducing road infrastructure investments or reducing the share of road infrastructure investments financed by toll revenues. Unfortunately, further analysis of is limited by the data.

7 Concluding remarks

Several Norwegian cities have urban toll rings around their city centres, serving as a means of collecting revenue for local road infrastructure improvement. Against the backdrop of the central government's desire for developing an electric vehicle industry in the late 20th century, schemes aimed at incentivising electric vehicle purchase was implemented. Many of these are still valid today, including electric vehicle exemption from road toll charges. Electric vehicles' proportion of new car sales in Norway has grown from 1 percent in 2011 to 30 percent in 2018. This rapid change in the composition of car types implies changes in the number of paying cars passing the toll rings, resulting in reduced revenue for local road infrastructure projects. Much of previous research have studied the effect of congestion charges on local industry, pollution and traffic flows. This paper is the first to explore effects caused by exempting some vehicle types from charge. By analysing the price in several urban toll rings in Norway over time, I find that a higher share of electric vehicles increase the toll charge. The positive result is robust to alterations in sample, although the effect seems to be stronger in the biggest cities in Norway. Finally, I find that municipalities with a left-wing majority or mayor react to increases in electric vehicle share by increasing toll charges, whereas right-wing municipalities do not.

A crude back of the envelope calculation can estimate how much more a conventional vehicle owner is paying per urban toll ring passing, as a consequence of higher vehicle share. In 2017, the mean electric vehicle share in municipalities within commuting distance to a toll ring was 4.11 percent. The average toll ring price was 23 NOK (2.7 USD). Building on the most conservative result found in the main estimation, the toll price increases by circa 3 percent per percentage point increase in electric vehicle share. Suppose instead, that every electric car is a paying vehicle, other things being equal. The average price of the toll rings would then be 20.5 NOK (3 USD). This naïve calculation suggests that a conventional vehicle owner pays 2.5 NOK (0.3 USD) more per toll ring crossing today, because electric vehicles are exempt from charge.

Exempting electric vehicles from paying toll charges is a way of incentivising commuters to buy vehicles that cause less local pollution. However, the consequences of this policy should be considered more carefully in the future. The price in a toll ring is uniform, regardless of the commuter's income level, which in isolation is considered as a regressive tax. An important aspect of assessing the consequences of electric vehicle exemptions is the income level of electric vehicle owners. For instance, 74 percent of electric vehicle owners have income above the average and median income interval (Institute of Transport Economics, 2016).[16] Consequently, exemption of electric vehicles may have distributional effects. First, it reduces revenue, which in turn can reduce investment in public transport. Second, as the results in this paper suggest, it can increase the incidence on motorist that are not able to buy an electric car and cannot switch to public transport. It should be stressed, however, that the welfare effect on the exemption of electric vehicles from toll charge is uncertain. The number of electric vehicles most likely influence both congestion and pollution, but also public budgets and the duration of toll ring projects. The net effect of electric vehicle exemption for society and for heterogeneous groups, is therefore a question open to future research.

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[16]The statistic comes from the National Travel Survey from 2013/14, including subjects driving to work five times a week with car as the main mode of transport. The income statistic is only available in nine intervals.

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Figures

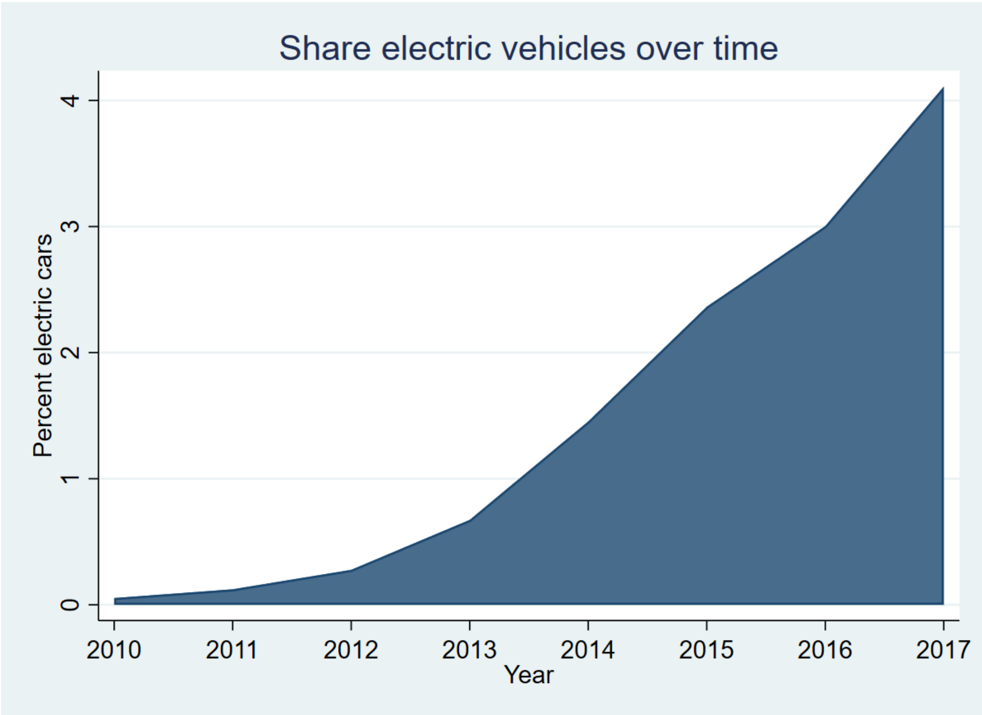

Figure 1: The average share of electric vehicles in municipalities with or within commuting distance to an urban toll ring from 2010 to 2017 in Norway. *Source: Statistics Norway.*

