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Encouraging adoption of fuel-efficient vehicles – A policy reform evaluation from Ethiopia *

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Abstract

The extent of vehicle ownership is increasing in many developing countries. Most of the increase takes place through import of second-hand vehicles that are usually fuel-inefficient and have poor emissions standards. This is creating enormous environmental pressures, since most developing countries also lack the necessary policies to regulate the sector. This study investigates the effect of a recent policy reform in Ethiopia that aimed at encouraging adoption of cleaner vehicles. In March 2020, Ethiopia introduced a new vehicle excise tax that linked the excise tax rate to engine size and age of vehicles, imposing lower rates on 'fuel-efficient' vehicles and higher rates on 'fuel-inefficient' ones. Exploiting the quasi-experimental nature of the reform and employing a difference-in-differences design, the study investigates the reform's effect on vehicle ownership and composition of the vehicles, and in reducing CO_2 emissions. The results show that while the reform has no significant effect on total vehicle ownership, it has a significant effect in increasing the adoption of newer vehicles. We also find no significant increase in the adoption of smaller-engine vehicles. The reform led to no significant reduction on CO_2 emissions intensity of the vehicles. The reform, however, significantly increased adoption of small-engine but new vehicles - relatively the most 'fuel-efficient' alternatives. The results are robust to various robustness checks. The study discusses the policy implications of the results, especially for developing countries.

Keywords: transportation, environment, policy instruments, developing countries

JEL Classifications: H23, Q40, Q58

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1 Introduction

The global demand for mobility is projected to increase substantially over the next few decades. The majority of the demand is expected to come from developing regions, including China, the Asia-Pacific region, India, and Africa (International Council on Clean Transportation, 2020). Rapid economic growth, and faster rate of urbanization that these countries are experiencing is fueling this demand. Private ownership of cars is expected to be one of the main modes which urban households will resort to in order to satisfy their mobility demand. However, the lack of stringent environmental policies that control the type of vehicles that can be imported, and availability of cheaper used vehicles, make it likely that most of the increase will be satisfied through import of used vehicles that are considered to be fuel-inefficient, and which have poor emission standards (U.N. Environmental Programme, 2020).

Used vehicles dominate the annual additions to the vehicle fleet in most developing countries. In Africa, more than 60 percent of vehicles added to the existing fleet annually are used vehicles imported from developed regions such as the European Union, USA and Japan (Baskin et al., 2020).[1] The importation of used vehicles is raising various environmental, safety and economic concerns for developing countries. First, used vehicles are believed to contribute greatly to air pollution and emissions of greenhouse gases due to their poor emission standards and fuel-inefficiency (Ayetor et al., 2021; Davis and Kahn, 2010). Second, used vehicles are one of the main factors associated with a high road accidents, due to their generally obsolete and road-unworthy status (Adeloye et al., 2016; Baskin et al., 2020; Bonnet et al., 2018) . Third, used vehicles are also imposing economic costs on developing countries, due to their high need for maintenance and their fuel-inefficiency (Baskin et al., 2020). Unfortunately, most developing countries lack policies that help to address these externalities. Policies such as periodic vehicle inspection and scrappage programs are nonexistent in most of these countries, possibly due to the countries' weak in-

[1] A recent analysis by the World Bank found that 70% of low- and middle-income countries imported more used vehicles than new ones, and that 58% of the countries imported more than three times as many used vehicles as new ones in 2018 (Gorham et al., 2022).

stitutional capacity.[2] This makes the implementation of policies that control the type of vehicles imported to a country in the first place an important policy tool for developing countries.

This study investigates the effect of one such reform implemented in Ethiopia, that aims to influence both the demand passenger vehicles, and the composition of the vehicles. The reform, implemented in early 2020, introduced a new Vehicle Excise Tax (VET) differentiated by the vehicles' engine capacity and age, imposing lower rates on small engine and new vehicles, and higher rates on large engine and older vehicles. The new VET replaced an existing tax regime that was based only on engine size of vehicles where smaller engine vehicles are taxed at lower rates than larger engine vehicles, and which also provided an incentive to own second-hand vehicles. The 2020 reform while maintaining lower rates on smaller-engine vehicles, introduced two important changes: (i) it introduced age-differentiated tax rates for vehicles with the same engine size, and (ii) it lowered tax rates paid on newer vehicles, or substantially increased the rates paid on older vehicles. The VET is a one-time tax payment paid along with other taxes when a vehicle is imported into the country the first time. The change in the tax rates, thus, applies only to those vehicles that are yet to be registered in Ethiopia.

The government announced three objectives for the reform: i) reducing fossil-fuel dependence and environmental pollution, ii) reducing importation of spare parts and maintenance costs, and iii) reducing road traffic accidents. As a consequence of the reform, the most 'fuel-efficient' vehicles - with up to 1,300 cubic centimeter (cc) engine size and which are new (e.g. a new Volkswagen Polo 1.2 TSI) will incur an excise tax rate of only 5%. At the other extreme, the highest rate is imposed on the most 'fuel-inefficient' vehicles – with engine sizes above 1,800 cc and are older than 7 years (e.g. a Volvo V70 2015 model) - a 500% tax rate. Besides revising the tax rates across the vehicles age and engine size, the reform also scrapped an existing rule that allowed applying a depreciation cost reduction of up to 30 % on the duty

[2] U.N. Environmental Programme (2020), for example, found that only 28 developing countries place emission requirements on imported vehicles, while 100 of these countries have no such requirements.

paying value of used vehicles when calculating the corresponding taxes (10 percent for each year that passed after manufacturing year).[3]

We estimate the effect of the reform on overall vehicle ownership, and the composition of the vehicles along age and engine size dimensions. The study also investigates the effect of the reform in reducing CO_2 emissions. We also investigate whether there is heterogeneity of the effects based on vehicles type. To do these analyses, the study exploits the quasi-experimental nature of the reform and uses a difference-in-differences design to identify the short-run impacts of the reform on the various outcomes. The study's settings are districts in Addis Ababa, Ethiopia – where more than two-thirds of registered vehicles in Ethiopia are located. We use monthly registration data of newly registered vehicles across all ten districts in Addis Ababa that spans three years – providing us with repeated cross-sections of vehicle registration in each district.

The results of our analysis show that the reform has no significant effect on overall vehicle ownership. When we analyze the effect on ownership across various vehicle types, however, we find that the reform led to a significant increase in the ownership of newer vehicles. We find no significant change in the ownership of small-engine vehicles. When looking at the composition of the vehicles, we find that the reform led to a significant increase in the share of new vehicles and significant decline in the share of used vehicles. Based on engine size composition, we find that the reform led to a decline in the share of small-engine vehicles. The results are inconclusive regarding the effect of the reform on CO_2 emissions. While we find that the reform led to a significant decline in the share of high-polluting vehicles and an increase in the share of diesel vehicles (less CO_2-emitting vehicles), we find there is no significant change in the average CO_2 emission intensity of the vehicles. The heterogeneity analysis conducted reveals that the reform's effect varies across vehicle groups. The results show that the reform has a significant effect in increasing the adoption of the relatively most fuel-efficient vehicles - small-engine new vehicles.

[3]While the main reason for having this policy is to base calculation of the taxes on the true economic values of used vehicles, it unintentionally encouraged adoption of used vehicles.

The remaining part of this paper is organized as follows: Section 2 presents the literature review, Section 3 provides background information about the institutional setting and the policy reform, Section 4 discusses the data and empirical strategy, Section 5 presents the descriptive and econometric results and provides discussion of the main results, and Section 6 concludes the paper.

2 Related Literature

The empirical literature on consumers' decisions to own a vehicle (or not to do), and what vehicle to own, has identified various factors, including the vehicle's features as well as sociodemographic, psychological, and environmental factors. Most of the economic studies on vehicle choice implement discrete choice models to investigate consumers' preferences where consumers are presented with various choices of vehicle alternatives described by their features or 'attributes' (McFadden et al., 1973; Ben-Akiva et al., 1985; Lave and Train, 1979). Consumers make their decisions by making trade-offs between the various attributes. The vehicles' purchase price, cost of operation, engine size, transmission type, horsepower, curb weight, fuel economy and safety features constitute the most often used attributes used in these studies.

Financial considerations constitute one of the important factors that affects individuals' vehicle choices. In particular, vehicle purchase price is the most important determinant of vehicle adoption (Mannering and Winston, 1985; Turrentine and Kurani, 2007; Lane and Potter, 2007). In addition, consumers also attach strong significance to fuel cost and resale value in their vehicle choice decisions (Mannering and Winston, 1985; Turrentine and Kurani, 2007; Train and Winston, 2007; Hackbarth and Madlener, 2013; Potoglou and Kanaroglou, 2007). Consumers tend to choose cars that offer better value for their money, taking into account the purchase price, long-term running costs, and potential resale value (Ozaki and Sevastyanova, 2011; Heffner et al., 2007; Cecere et al., 2018).

Functional factors including vehicle size, performance, reliability, safety features, and fuel efficiency are also essential determinants of individual vehicle choice (Potoglou and Kanaroglou, 2007; Choo and Mokhtarian, 2004; Train and Winston, 2007). Consumers often prioritize specific functional attributes based on their needs and preferences - for example, families require larger vehicles with more seating capacity, or individuals may look for vehicles with better fuel efficiency if needed for long commutes.

Environmental concerns such as concerns about air quality, climate change, and local regulations are also found to influence individuals' vehicle choices. Consumers concerned about preserving the environment take actions by opting for environmentally friendly low-emitting vehicles (Ewing and Sarigöllü, 1998; Heffner et al., 2007; Turrentine and Kurani, 2007; Mourato et al., 2004). Investigating adoption of hybrid electric vehicles in Los Angeles Country, Kahn (2007) found that individuals with pronounced environmental concerns are more likely to purchase these vehicles than non-environmentalists (Anable, 2005; Gallagher and Muehlegger, 2011).

Sociodemographic factors such as income, age, gender, education, and family structure also influence individuals' vehicle choice decisions. For example, younger individuals often prefer smaller, more affordable vehicles, while families with higher incomes often opt for larger, more luxurious vehicles (Nolan, 2010; Dargay et al., 2007; Dargay, 2001; Brownstone et al., 2000). Households with more members or those with children tend to have higher vehicle ownership rates due to increased transportation needs. Furthermore, life stage transitions, such as getting married or having children, can trigger changes in vehicle ownership behavior (Oakil et al., 2014).