Tables

Table 1: Overview of electric vehicle promoting policies

Exemption from registration tax	1996
Reduced annual vehicle tax	1996
Exemption from road tolls	1997
Free parking (on public parking spaces)	1999
Reduced company car tax	2000
VAT exemption	2001
Access to public transit lanes	2005
Exemption from paying ferry fees	2009

Note: The stated years are the year the policy became permanent. For example, the exemption from registration tax was on trial from 1990 to 1995.

Table 2: Overview of cities with an urban toll ring, year of implementation, prices, population and electric vehicle share

City	Year opened	Price (2010)[1]	Price (2017)	Population (2017)	Electric vehicle share (2017)
Bergen	1986	10.31	23	278 556	11.25%
Oslo	1990	23.68	36.65	666 759	9.97 %
(Bærum)	(2008)	(11.61)	(12.83)	(124 008)	(11.5 %)
Trondheim[2]	1991-2005, 2010	8.8	12.93	190 464	6.64 %
Kristiansand	1997	12.03	12.37	89 268	9.06 %
Stavanger area	2001	13.75	16	208 225	6.12 %
Namsos	2003	8.6	10.2	13 051	1.16 %
Tønsberg	2004-2016	8.6	7.61[3]	44 922	4.93 %
Haugalandet	2008	6.86	6	91 485	5.3 %

Note: The price is calculated as average hourly real price, to encompass hours with higher or zero charge.

1) In terms of 2017 prices.

2) Trondheim has a scheme with one inner and one outer ring, and commuter pay both when entering and leaving the rings. The price differs between the two rings, so the stated price is the average price.

3) The stated price is the price valid in 2016, the last year the ring was in operation.

Source: Fjellinjen AS, Ferde AS, Agder Bomdrift AS, Vegamot AS, The Norwegian Public Roads Administration, Statistics Norway.

Table 3: The influence of share of electric vehicles in adjacent municipalities on urban toll ring price (2010 − 2017)

Municipalities with an urban toll ring and adjacent municipalities							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	FE	FE	FE	FE	FE	FD
Share electric vehicles	0.060***	0.042***	0.036***	0.033***		0.038*	0.031**
	(0.013)	(0.008)	(0.008)	(0.008)		(0.019)	(0.014)
Population (/1000)			0.004	0.019	0.064**	0.012	0.006**
			(0.003)	(0.015)	(0.028)	(0.015)	(0.003)
Share urban population			0.008	0.006	0.011*	0.005	-0.002***
			(0.005)	(0.005)	(0.006)	(0.005)	(0.001)
log (Income)				0.563*	0.885*	0.097	0.075
				(0.302)	(0.447)	(0.210)	(0.067)
Unemployment rate				0.002	0.029	-0.002	0.008
				(0.014)	(0.021)	(0.016)	(0.007)
Higher education (/1000)				-0.015	-0.059*	-0.009	-0.004
				(0.014)	(0.030)	(0.015)	(0.004)
Electric vehicles (/1000)					0.047**		
					(0.020)		
Conventional vehicles (/1000)					-0.009**		
					(0.009)		
Constant	2.537***	2.581***	1.883***	-5.711	-11.064*	0.541	0.023**
	(0.069)	(0.019)	(0.353)	(3.782)	(5.564)	(2.734)	(0.010)
Year dummies	No	No	No	No	No	Yes	Yes
R^2	0.114	0.357	0.388	0.411	0.306	0.456	0.190
N	491	491	491	491	491	491	429

Note: The dependent variable is the natural logarithm of urban toll ring price. The standard errors in parenthesis are clustered at municipality level. ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 4: The influence of share of electric vehicles in a broader municipality selection on urban toll ring price (2010 − 2017)