Policy instruments play an important moderating role in influencing both the supply and demand side of vehicle ownership. Through various of instruments they introduce, governments may influence manufacturers' incentives to produce and supply vehicles meeting certain emissions, performances and environmental standards. This may in turn affects the composition of the vehicle attributes which consumers base their vehicle choice decisions on, such as fuel efficiency and emission levels. Some of the supply-side policies of relevance include Corporate Average Fuel Economy (CAFE) standards, fuel-economy standards, and emission standards

(Marz and Goetzke, 2022; Ito and Sallee, 2018; Timilsina and Dulal, 2011; Klier and Linn, 2016; Lipman, 2017; Siskos et al., 2015).

Similarly, governments also introduce various policy instruments that affect consumers' incentives - both financial and non-financial, in their vehicle purchase decisions. Vehicle purchase taxes, fuel taxes, registration taxes, carbon taxes, subsidies, and environmental labeling are some of the main instruments used to influence individuals' vehicle choice decisions (Grigolon et al., 2018; Hennessy and Tol, 2011; Huse and Lucinda, 2014; Ji et al., 2022; Coad et al., 2009). For example, vehicle purchase taxes or introduction of fuel taxes will further increase the price and/or maintenance costs of vehicles. Consumers with higher concerns over financial considerations may then adjust their vehicle purchase decisions by opting not to own purchase a vehicle and/or opting for more fuel-efficient alternatives.

Below, we summarize some of the findings about the effect of demand side instruments, particularly of vehicle purchase or registration taxes, in influencing consumers' purchase behavior, and the corresponding environmental consequences with regards to CO_2 emissions. The main reason for our focus on vehicle purchase or registration taxes is that these are the instruments that most closely resemble the policy change we are investigating in the current study. Vehicle purchase or registration taxes have been implemented in various forms across many countries - sometimes differentiated by the vehicles' engine capacity and sometimes differentiated by emission levels of the vehicles.

Ji et al. (2022) investigate how an increase in the rate of purchase tax for internal combustion engine vehicles (ICEVs) in China, introduced since 2017, affects sales of ICEVs and battery electric vehicles as well as CO_2 and $PM_{2.5}$ emissions. The study finds that the increase in purchase tax led to a reduction in the sales of ICEVs and an increase of battery electric vehicles. Ji et al. (2022) also find that the increase in purchase tax rate by 2.5% for ICEVs with a displacement no higher than 1.6L in 2017 has reduced the environmental externalities caused by CO_2 and $PM_{2.5}$ emissions.

Kok (2015) examines the effects of tax changes in the Netherlands, including vehicle purchase taxes, which are among the most stringent and most salient in Europe, and assesses the impacts on vehicle purchases and CO_2 emissions. Kok (2015) finds that the Dutch tax incentives resulted in 13 g/km, or 11% lower average CO_2 emissions in 2013, helping the Netherlands to become Europe's number one country in terms of the lowest average new car CO_2 emissions and the highest share of electric vehicles in 2013.

Chandra et al. (2010) estimate the effect of tax rebates offered by Canadian provinces on the sales of hybrid electric vehicles. The study finds that the rebates led to a substantial increase in the market share of hybrid vehicles. In particular, Chandra et al. (2010) estimate that 26% of the hybrid vehicles sales during the rebate program period can be attributed to the rebate.

Gallagher and Muehlegger (2011) investigate the relative efficacy of state sales tax waivers, income tax credits, and non-tax incentives in increasing adoption of hybrid-electric vehicles across various states in the US. By exploiting within-state-model variation in incentives during the period 2000 to 2006, the study finds that state tax incentives are positively correlated with hybrid vehicle adoption. When the authors investigate the effect of each of the taxes separately - sales tax waiver (an automatic and immediate deduction of sales tax at the point of purchase), and income tax credit (a refundable tax credit to be claimed in the future), they find that the two types of incentives are associated with different changes in hybrid vehicles sales. In particular, Gallagher and Muehlegger (2011) estimate that a sales tax waiver at its mean value ($ 1,037) is associated with over three times the effect of an income tax credit at its mean value ($ 2,011).

Klier and Linn (2015) examine the effectiveness of CO_2-differentiated vehicle purchase taxes in France, Germany, and Sweden in influencing new vehicle registrations and average CO_2 emission rates. The authors exploit the variation in taxes in these three countries where France taxes (high-emission vehicles) and subsidizes (low-emission vehicles) vehicle purchases, and the amount changes discretely with the vehicle's emission rates whereas Germany and Sweden impose circulation taxes (i.e., registration taxes) that increase linearly with the emissions rate. Klier and Linn (2015) find that the tax change in France had a very large effect on vehicle registrations and explains nearly all of the observed reduction in the average emissions rate between

2007 and 2008. Compared with the French tax, the authors find that the German and Swedish taxes have smaller effects.

On the other hand, in Switzerland, Alberini and Bareit (2019) study the effect of registration taxes on new car sales and emissions by exploiting variations in the registration taxes set by the 26 cantons and their variation over time as natural experiment. The authors investigate whether linking taxes to vehicles' CO_2 emissions rate has helped to shift new cars sales towards lower-emitting vehicles. Alberini and Bareit (2019) find that even when the penalty associated with a highly polluting vehicle is large, the effect is relatively small.

Alberini and Horvath (2021) investigate the effectiveness of a series of annual registration taxes introduced in Germany during January 2011 to March 2019 in redirecting new car purchases towards model with lower emission rates. Using monthly new car sales for the study period during which registration taxes were tightened three times, the study finds that the introduction of the taxes affected new car sales with a magnitude of 2 to 5% reductions in new car sales. Alberini and Bareit (2019) however also find that the effect on the average CO_2 emissions rate is small.

In Norway, Yan and Eskeland (2018) examines the effect of Norway's 2007 CO_2-differentiated vehicle registration tax in encouraging consumers to shift to low-emitting vehicles, and its effect on average emission rates. Using a panel data set and exploiting the quasi-experimental nature of the tax reform, the authors estimate that a 1000 NOK (125 USD) tax increment reduces new vehicle sales by 1.06 to 1.58%. Based on this estimate tax effect, Yan and Eskeland (2018) establish that the CO_2-differentiated tax in 2007 explains the majority of the average CO_2 intensity reduction from 2006 to 2007 (see also for e.g., Fridstrøm and Østli, 2017; Ciccone, 2018).

In summary, the findings presented above show that vehicle taxes, albeit in various forms, have been used to influence consumers' vehicle choice and mitigate the externalities caused by increased vehicle ownership. In particular, there is considerable empirical evidence regarding the effectiveness of taxes in encouraging adoption of more fuel-efficient and also cleaner vehicles across many developed countries. Empirical evidence is, however, scarce to what extent that such policies are effective in achieving similar effects in developing countries, given that such instruments are still rare in most of these countries. Most importantly, understanding the effectiveness of policies such as taxes that control the type of vehicles that are added to the vehicle fleet in the first place could be critical for governments in developing countries, since implementing alternative policies such as those that control the types of vehicles already in circulation (e.g. through periodic vehicle inspection) might be infeasible given weak institutional capacity in these countries. By studying the effect of an introduction of a policy instrument in a developing country, the current study aims to fill this evidence gap.

The current study contributes to the existing literature on the effectiveness of fiscal instruments, particularly vehicle excise tax, in influencing demand for vehicles and potentially improving the composition of the vehicles fleet. While many existing studies are based on ex-ante evaluation of the effects of environmental policies (BenDor and Ford, 2006; Giblin and McNabola, 2009; Greene et al., 2005; Kloess and Müller, 2011), the present work belongs to a growing literature on ex-post evaluation of fiscal instruments as introduced in Europe and other developed regions.

The study also fills an important gap regarding the lack of evidence from developing countries about the effectiveness of fiscal instruments in influencing adoption of green technologies in general, and vehicles technology in particular. Most of the existing evidence is from developed countries: Ireland (Hennessy and Tol, 2011), Germany (Klier and Linn, 2015), Norway (Ciccone, 2018; Yan and Eskeland, 2016), Sweden (Andersson, 2019; Klier and Linn, 2015) and Switzerland (Alberini and Bareit, 2019). By investigating the issue in a rapidly developing country, the study fills the evidence gap on the effectiveness fiscal policy instruments in increasing adoption of 'fuel-efficient' vehicles in a developing country setting. Though the vehicle fleet size in most developing countries is still small, contributing little to global emissions, the fact that the composition of the fleet has been dominated by fuel-inefficient vehicles is concerning. The problem will only get worse with increased urbanization and increases in incomes in these countries over the next few decades (Ayetor et al., 2021; Baskin et al., 2020; Li et al., 2020).

The current setting also allows investigation of a policy instrument which may be relatively ease to to implement in developing countries. Policies such as circulation taxes, periodic vehicle inspections, scrappage programs, and subsidies have been implemented in many developed countries and found to be effective in encouraging adoption of fuel-efficient and clean vehicles (Damert and Rudolph, 2018; Klier and Linn, 2015; Mandell, 2009; Ryan et al., 2009). For developing countries, most of these policies may be infeasible, since they require relatively strong institutional capacity to enforce (e.g. circulation taxes, periodic inspection) or fiscal capacity (e.g. subsidies). Vehicle excise taxes may be attractive in this regard, since they can be easily implemented and enforced given they are paid once and at the country's ports of entry.

3 Institutional Background

3.1 Institutional Details

Ethiopia, with an estimated total population of 120 million in 2023, is the second most populous country in Africa. It is one of the fastest growing countries with an average annual GDP growth rate of 10% in the last two decades. Ethiopia is also undergoing rapid urbanization, at annual rates of about 5%.[4] While the country's total vehicle fleet is still a little above 1 million vehicles, it has experienced rapid rise over the last two decades. Between 2007 and 2018, Ethiopia's vehicle fleet grew from 244,257 to 1,071,345 - an increase of about 339%. Ethiopia is not a vehicle-producing country. The country imports its vehicles mainly from Europe and the Middle East (Gulf States). Ethiopia imposes no restriction on the age of vehicles that can be imported. Toyota models dominate the country's vehicle fleet (Uinted Nations Economic Commission for Europe, 2020). About two-third of the country's vehicle fleet is concentrated in the capital Addis Ababa.

[4] https://datacatalog.worldbank.org/search/dataset/0037712/World-Development-Indicators

The Ethiopian government levies five types of taxes on passenger vehicles. Before March 2020, these five taxes and their corresponding rates were constituted by a customs duty (30%), an excise tax (up to 100%), value-added tax (15%), surtax (10%), and a withholding Tax (3%). The total tax amount was calculated by including each of these tax rates sequentially in their order of imposition. The customs duty is first calculated by applying the 30% rate on the Cost-Insurance-Freight (CIF) value of the vehicle. Next, the excise tax is calculated by applying the appropriate tax rate (based on engine size) on the sum of the CIF value and the customs duty amount. The process continues like this sequentially for the remaining taxes.

Unlike the other four taxes, the excise tax rates levied on vehicles varied depending on the vehicles' engine sizes. The excise tax prior to March 2020 had three taxation brackets – 30% on vehicles with engine sizes up to 1,300 cc, 60% on those with 1,301 cc up to 1,800 cc, and 100% for those with more than 1,800 cc. There is, however, no such difference of tax rates based on the vehicles' ages for any of the taxes imposed on vehicles including the excise tax. The respective tax rates of all the five taxes paid on both new and used vehicles are the same. An exception, however, was that there was a depreciation cost deduction granted to used vehicles amounting up to 30% of their CIF values.

In December 2019, the Ethiopian government proposed introducing a new VET that aimed at encouraging a shift towards fuel-efficient vehicles. The new policy proposed the VET rates to based not only on the vehicles' engine capacity (as was the case up to that point) but also on the age of the vehicles. The policy proposed imposing very low rates on 'fuel-efficient' vehicles (new and small-engine vehicles) and higher rates on fuel-inefficient ones (old and/or large-engine vehicles). At the lowest end, a 5% VET would be levied on vehicles that are new and have a cylinder capacity up to 1,300 cc, whereas at the highest end a 500% VET rate would be levied on vehicles older than 7 years and having a cylinder capacity of more than 3,000 cc. After holding public consultations and making some revisions in the draft proposal, the government enacted the new VET policy in March 2020.

Table 1 presents a detailed structure of the new VET policy and that of the old one. As can be seen from Table 1, it is attractive to buy newer vehicles across each engine

Table 1. Structure of the new vehicle excise tax

	Engine capacity		
	<=1,300 cc	1,301 - 1,800 cc	>1,800 cc
New	5%	60%	100%
1- 2 years	55%	110%	150%
2 - 4 years	105%	160%	200%
5 - 7 years	205%	260%	300%
> 7 years	405%	460%	500%
Old VET regime	30%	60%	100%

size category, whereas it is also attractive to buy smaller engine vehicles for each age group. A vehicle that is both small-engine (up to 1,300 cc) and new faces a VET rate of just 5%. The rate on small-engine vehicles increases with their age and reaches a maximum of 405% for those that are 7 years old and above. For medium-engine vehicles (1,301 - 1,800 cc), the lowest rate is 60% for those that are new, and the highest is 460% for vehicles that are 7 years old and above. Large-engine vehicles (>1,800 cc) that are new face a 100% tax rate with the rate increasing up to 500% for those that have same engine capacity but are at least 7 years old and above.

3.2 Expected Effects

One of the potential effects of the reform is to discourage overall ownership of vehicles. Under the previous excise tax regime, second-hand vehicles were a cheap alternative for many car buyers. The increase in tax rates imposed on these vehicles due to the reform is expected to significantly increase their prices. Though the reform lowered the tax rates on small-engine new vehicles, the fact that brand new vehicles fetch higher prices than their second-hand counterparts means that small-engine new vehicles are still more expensive than what second-hand small-engine vehicles would cost under the previous tax regime.

In Table 2, we provide information on how the prices of different types of vehicles evolve under the old and new tax regimes. We calculate the prices by applying the various tax rates on the prices of on a selection of vehicle types. A 2012 Toyota

Yaris 1,300 cc vehicle, one of the most dominant and affordable vehicles types in the pre-reform period, is estimated to cost US $18,016 under the old tax regime. Under the current reform, importing this vehicle will result in paying a 405% VET rate. This is estimated to increase its price to just under US $100,000. On the other hand, a 2020 model of the same vehicle that would have cost US $35,661 under the old regime will now cost US $28,803. This price is, however, at least US $10,000 higher than what the most affordable vehicle under the old regime (a 2012 Toyota Yaris 1,300 cc) would have cost. The price changes for other types of vehicles are also similar, as shown in the table.

Table 2. Average price of vehicles using the old and new excise tax in USD

	Model Year	Price at origin (USD)	Price under old VET (USD)	Price under new VET (USD)
Toyota Yaris 1,300 cc	2020	15,595	35,661	28,803
	2016	13,640	21,833	49,185
	2012	11,255	18,016	99,977
Toyota Corolla 1,800 cc	2020	19,600	55,162	55,162
	2016	16,950	33,393	77,518
	2010	15,450	30,437	152,187
Toyota RAV4 2,500 cc	2020	25,950	91,291	91,291
	2016	23,680	58,314	124,958
	2010	21,675	53,376	228,756

The reform is expected to influence the age composition of vehicles. By imposing lower rates on newer vehicles, and very much higher rates on older ones, the reform is expected to encourage individuals to shift to newer vehicles. For each engine size category of the vehicles, the reform imposes progressively higher rates the older the vehicle gets. In addition, the reform also scrapped the existing depreciation cost deduction of up to 30% on used vehicles that lowered the value on which the tax rates were calculated for used vehicles. Thus, the combined effect of much higher rates imposed on used vehicles and the eradication of the depreciation cost deduction is expected to make used vehicles unattractive and new ones very attractive.

The expected effect of the reform on engine size structure of vehicles that individuals adopt is not clear. The reform can be expected to increase adoption of small-engine vehicles as it imposes lower rates on these vehicles and higher rates on large-engine ones. However, large-engine vehicles may provide other superior benefits than small-engine vehicles in terms of power and functionality. Thus, unlike substituting second-hand vehicles with brand new alternatives, a shift from large-engine to small-engine vehicles may involve forgoing significant benefits that comes with owning the former. Some section of consumers may find it difficult to make this substitution.[5] Therefore, the net effect of the reform on the engine size structure of the vehicles that household may adopt could go either way.

The reform's effect on CO_2 emissions is also not clear. The most important reason for this is the fact that the reform does directly link the tax rates with the vehicles' CO_2 emissions levels. If the reform leads to an increased in the ownership of newer vehicles, this may result in the decline on the average CO_2 emissions intensity of vehicles, since newer models have generally lower emissions levels (Peters et al., 2008). On the other hand, if the shift towards those newer vehicles is due to an increase in the ownership of large-engine vehicles, we may not necessarily observe a decrease in emission levels; if anything, CO_2 emission levels may go up. The long-run effect of the reform on CO_2 emissions is even more complex since a number of factors may have concurrent impacts - including driving behavior, how long the vehicles remain in service, and others.[6] The current study is not able to investigate this issue - our analysis is only limited to analyzing the emissions intensity of newly registered vehicles during our estimation window.

[5]These are of course other considerations that car buyers will take into account in making the trade off - the fuel-economy standard of the vehicles being one such consideration. Allcott and Wozny (2014) provide suggestive evidence that individuals may undervalue future fuel cots.

[6]For example, if car buyers find it expensive to buy new vehicles to replace their old vehicles, they may keep on driving the old cars for many years past their optimal ages. This will increase the emission levels, since older vehicles can be expected to emit more. The magnitude of this effect may of course depend on the extent to which car buyers take into account the cost of maintenance.

4 Data and Method

4.1 Data Description

The main data for our analysis is obtained from the Addis Ababa Driver and Vehicle License and Control Authority. The data pertains to 125,000 passenger and light-duty vehicles registered in Addis Ababa for the period 2017 to 2021. The data is organized as a monthly registrations for each of the ten districts (sub-cities) in Addis Ababa for this period. The data contains various vehicle features, including year of production, date of registration, engine capacity, model, brand, and other characteristics. We measure our main outcome variables at the district level.

The CO_2 emission levels of the vehicles is not captured in the city's vehicles registration database. We construct this data for all the vehicles in our sample from online sources such as the European Environment Agency.[7] To construct the emission data, we make use of the information on vehicles model, engine capacity and year of production obtained from the registration database. The vehicles emission levels are measured in g/km units.

We obtained monthly fuel prices for both petrol and diesel fuels from the Ministry of Trade. Fuel prices are regulated in Ethiopia, whereby, the government makes periodic adjustments by taking international prices into account. The retail prices are announced every month with the possibility that the prices are either adjusted or remain unchanged for another month. Though there are spatial variations in the prices of fuels that the government announces nationally, all the districts in Addis Ababa are under the same price category. We deflate the monthly fuel prices using the Consumer Price Index obtained from the Ethiopian Statistics Service.[8]

To account for the effect of income level, we use monthly night light data for each of the districts as a proxy for district-level average income. Per capita income levels are not available at the district level of disaggregation and hence, we rely on luminosity

[7]We also used two additional sources: https://www.cars-data.com/en/, and https://car-emissions.com/.

[8]https://www.statsethiopia.gov.et/consumer-prices/

data as our proxy measure. Previous studies have shown that night light data indeed serves as a good proxy to account for locations' level of economic activity. We obtain the monthly night light data from the Earth Observation Group. We use the Visible and Infrared Imaging Suite (VIIRS) Monthly Cloud-free Day Night Band Composite version 2.1 data.[9] We also include annual population size of the districts using data obtained from the Ethiopian Statistics Service.

Outcome Variables The first set of outcome variables we identify pertain to the number of vehicles registered each month in each of the districts. This is intended to capture the effect of the reform on vehicle ownership in general. We construct this measure both for total monthly registration and for different vehicle types as defined by their engine size and age groups. As presented in Table 1 above, the reform classifies vehicles into three different tax brackets based on their engine size: up to 1,300 cc, 1,301 – 1,800 cc, and more than 1,800 cc. Similarly, the reform categorizes vehicles into four groups based on their age- new (up to 1 year), 2 to 4 years, 5 to 7 years, and older than 7 years. We follow this classification and create groups for the vehicle types. Based on engine size, we categorize the vehicles into three groups: small-engine vehicles (up to 1,300 cc), medium-engine vehicles (1,301 - 1,800 cc), and large-engine vehicles (>1,800 cc). Based on the vehicles' age, we similarly categorize them into three groups: new vehicles (up to 1 year), moderately old vehicles (2 to 7 years)[10], and very old vehicles (older than 7 years).