Municipalities with an urban toll ring and municipalities in the same commuting region							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	FE	FE	FE	FE	FE	FD
Share electric vehicles	0.062***	0.053***	0.049***	0.039***		0.026**	0.024***
	(0.012)	(0.006)	(0.007)	(0.007)		(0.011)	(0.008)
Population (/1000)			0.002	0.008	0.056**	0.001	0.006**
			(0.003)	(0.012)	(0.024)	(0.013)	(0.003)
Share urban population			0.007***	0.005*	0.007***	0.003	-0.001
			(0.002)	(0.002)	(0.003)	(0.002)	(0.001)
log (Income)				1.235***	1.668***	0.397	0.238**
				(0.256)	(0.317)	(0.246)	(0.100)
Unemployment rate				0.004	0.019	0.003	0.001
				(0.011)	(0.013)	(0.011)	(0.004)
Higher education (/1000)				-0.007	-0.062**	-0.001	-0.007*
				(0.011)	(0.027)	(0.013)	(0.004)
Electric vehicles (/1000)					0.063**		0.023***
					(0.030)		(0.008)
Conventional vehicles (/1000)					-0.009		
					(0.013)		
Constant	2.680***	2.695***	2.241***	-13.663***	-19.990***	-2.696	0.022***
	(0.041)	(0.010)	(0.138)	(3.239)	(3.984)	(3.173)	(0.008)
Year dummies	No	No	No	No	No	Yes	Yes
R^2	0.075	0.327	0.350	0.436	0.329	0.499	0.196
N	1343	1343	1343	1343	1343	1343	1174

Note: The dependent variable is the natural logarithm of urban toll ring price. The standard errors in parenthesis are clustered at municipality level. ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 5: Instrument variable estimation of share of electric vehicles on urban toll ring price (2010 − 2017)

	Leave one area out		Distant municipalities	
	(1)	(2)	(3)	(4)
	Adjacent	Commuting	Adjacent	Commuting
Share electric	0.029***	0.048***	0.030***	0.049***
vehicles	(0.007)	(0.007)	(0.007)	(0.007)
Population	0.021	0.001	0.020	-0.000
(/1000)	(0.016)	(0.012)	(0.016)	(0.012)
Share urban	0.007	0.004*	0.007	0.004
population	(0.005)	(0.002)	(0.005)	(0.002)
log	0.606*	1.136***	0.595*	1.122***
(Income)	(0.325)	(0.251)	(0.316)	(0.243)
Unemployment	0.007	0.000	0.006	-0.001
rate	(0.016)	(0.011)	(0.016)	(0.011)
Higher education	-0.016	-0.002	-0.016	-0.002
(/1000)	(0.015)	(0.011)	(0.015)	(0.011)
First stage F-statistic	168.94	254.32	199.72	285.36
R^2	0.408	0.429	0.410	0.427
N	491	1343	491	1343

Note: The dependent variable is the natural logarithm of urban toll ring price. The standard errors in parenthesis are clustered at municipality level. ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 6: Jackknife analysis

Excluded ring	Share electric vehicles	N	R^2
Adjacent sample			
Oslo	0.021**	379	0.363
	(0.009)		
Bergen	0.015***	403	0.353
	(0.006)		
Trondheim	0.021***	443	0.402
	(0.006)		
Stavanger	0.036***	435	0.473
	(0.007)		
Kristiansand	0.033***	443	0.434
	(0.007)		
Namsos	0.031***	435	0.421
	(0.007)		
Haugalandet	0.033***	443	0.483
	(0.007)		
Tønsberg	0.031***	456	0.434
	(0.007)		
Commuting sample			
Oslo	0.046***	935	0.361
	(0.010)		
Bergen	0.028***	1127	0.447
	(0.006)		
Trondheim	0.040***	1143	0.432
	(0.006)		
Stavanger	0.058***	1199	0.467
	(0.008)		
Kristiansand	0.054***	1215	0.445
	(0.008)		
Namsos	0.051***	1231	0.437
	(0.007)		
Haugalandet	0.053***	1271	0.467
	(0.007)		
Tønsberg	0.050***	1280	0.451
	(0.007)		

Note: The dependent variable is the natural logarithm of urban toll ring price. The standard errors in parenthesis are clustered at municipality level. ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Table 7: Analysis on whether majority or mayor's affiliation affect urban toll ring pricing strategies.

	Left wing municipalities		**Right wing municipalities**	
	(1)	(2)	(3)	(4)
	Left majority	Left mayor	Right majority	Right mayor
Share electric vehicles	0.026***	0.034***	-0.007	-0.002
	(0.007)	(0.008)	(0.004)	(0.005)
First stage F-statistic	9.16	12.04	118.98	90.35
R^2	0.547	0.522	0.317	0.338
N	80	166	337	325

Note: The dependent variable is the natural logarithm of urban toll ring price. The regression is estimated using 2SLS and includes the same controls as in the baseline estimation (table 5). The standard errors in parenthesis are clustered at municipality level. ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Appendix A

Table A1: Alternative cluster level of benchmark estimation

	(1) Adjacent	(2) Commuting
Share electric vehicles	0.029*	0.048**
	(0.015)	(0.020)
First stage F-statistic	44.34	51.18
R^2	0.408	0.429
N	491	1343

Note: The dependent variable is the natural logarithm of urban toll ring price. The standard errors in parenthesis are clustered at urban toll ring level. ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Table A2: Estimating on group level averages

	(1) Adjacent	(2) Commuting
Share electric vehicles	0.031***	0.037***
	(0.008)	(0.013)
R^2	0.351	0.350
N	63	63

Note: The dependent variable is the natural logarithm of urban toll ring price. The model includes toll ring fixed effects and the logarithm of income. ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.