The second set of outcome variables we construct are intended to capture the effect of the reform on the age and engine size composition of the newly registered vehicles. To measure the change in age composition, we first use the average age (in years) of vehicles newly registered in each district every month. Second, we construct the share of each type of vehicles as defined by their age group: share of new, share of moderately old, and share of very old vehicles. To capture the change in engine size composition, we first use the average engine size of vehicles registered every month

[9] https://eogdata.mines.edu/products/vnl/

[10] Due to the small proportion of vehicles aged 2–4 years, and 5–7 years categories, we combine them together for our analysis and form the *moderately old* category.

across each of the districts. Second, we construct the shares of each type of vehicles as defined by their engine size: shares of small, medium, and large vehicles.

The third set of outcome variables we construct focus on measuring the effect of the reform on CO_2 emissions. Green house gas emissions from vehicles is one of the main contributing factors to climate change, with CO_2 being the main gas produced from vehicles exhaust. While the reform did not directly link the tax rates with the CO_2 emissions levels of the vehicles, one of the ultimate objectives of the reform is to reduce the environmental externalities caused by the passenger transport sector in the economy. The success of the reform from an environmental point of view can be analyzed by investigating its effect in reducing CO_2 emissions. To shed light on the effect of the reform on the CO_2 emissions, we focus on three outcome variables. The first one is the average CO_2 emissions intensity of newly registered vehicles. A higher CO_2 number means that a car emits more carbon dioxide (CO_2) from its tailpipe and hence, is not environmentally sustainable whereas smaller CO_2 emissions number indicate the opposite. We thus investigate whether, on average, the CO_2 emissions intensity of newly registered vehicles post-reform is lower than the emissions intensity of newly registered vehicles pre-reform. The second measure we use is the share of high-polluting vehicles registered every month across each district. We define high-polluting vehicles as those that have CO_2 emission levels above 130 g/km following the European Union target of passenger cars emissions levels for 2015 (International Council on Clean Transportation, 2014). The third outcome variable we use is the share of diesel vehicles registered each month in each of the districts. Diesel vehicles are known to have lower CO_2 emission levels than their gasoline counterparts. A shift towards diesel vehicles is, thus, seen an important step to reduce CO_2 emissions from passenger transport.

To investigate the heterogeneity of the effect of the reform across various vehicles types, we construct various outcome variables by combining both the engine size and age of the vehicles. For each of the small, medium and large vehicle types, we calculate both the number and the shares that are new, moderately old and very old. For the small vehicles, this results in small-new, small-moderately old, and small-very old vehicles.[11]

4.2 Empirical Strategy

As briefly explained in the previous section, the main unit of analysis in this study are the 10 districts in Addis Ababa. As we do not observe the individuals' car purchase decision, we are not able to conduct individual level analyses to understand the reform's effect. We do not observe the prices of the vehicles as well as the socioeconomic characteristics of the vehicle owners. Our analysis is rather confined to understanding the effect of the reform in affecting the various outcome variables at the district level. At the district level, we observe all the vehicles that have been newly registered and went into operation every month. These are the newly added vehicles that were never in operation in Ethiopia before that and have not been issued plate numbers. We also do not observe deregistration of vehicles in our data, and hence we are not able to investigate the reform's effect on the overall vehicle fleet and scrappage of vehicles.

To differentiate the impact of the 2020 vehicle excise tax on our outcome variables, we employ a Difference-in-Differences (DID) approach. By using the DID approach, the current study aims to estimate the causal vehicle composition effects of the reform in the short-run. In particular, we estimate the impact of the reform on total registration, age and engine size composition of newly registered vehicles, and on the CO_2 emissions intensity of the vehicles.

The use of the DID estimator allows us to estimate the causal effect of the reform while netting out time trends and seasonality in the market and control for other important exogenous covariates. In our current case, the VET reform is applied to all vehicles at the same time, both in Addis Ababa and throughout Ethiopia. Given this aspect of the reform, we do not have optimal control group in the standard sense– that is, certain groups or areas where the reform is not introduced. A simple calculation of

[11] To obtain the shares, we calculate the values not from the total number of vehicles registered but from the total number of (for example) small-, medium- or large-engine vehicles registered each month in each of the districts.

the difference in the share of vehicle types between post- and post-reform periods would only give us a biased estimate of the true effect of the policy, as long as we fail to take into account time trends, market seasonality and control for other exogenous factors that may affect the outcome variables. Thus, to isolate the causal impact of the policy reform from such seasonal effects, we use a control group observations of vehicle registrations in the same months and at the same municipalities but in years in which no reform took place. Our approach closely follows a similar strategy used by Ciccone (2018), that evaluated the impact of a CO_2-differentiated vehicle registration tax in Norway. Such a strategy has also been used in other empirical undertakings such as evaluations of changes in labor market policies (Ekberg et al., 2013; Lalive and Zweimüller, 2009; Schlosser et al., 2010; Schönberg and Ludsteck, 2014; Johansson and Palme, 2005).

Our approach, to isolate the causal impact of the reform using the DID approach, is informed by the timeline of the reform process. In particular, we use observations in previous years, where no reform took place, as a control. We formulate our *treatment* observations as a two ten-month periods in 2019 and 2020- one ten-month period immediately pre-reform, and one ten-month period immediately post-reform. We then use two corresponding ten-months periods in 2017 and 2018 as our control observations.

Equation (1) below presents our DID specification that is estimated for our different outcome variables. Our outcome measures are aggregated at a district level $d = 1, 2, ..., D$ and months $m = m_1, m_2, m_3, m_4$.

$$Y_{dm} = \alpha + \beta Reform_{m_3,m_4} + \delta Post_{m_2,m_4} + \phi Post * Reform_{m_4} + \theta \mathbf{X'}_{dm} + \mu_d + \mu_m + \epsilon_{dm} \quad (1)$$

Where

- m_1 refers to the months between February and November 2017
- m_2 refers to the months between March and December 2018
- m_3 refers to the months between February and November 2019
- m_4 refers to the months between March and December 2020

The variable $Reform_m$ is a dummy variable taking a value = $1 for t = m_3, m_4$ indicating the observations that belong to the years of the treatment - *group effect*. On the other hand, the variable $Post_m$ refers the periods after the reform in the year of the reform, and for the control group - *time effect*. This dummy variable equals 1 for the ten months between March and December 2018 and from March to December 2020, and is otherwise equal to zero. The main variable of interest, $Post * Reform_m$, is the interaction term that identifies the ten-months period immediately after the 2020 reform. The variable takes the value 1 for the months between March and December 2020, and is otherwise equal to zero. The coefficient δ captures the corresponding effect of the reform on our outcome variables. $\mathbf{X'}$ is a vector of control variables. We also include district and month fixed effects to capture any district specific effects and seasonal patterns that may be affecting the treatment effect estimates. The variables μ_d and μ_m represents the district and month fixed effects, respectively. Last, ϵ_{dm} is the error term.

4.2.1 Identification Concerns

A potential threat to identification may arise if car buyers would change their behavior as a consequence of the treatment, or in anticipation of it. This is particularly important if car buyers changed their purchase decisions during the months around the first announcement of the VET reform until it was finally enacted into law. This could, for example, be the case if car buyers bring their purchase decisions forward, anticipating that a higher VET rate may soon make certain or all vehicle types more expensive. This is a possibility for the months when the reform is first announced to when it was finally implemented. There was no mention of the tax reform before it was first announced to the public in December 2019. A search in two of the country's largest newspapers – *Addis Fortune*[12], and *Ethiopian Reporter*[13], confirms this. The first article typically appeared in the second week of December 2019 in the Ethiopian Reporter whereas Addis Fortune published its first article on the reform only one month after the reform was first proposed. It should also be noted that the

[12] https://addisfortune.news/on-the-500pc-proposed-excise-tax/

[13] https://www.thereporterethiopia.com/9186/

magnitude of this effect would be limited by the supply side of the market. Since Ethiopia is not a car-producing country, it relies on imports from regions such as the Gulf, the EU and Japan to satisfy vehicles demand. It thus takes at least a couple of months for the supply to sufficiently respond to any anticipated change in demand. Nevertheless, to deal with the possibility of such anticipatory behavior, we exclude the months between December 2019 and February 2020 from the analysis.

5 Results

In this section, we present our main findings. First, we present various descriptive results that document the changes observed in the composition of vehicles registered over the last few years across all districts in Addis Ababa - covering both the pre- and post-reform periods. Second, we proceed to presentation of the econometric results to quantitatively measure the effect of the tax reform in affecting the share of various groups of vehicles. Third, we present some robustness analysis of our results. Finally, we discuss the policy implications of the results, especially in a developing country context.

5.1 Descriptive Results

In Table 3, we present the summary statistics of the main variables for the pre-reform and post-reform periods. To ensure comparability between the two periods, we present the descriptive statistics using 18-month windows- the last 18 months before the reform, and the first 18 months after the reform. Looking at the results, we observe that, on average, about 147 vehicles were being newly registered every month across the districts during pre-reform months. The average number of newly registered vehicles during the post-reform months was 129 vehicles. When we disaggregate the registration by engine size, we observe that small-engine vehicles were the dominant vehicle types; with 110 of this vehicles registered every month during the pre-reform months. The registration of this vehicle type declines to about 82 vehicles during the post-reform months. On the other hand, the number of newly registered new vehicles during the pre-reform months was small at around 26 during pre-reform period. During the post-reform period, the number of newly registered new vehicles more than doubles compared to the pre-reform level. In contrast, we observe a substantial decline in the number of newly registered very old vehicles during the post-reform months (56 vehicles) compared to the pre-reform period (107 vehicles).

We also look at the composition of the vehicles- measured by the share of the different types of vehicles. Here, we also observe important changes. In line with the observed change in the number of registrations, we observe that the share of newly registered small-engine vehicles declines during the post-reform months (67%) compared to pre-reform period (76.3%). We also observe a slight increase in the share of both medium- and large-engine vehicles. On the other hand, we observe a substantial change in the share of newly registered new vehicles, which now account for about 44% of the newly registered vehicles compared to their share of just 16% in the pre-reform periods. In contrast, there is a considerable drop in the share of newly registered very old vehicles - from 74.2% in the pre-reform period to 48.7% post-reform.

The average CO_2 emission intensity of newly registered vehicles during the pre-reform period was 147 g/km, whereas the value post-reform was 143 g/km. The share of newly registered high-polluting vehicles underwent a decline in the post-reform period (58.3%) compared to the level in the pre-reform months (73.5%). We also observe an increase in the share of newly registered diesel vehicles during the post-reform period - from 12.6% to 19.1%.

Below we provide additional graphical descriptive statistics for some of the main variables. We aim to show in more detail how the variables have evolved over certain period of time both before and after the reform.

Table 3. Summary statistics

	Pre-reform		Post-reform	
	Mean	sd	Mean	sd
Number of newly registered vehicles per month	147.483	(63.705)	129.175	(93.269)
Number of newly registered small vehicles	110.172	(46.927)	81.831	(56.383)
Number of newly registered medium vehicles	11.017	(9.463)	16.281	(18.175)
Number of newly registered large vehicles	26.294	(23.901)	31.063	(30.129)
Number of newly registered new vehicles	26.486	(25.696)	63.769	(67.673)
Number of newly registered moderate old vehicles	14.417	(9.517)	9.319	(9.181)
Number of newly registered very old vehicles	106.728	(44.859)	56.087	(42.875)
Average engine size of newly registered vehicles (in cubic cylinders)	1427.757	(261.822)	1558.445	(338.269)
Share of newly registered small vehicles	0.763	(0.122)	0.67	(0.141)
Share of newly registered medium vehicles	0.071	(0.051)	0.107	(0.072)
Share of newly registered large vehicles	0.166	(0.107)	0.222	(0.136)
Average age of newly registered vehicles (in years)	11.054	(1.789)	7.826	(3.173)
Share of newly registered new vehicles	0.162	(0.115)	0.442	(0.221)
Share of newly registered medium vehicles	0.096	(0.044)	0.071	(0.048)
Share of newly registered large vehicles	0.742	(0.124)	0.487	(0.220)
Average CO_2 emission intensity of newly registered vehicles (g/km)	147.009	(5.808)	143.273	(10.741)
Share of newly registered high-polluting vehicles	0.735	(0.062)	0.583	(0.144)
Share of newly registered diesel vehicles	0.126	(0.091)	0.191	(0.129)

Number of Newly Registered Vehicles Figure 1 presents the trend in the number of newly registered vehicles in each month between January 2017 and August 2021. We present the analysis for the total number of vehicles. Looking at the figure, we observe a decline in the number of newly registered vehicles in the months after the reform (after March 2020), compared to the levels of registration pre-reform. During January 2017 and November 2019, there have been, on average, new registrations of 1,485 vehicles each month across the combined districts. The number of new registrations during March 2020 and August 2021 is 1,421 vehicles, on average. In our econometric analysis below, we investigate further whether this reduction in new registrations is the effect of the reform and whether the decline is statistically significant.

Figure 1. Change in the Number of Newly Registered Vehicles

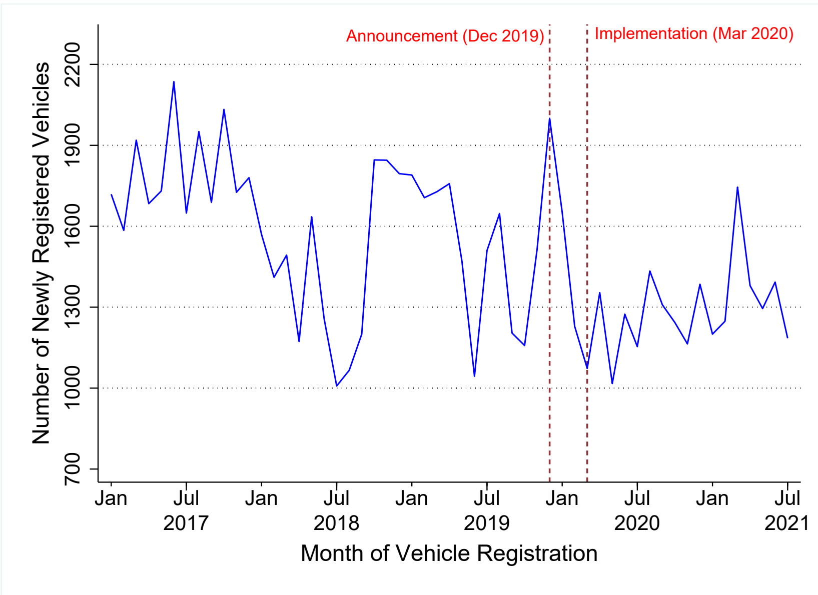
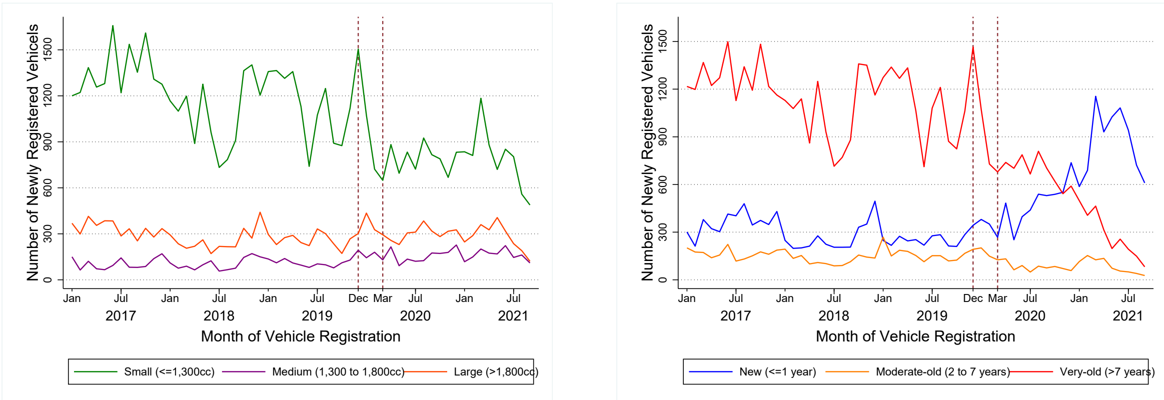


Figure 2 disaggregates the change in registration by different types of vehicles - based on engine size in Panel (a), and age category in Panel (b). We see from Panel (a) that there is a considerable decline in new registrations of small-engine vehicles, which also are the most dominant vehicle types. On the other hand, we observe a slight increase in new registration of medium- and large-engine vehicles. In Panel (b), we observe a substantial and continuous decline in new registration of very old vehicles, the dominant vehicle type pre-reform, whereas we observe the opposite for new vehicles. There is also an observed decline in new registration of moderately-old vehicles. Taken together, the observations from Panel (a) and Panel (b) suggest that there has been a considerable change in a new registrations of small-engine very old vehicles post-reform, compared to pre-reform levels.

Figure 2. Change in Vehicle Registration by Age and Engine Size Composition

(a) Number of Newly Registered Vehicles by Engine size

(b) Number of Newly Registered Vehicles by Age group

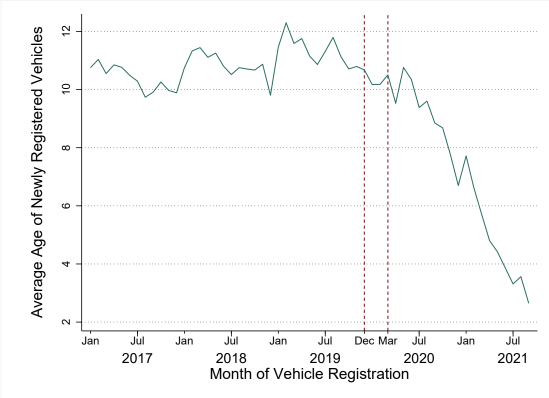


Age Composition of Vehicles In Figure 3, we observe from Panel (a) that the average age of newly registered vehicles during the pre-reform months was between 10 and 12 years implying that very old vehicles dominated the new addition of vehicles during this period. Post-reform, we observe a substantial though gradual decline in the average age of newly registered vehicles. Panel (b) explains the mechanism behind this change. The share of very old vehicles, that previously accounted for more than 70% of newly registered vehicles, underwent a substantial reduction post-reform - with its share accounting for only about 15% of new registrations in the summer of 2021. On the contrary, the share of new vehicles, which only accounted for less than 20% registrations for greater part of the pre-reform period, underwent a substantial increase post-reform, accounting for about 80% of new registrations 18 months after the reform.

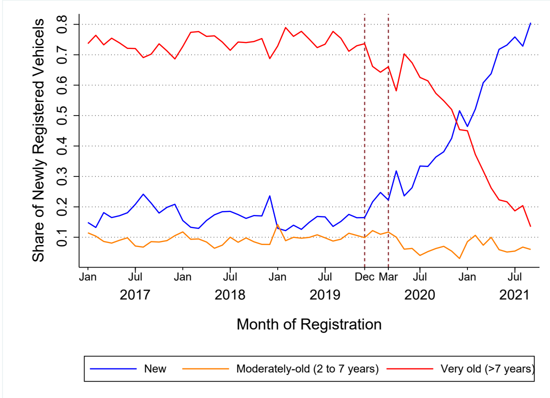
Engine Size Composition of Vehicles In Figure 4, we graphically investigate how the engine size composition of the newly registered vehicles has evolved in the months before and after the reform. Panel (a) shows there is an increase in the average engine size of newly registered vehicles post-reform, compared to the level during pre-reform months. The disaggregated results presented in Panel (b) also support this observation. Panel (b) shows that small-engine vehicles accounted, on

Figure 3. Change in the Age Composition of Newly Registered Vehicles

(a) Average Age of Newly Registered Vehicles



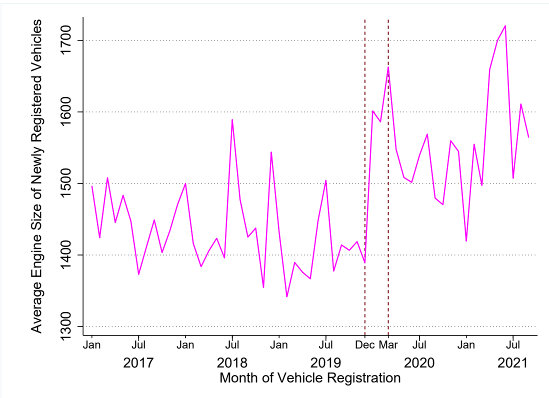
(b) Share of Newly Registered Vehicles by Age Group



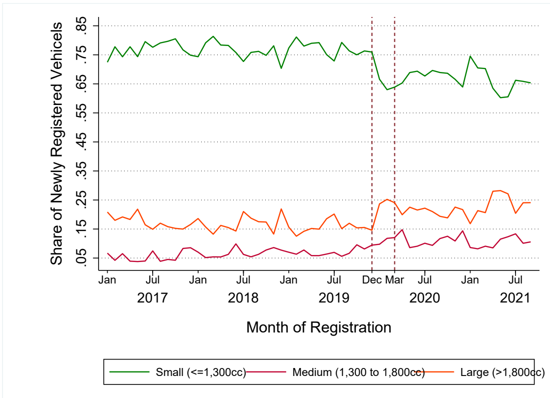
average, for 75% of newly registered vehicles pre-reform. During the same period, we observe that large-engine vehicles were the second largest group accounting, on average, for 18% of newly registered vehicles. Following the reform, we observe a decline in the share of small-engine vehicles and an increase in the share of both medium- and large-engine vehicles.

Figure 4. Change in the Engine Size Composition of Newly Registered Vehicles

(a) Average Engine Size of Newly Registered Vehicles

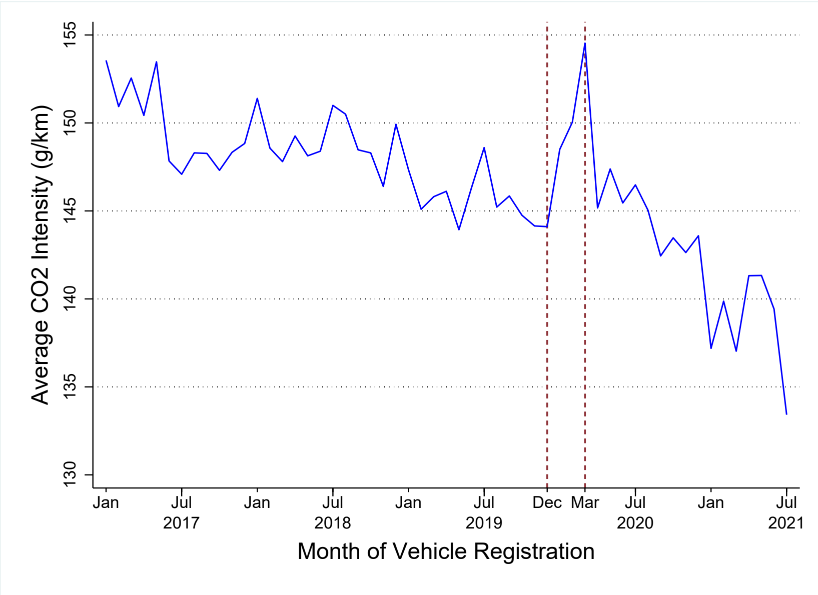


(b) Share of Registered Vehicles by Engine Size



CO_2 Emission Intensity of Vehicles The CO_2 emission intensity of vehicles is the other outcome we investigate. The emission intensity of vehicles have a direct environmental consequences. As shown in Figure 5, the CO_2 emission intensity of vehicles has undergone a decline in the post-reform months compared to the levels during pre-reform months. It should be noted, however, that even during pre-reform months there is a gradual decline in the CO_2 emission intensity of newly registered vehicles. This is of course not surprising, since car manufacturers are producing more and more low-emission vehicles to respond to the global pressure to reduce emissions. We, however, observe that the post-reform decline in emission intensity of newly registered vehicles is larger in magnitude, and is happening faster suggesting a potential effect of the VET reform.

Figure 5. Change in CO_2 Emissions Intensity of Newly Registered Vehicles



5.2 Main Results

We now present the results from the econometric analysis using DID estimation. We first present the effect of the reform on the overall vehicle ownership. We then investigate the effect on engine and age composition of newly registered vehicles. Next, we present the effect of the reform on CO_2 emissions which will be followed by a heterogeneity analysis. Finally, we also provide some robustness analysis.

5.2.1 Effect on Vehicle Ownership

First, we present the effect of the reform on the overall vehicle ownership as measured by the number of newly of registered vehicles. Table 4 presents the DID estimation results. The reform has no significant effect on vehicle ownership. In Column (1), we observe that there is a negative and statistically significant group effect and time effect, whereas there is no statistically significant effect for the DID coefficient. The result for the main coefficient remains unchanged when we included the additional control variables in Column (2). Hence, we cannot attribute any of the changes in the overall vehicle registration to the implementation of the policy.

Table 4. Estimation of reform effects: overall ownership of vehicles

	(1)	(2)
	Coeff.	Coeff.
Post*Reform	14.520	14.292
	(10.433)	(12.106)
Reform (Group effect)	-33.630***	18.498
	(6.577)	(36.923)
Post (Time effect)	-40.632***	-14.177
	(6.262)	(20.688)
Average income		-2.131
		(1.553)
Petrol price (real)		1.373
		(2.247)
Population size (log)		-972.415
		(741.539)
Constant	103.745***	12,438.018
	(10.628)	(9,409.102)
District dummies	Yes	Yes
Month dummies	Yes	Yes
Observations	400	400
R-squared	0.46	0.46

Note: The dependent variable is the number of newly registered vehicles in each district. Robust standard errors given in parenthesis. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Next, we investigate whether there is heterogeneity in the change on vehicle ownership across age and engine size categories. Table 5 presents the difference-in-differences estimation of the effect of the reform on vehicle ownership disaggregated by the vehicles' age group. Column (2) shows that the reform has led to a statistically significant increase in the registration of newer vehicles. On average, the reform led to an increase in the ownership of 27 new vehicles each month across the districts. The effect is statistically significant at the 1% level. The attractive tax rates provided on newer vehicles seem to encourage households to opt for such vehicles.

Table 5. Estimation of reform effects: Ownership of vehicles by age group

	(1)	(2)	(3)	(4)	(5)	(6)
	New		Moderately old		Very old	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Post*Reform	31.282***	26.805***	-2.520*	-2.289	-14.260**	-10.252
	(4.476)	(5.181)	(1.479)	(1.604)	(7.047)	(7.785)
Reform	-11.030***	7.594	-1.060	-1.590	-21.540***	12.486
	(2.372)	(17.796)	(1.163)	(4.091)	(4.880)	(23.386)
Post	-12.392***	-0.881	-3.973***	-4.003	-24.248***	-9.270
	(2.568)	(9.523)	(1.066)	(2.540)	(4.541)	(13.305)
Average income		0.628		-0.349**		-2.408***
		(0.924)		(0.149)		(0.781)
Petrol price (real)		0.964		0.196		0.211
		(0.859)		(0.399)		(1.533)
Population size (log)		-277.878		26.434		-720.912
		(356.431)		(74.327)		(470.065)
Constant	-0.485	3,496.6	9.270***	-324.09	95.000***	9,264.80
	(3.718)	(4,522.3)	(1.887)	(942.57)	(8.842)	(5,963.5)
District dummies	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	399	399	400	400	400	400
Adjusted R^2	0.59	0.59	0.38	0.39	0.52	0.53

Note: The dependent variable is the number of newly registered vehicles in each district. Robust standard errors given in parentheses. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

The effect of the reform on the ownership of older vehicles is negative, though the effect is not statistically significant in our full models. In Column (3), we observe that the reform led to a reduction in the ownership of moderately old vehicles. The effect is statistically significant only at the 10% level. However, once we include the full set of control variables, this effect is no longer statistically significant, though the sign remains negative as shown in Column (4). Similarly, in Column (5) we observe that the reform led to a reduction in the ownership of very old vehicles and the effect is statistically significant at the 5% level. In Column (6), when we include the full set of control variables, the effect on the ownership of very old vehicles is no longer statistically significant, though the coefficient is negative.

Table 6. Estimation of reform effects: Ownership of vehicles by engine size

	(1)	(2)	(3)	(4)	(5)	(6)
	Small-engine		Medium-engine		Large-engine	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Post*Reform	-1.950	3.769	4.200**	4.434**	12.270***	6.089
	(7.532)	(8.896)	(1.860)	(2.076)	(3.602)	(4.035)
Reform	-27.150***	26.799	1.090	-9.018*	-7.570***	0.718
	(5.181)	(26.112)	(0.995)	(5.097)	(2.161)	(13.982)
Post	-31.592***	-9.191	0.156	-4.953	-9.196***	-0.033
	(4.872)	(15.026)	(1.130)	(3.118)	(2.221)	(7.473)
Average income		-2.201**		0.258		-0.189
		(0.953)		(0.294)		(0.653)
Petrol price (real)		-0.709		-0.212		2.294***
		(1.682)		(0.375)		(0.783)
Population size (log)		-1,228.76**		191.975*		64.365
		(511.942)		(100.923)		(283.336)
Constant	95.957***	15,716.0**	0.610	-2,433.1*	7.178***	-844.900
	(8.943)	(6,492.7)	(1.346)	(1,279.7)	(2.697)	(3,597.2)
District dummies	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	400	400	400	400	400	400
Adjusted R^2	0.47	0.48	0.35	0.35	0.57	0.58

Note: The dependent variable is the number of newly registered vehicles in each district. Robust standard errors given in parentheses. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

We now focus on the effect on registration of vehicles based on engine size. Table 6 presents the difference-in-differences estimation results of this analysis. The reform led to no statistically significant change in the ownership of small vehicles. While in Column (1) the effect on the registration of small vehicles is negative, it is not statistically significant. In Column (2), when we include the additional control variables, the effect becomes positive though still not statistically significant. On the other hand, we find the reform led to an increase in the ownership of medium-engine vehicles. The number of newly registered medium-engine vehicles increased, on average, by 4 vehicles every month across the districts (Column (4)). The effect is statistically significant at the 5% level. We find no statistically significant effect on the registration of large-engine vehicles. Though we find a positive and statistically significant effect in column (5), the effect becomes not significant when we include the full set of control variables in column (6).

To summarize, the results presented above reveal that though the reform did not lead to significant change in the overall ownership of vehicles, there is heterogeneity in the effects when looking at the various vehicles types. In particular, the results show that the reform led to an increase in the ownership of newer vehicles. Following the reform, car buyers have increasingly adopted new vehicles. The lower tax rates granted to newer vehicles through the reform has encouraged their increased adoption. When looking at the engine size groups, the reform also led to an increase in the registration of medium-engine vehicles but to a statistically insignificant change in the registration of small-engine vehicles.

5.2.2 Effect on Age Composition

The results presented in the preceding sub-section revealed that the reform led to changes in the number of registration of vehicles at least for some group of the variables. Here, we investigate to what extent the introduction of the new VET reform altered the age composition of the newly registered vehicles. We estimate the effect of the reform on both on the average age of newly registered vehicles and the share of vehicles groups categorized based on their age. Table 7 presents the results from the difference-in-differences estimation for this analysis. The reform led to a statistically significant reduction in the average age of newly registered vehicles. This effect remains the same after we include the full set of control variables in column (2). This result is in line with the result presented in Table 5 regarding the increase in the ownership of new vehicles.

Table 7. Estimation of reform effects: Composition of vehicles by age group

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	All vehicles		New		Moderate old		Very old	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Post*Reform	-2.537***	-2.297***	0.202***	0.183***	-0.032***	-0.031***	-0.170***	-0.152***
	(0.245)	(0.284)	(0.017)	(0.019)	(0.008)	(0.009)	(0.017)	(0.020)
Reform	0.955***	1.563**	-0.037***	-0.067	0.013***	-0.005	0.024**	0.072
	(0.151)	(0.707)	(0.010)	(0.050)	(0.005)	(0.022)	(0.011)	(0.049)
Post	0.692***	0.875**	-0.031***	-0.037	0.001	-0.007	0.030***	0.045
	(0.146)	(0.397)	(0.010)	(0.027)	(0.005)	(0.012)	(0.010)	(0.028)
Average income		-0.091**		0.007***		-0.001		-0.007***
		(0.037)		(0.003)		(0.001)		(0.002)
Petrol price (real)		-0.019		0.001		0.001		-0.002
		(0.047)		(0.003)		(0.002)		(0.003)
Population size (log)		-15.913		0.865		0.427		-1.293
		(13.614)		(0.989)		(0.424)		(0.926)
Constant	13.191***	216.541	0.026	-11.072	0.076***	-5.338	0.898***	17.411
	(0.283)	(172.695)	(0.017)	(12.550)	(0.010)	(5.384)	(0.019)	(11.742)
District dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	400	400	400	400	400	400	400	400
Adjusted R^2	0.683	0.689	0.705	0.713	0.146	0.143	0.704	0.710

Note: Dependent variable in column (1) - (2) is average age (in years) of newly registered vehicles in each district. In column (3) - (8), dependent variable is share of *new*, *moderate-old*, and *very old* vehicles. Robust standard errors given in parenthesis. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

The reform also led to a substantial increase in the share of new vehicles. The results from the full estimation in column (4) shows that the share of new vehicles increased by 18.3% percentage points. On the other hand, we find the reform led to a considerable decline in the share of very old vehicles suggesting that consumers might have moved away from buying this vehicles and adopted newer vehicles instead. Following the introduction of the reform, the share of very old vehicles declined by 15.2% percentage points. Pre-reform the share of very old vehicles accounted for the overwhelming majority of newly registered vehicles each month across the districts. Though the magnitude is not as large, we also find similar effect of decline in the share of moderately old vehicles.

5.2.3 Effect on Engine Size Composition

Table 8 presents the difference-in-differences estimation results on the engine size composition of the vehicles. Looking at the average engine size of newly registered vehicles, we find that there is an increase in the average engine size of newly registered vehicles following the reform. In column (2), we observe that the average engine size of newly registered vehicles has gone up by about 112 cc following the reform. The effect is statistically significant at the 5% level.

Looking at the group of vehicles, we find that there is a statistically significant decline in the share of small vehicles following the reform. The share of small vehicles declined by 7% points following the reform as shown in column (4). On the other hand, we find that the shares of both medium and large vehicles increased following the reform. The largest increase is observed for the large vehicles whose share increased by 3.7% points following the reform (column (8)).

Table 8. Estimation of reform effects: Composition of vehicles by engine size

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	All		Small-engine		Medium-engine		Large-engine	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Post*Reform	128.253***	111.707**	-0.084***	-0.070***	0.026***	0.033***	0.058***	0.037**
	(38.560)	(47.486)	(0.016)	(0.019)	(0.009)	(0.010)	(0.015)	(0.019)
Reform	-33.598	-215.744*	-0.005	0.143***	0.018***	-0.049*	-0.013	-0.093**
	(21.576)	(123.428)	(0.011)	(0.046)	(0.005)	(0.026)	(0.010)	(0.046)
Post	-4.432	-76.427	-0.008	0.050*	0.015**	-0.022	-0.007	-0.028
	(22.868)	(71.111)	(0.011)	(0.027)	(0.006)	(0.016)	(0.010)	(0.027)
Average income		2.311		-0.002		0.001		0.001
		(7.222)		(0.002)		(0.001)		(0.002)
Petrol price (real)		5.432		-0.004		-0.002		0.007**
		(8.176)		(0.004)		(0.002)		(0.003)
Population size (log)		4,392.152*		-3.558***		1.161**		2.397***
		(2,240.966)		(0.870)		(0.546)		(0.824)
Constant	1,171.8***	-54,630.7*	0.917***	46.122***	0.027***	-14.655**	0.055***	-30.466***
	(32.627)	(28,415.8)	(0.018)	(11.032)	(0.007)	(6.934)	(0.016)	(10.450)
District dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	400	400	400	400	400	400	400	400
Adjusted R^2	0.55	0.55	0.64	0.65	0.39	0.40	0.59	0.60

Note: Dependent variable in column (1) - (2) is average engine size (in cc) of newly registered vehicles in each district. In column (3) - (8), dependent variable is share of *small*, *medium*, and *large* vehicles. Robust standard errors given in parenthesis. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

5.2.4 Effect on CO_2 Emissions

So far we have analyzed the effect of the reform on the overall registration and composition of the newly registered vehicles. While these outcomes are important on their own, assessing the direct environmental consequence of the reform is crucial to understand the effectiveness of the policy in improving environmental outcomes. The focus of the this sub-section is assessing such environmental effects of the reform. To shed light on this, we focus on three outcomes: average CO_2 intensity of newly registered vehicles, share of high-polluting vehicles, and share of diesel vehicles.

Table 9. Estimation of reform effects: CO_2 emissions

	(1)	(2)	(3)	(4)	(5)	(6)
	Average CO_2 Intensity		High-polutting		Diesel	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Post*Reform	0.669	0.180	-0.042***	-0.043***	0.070***	0.055***
	(1.275)	(1.535)	(0.013)	(0.016)	(0.014)	(0.018)
Reform	-3.867***	-12.693***	-0.061***	-0.081**	-0.022**	-0.079*
	(0.712)	(3.331)	(0.007)	(0.039)	(0.009)	(0.044)
Post	-0.528	-4.275**	-0.006	-0.011	-0.012	-0.026
	(0.726)	(2.088)	(0.008)	(0.024)	(0.009)	(0.026)
Average income		0.110		-0.003*		0.001
		(0.220)		(0.002)		(0.002)
Petrol price (real)		0.153		0.003		0.005
		(0.288)		(0.003)		(0.003)
Population size (log)		201.314***		0.661		1.723**
		(57.290)		(0.719)		(0.798)
Constant	145.484***	-2,410.7***	0.829***	-7.547	0.042***	-21.897**
	(1.185)	(726.666)	(0.012)	(9.115)	(0.013)	(10.127)
District dummies	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	400	400	400	400	400	400
Adjusted R^2	0.30	0.31	0.44	0.44	0.52	0.52

Note: Dependent variable in column (1) - (2) is average CO_2 intensity in g/km of newly registered vehicles in each district. In column (3) - (4), dependent variable is share of *High-polluting* vehicles, and In column (5) - (6) dependent variable is share of *Diesel* vehicles. Robust standard errors given in parenthesis. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table 9 presents the results for the analysis on CO_2 emissions. We find the reform has not led to a statistically significant change on the average CO_2 intensity of newly registered vehicles. The reform of course did not directly link the tax rates on the emission levels of the vehicles but rather on the age and engine size of the vehicles. While it is possible that encouraging adoption of newer and smaller vehicles may also imply a reduction in emissions levels, the results show that this effect is not strong to result in a reduction in the average CO_2 intensity of newly registered vehicles. We speculate lack of linking the tax rates directly with the emission levels might have encouraged strong reaction from car buyers as shows in other settings.

The reform led to a statistically significant decline in the share of high-polluting vehicles - with a CO_2 emission levels of at least 130 g/km. In column (4), we observe that the share of high-polluting vehicles declined by 4.3 percentage points. The effect is statistically significant at the 1% level. Diesel vehicles are known to have higher fuel economy and lower CO_2 emissions than gasoline vehicles. The estimation results show that the reform led to a statistically significant increase in the share of newly registered diesel vehicles. On average, the share of diesel vehicles increased by 5.5 percentage points following the reform as seen in column (6).

5.3 Heterogeneity Analysis

The results presented in the previous section document that the reform is associated with substantial changes on the composition of newly registered vehicles. In comparison, the reform has a stronger effect in shifting consumers' preferences towards adoption of newer vehicles but less so also towards smaller engine vehicles. The results show that there is no strong substitution of larger engine vehicles with smaller ones as encouraged by the reform. In this section, we investigate whether the observed shift towards newer vehicles is driven by a change in just certain group of vehicles or whether the shift is across all engine size vehicles.

Table 10 presents the analysis for small engine vehicles. We look at the effect of the policy in the number of vehicles across the different age groups. The reform led to a strong increase in the number of newer vehicles registered. As discussed earlier, the reform imposed the lowest excise tax rate of just 5% on the small engine new vehicles as they are considered to be the most fuel-efficient alternatives among internal combustion engine vehicles. On the other hand, we find a decline in the number of very old vehicles following the reform. The small engine very old vehicles were the most affordable vehicles in the market prior to the reform as this vehicles enjoyed the lowest tax rates and are also imported at lower prices given their second hand status. The exorbitant tax rates imposed on this vehicles under the reform appears to discourage individuals from owning this vehicles. Further analysis we conducted on looking at the share of the vehicles rather than the numbers as reported here reveals similar pattern (see Table B.1 in Appendix).

Table 10. Estimation of reform effects: Small engine vehicles

	(1)	(2)	(3)	(4)	(5)	(6)
	New		Moderate old		Very old	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Post*Reform	16.840***	18.395***	-0.600	0.808	-18.190**	-18.281**
	(2.077)	(2.225)	(0.811)	(1.110)	(8.299)	(8.149)
Reform	-6.290***	-10.191***	-0.980*	-3.325***	-19.880***	-18.339**
	(1.087)	(1.959)	(0.572)	(1.249)	(6.077)	(8.106)
Post	-5.640***	-9.286***	-2.080***	-4.294***	-23.370***	-20.731***
	(1.044)	(1.900)	(0.603)	(1.254)	(6.194)	(7.673)
Average income		0.360***		-0.059*		-1.306***
		(0.118)		(0.034)		(0.283)
Petrol price (real)		-0.809***		-0.439**		1.048
		(0.311)		(0.192)		(1.263)
Population size (log)		1.862		2.077**		58.540***
		(1.445)		(0.876)		(7.184)
Constant	9.780***	-4.891	6.190***	-12.558	122.330***	-624.362***
	(0.984)	(19.345)	(0.441)	(11.862)	(4.368)	(94.069)
District dummies	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	400	400	400	400	400	400
Adjusted R^2	0.16	0.20	0.10	0.14	0.22	0.39

Note: Dependent variable is number of small engine vehicles that are *new*, *moderate old*, and *very old* vehicles. Robust standard errors given in parenthesis. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

In Table 11, we investigate the effect on medium engine vehicles. Similar to that of small engine vehicles, we find the reform led to an increase in the adoption of newer medium engine vehicles though the magnitude of the effect is smaller. While the previous excise tax regime did not impose differential rates on newer and older vehicles as long as the vehicles are of identical engine size, the lower rates imposed on newer vehicles under the reform encouraged car buyers to own this vehicles. We do not find a statistically significant change in the moderate old and very old vehicles. When we estimate the effect on the share of the vehicles, we find a statistically significant increase in the share of new vehicles and decrease in the share of moderate old vehicles (see Table B.2 in Appendix B).

Table 11. Estimation of reform effects: Medium engine vehicles

	(1)	(2)	(3)	(4)	(5)	(6)
	New		Moderate old		Very old	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Post*Reform	4.930**	5.246**	-1.250**	-0.766	0.520*	0.481
	(1.958)	(2.048)	(0.557)	(0.567)	(0.305)	(0.348)
Reform	0.700	-1.085	1.250***	0.382	-0.860***	-0.908**
	(0.909)	(1.611)	(0.399)	(0.487)	(0.246)	(0.416)
Post	1.790	0.186	0.250	-0.532	-1.100***	-1.113***
	(1.180)	(1.701)	(0.311)	(0.415)	(0.233)	(0.396)
Average income		0.363***		-0.025		0.018
		(0.106)		(0.017)		(0.012)
Petrol price (real)		-0.385		-0.147**		0.000
		(0.239)		(0.063)		(0.075)
Population size (log)		2.205		2.357***		1.285***
		(1.472)		(0.523)		(0.291)
Constant	4.560***	-21.292	2.500***	-24.842***	2.420***	-14.119***
	(0.756)	(19.633)	(0.195)	(6.699)	(0.195)	(4.066)
District dummies	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	400	400	400	400	400	400
Adjusted R^2	0.08	0.12	0.022	0.08	0.10	0.13

Note: Dependent variable is number of medium engine vehicles that are *new*, *moderate old*, and *very old* vehicles. Robust standard errors given in parenthesis. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table 12 provides the estimation results for large vehicles. The reform has not led to a significant change in the registration of newer vehicles. While the effect is significant in the reduced model in column (1), this is no longer the case when we include the full set of control variables in column (2). The reform led to a statistically significant decline in the registration of the moderate old vehicles. We find the number of very old vehicles increased following the reform though the effect is only marginally significant. When we conduct similar analysis on the share of the vehicles, we find that the reform led to significant increase in the share of new vehicles and a decline in the share of moderate old vehicles whereas there is no significant change in the share of very old vehicles (see Table B.3 in Appendix B).

Table 12. Estimation of reform effects: Large engine vehicles

	(1)	(2)	(3)	(4)	(5)	(6)
	New		Moderate old		Very old	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Post*Reform	9.530**	5.695	-0.670	-3.671***	3.410***	2.629*
	(4.444)	(4.244)	(1.073)	(0.873)	(1.280)	(1.413)
Reform	-5.440*	-3.261	-1.330	2.998***	-0.800	0.390
	(3.021)	(4.232)	(0.944)	(1.044)	(0.522)	(1.030)
Post	-4.870	-2.701	-2.270**	1.972**	-0.560	0.608
	(3.247)	(4.273)	(0.888)	(0.986)	(0.509)	(0.993)
Average income		1.526***		0.245***		0.039
		(0.197)		(0.046)		(0.063)
Petrol price (real)		0.153		0.847***		0.239
		(0.758)		(0.277)		(0.171)
Population size (log)		-7.340**		1.900**		0.782
		(3.084)		(0.756)		(0.825)
Constant	21.450***	95.646**	7.330***	-33.032***	4.470***	-9.715
	(2.421)	(41.192)	(0.807)	(11.570)	(0.420)	(11.133)
District dummies	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	400	400	400	400	400	400
Adjusted R^2	0.01	0.23	0.07	0.18	0.02	0.02

Note: Dependent variable is number of large engine vehicles that are *new*, *moderate old*, and *very old* vehicles. Robust standard errors given in parenthesis. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

5.4 Robustness Tests

In setting up the treatment periods for the baseline regressions, we used ten-months windows. In doing so, we defined the post-treatment period to start immediately from the month of the excise tax reform. Two potential drawbacks of such a construction could be that: (i) it may take sometime for the policy to be implemented fully, and (ii) it will require the supply-side some time to respond to the change in policy and avail vehicles that reflect the tax rates implied in the policy. The fact that the reform is implemented by a dedicated government ministry - Ministry of Customs of Ethiopia, and that implementation of policies follow specific working arrangements makes it very unlikely that there will be delay on its immediate implementation. A policy gazetted in the government's gazette - *Federal Negarit Gazeta* will become a law starting from its days of publication.

A delay in the supply-side adjusting to the new policy environment is a possibility especially given vehicles are imported from abroad from regions such as the Gulf states, Europe or Asia. The fact that three months have elapsed from the first time the reform is announced and finally implemented is likely to allow the supply-side to adjust to the expected policy environment at least partially. Having said that, however, we conduct robustness tests to investigate whether such changes in the definition of the treatment window affects our baseline results. To do this, we set the post-reform period to start from May 2020 rather than March 2020 allowing in the process an additional two months of market adjustment. To maintain the symmetry for the difference-in-difference setup, we keep the same end points for all the four periods as above. This implies our treatment windows will be of eight-months rather than ten-months as for the baseline setup.

Table B.4 (Appendix B) provides the robustness estimate for the overall vehicle ownership. Similar to our baseline results, we find that the reform has not led to a statistically significant change in the number of vehicles registered. When we look at the effect for vehicles types based on their age categories as provided in Table B.5 (Appendix B), we find similar results to our baseline estimation if not stronger effects of the reform. We find that the reform led to substantial increase in the ownership of newer vehicles. The effect of the reform on ownership of moderate old and very old vehicles in negative and now statistically significant at the 1% and 5% levels, respectively. We also find similar results as our baseline estimates when we look at the ownership across vehicle engine size categories. As can be seen from Table B.6 (Appendix B), the reform led to no significant change in the ownership of both small and large vehicles whereas we effect on medium vehicles is also no longer statistically significant.

Turning our attention to the change in composition of the vehicles as analyzed based on the share of vehicle types across age and engine size classifications, we find similar results as the baseline estimates. Table B.7 (Appendix B) provides the results for the estimates on the vehicles age composition. The results obtained are almost identical to the baseline estimates provided in Table 7 with small differences in magnitude of the coefficients. The estimates for the change in the vehicles engine size composition provided in Table B.8 (Appendix B) also produced similar results as the baseline estimates with slight changes in the significance levels and magnitudes for some of the estimates.

We also find that the estimated effects for the CO_2 emission outcome variables are robust to changes in the definition of the treatment windows. Table B.9 (Appendix B) provides the robustness estimates for the outcome variables. The estimated effect on the average CO_2 intensity is not statistically significant though the sign of the coefficient is now negative. The effect on the shares of high-polluting vehicles and diesel vehicles are statistically significant with negative and positive signs, respectively.

5.5 Discussion

The results presented in the previous part of this section unravel important findings. The reform has a strong effect in improving the age composition of newly registered vehicles. Car buyers are increasingly opting to buy newer vehicles following the reform rather than second hand alternatives that had dominated the fleet additions during pre-reform periods. As it was the case across many developing countries, the overwhelming majority of the annual vehicle additions in Ethiopia has been satisfied through importation of second hand vehicles. The incentive that the current reform provided on new vehicles and the disincentive it has attached on second hand ones seems to have significantly altered this trajectory.

The effect of the reform on engine-size composition of newly registered vehicles reveal that the policy is *less effective* in pushing car buyers towards small-engine vehicles. We find the reform led to no significant change in the ownership of small vehicles. If anything, we find an evidence of an increase, though in small magnitude, in the ownership of medium vehicles. While this result is unexpected, we speculate possible reasons for this. First, unlike age, some car buyers might find it inconvenient to trade off engine capacity as this involves giving up some level of power and functionality. Shifting from used to new vehicles of same engine size vehicle may provide superior benefits in terms of fuel-efficiency, safety and technology. Shifting from a larger vehicle to smaller one, however, involves sacrificing benefits that come with the latter. Second, smaller vehicles were the dominant vehicles types in the city. At least 72% of newly registered vehicles during pre-reform were small vehicles. This may imply that there is really small section of car buyers that could be persuaded to shift from owning larger vehicles to smaller ones.

The supply-side of the market may also have contributed at least partially to the unexpected effect of the reform on engine-size . It is possible that the new models of vehicles available in the market do not mostly come with smaller engines, and this may force car buyers to adopt larger vehicles. There is an anecdotal evidence for this that we observed in the Ethiopian market. Toyota vehicles have been the dominant brand in Ethiopia during pre-reform period accounting for more than 80% of the vehicles. Such dominance of the model is believed to have created a strong brand loyalty as car buyers associate this model with quality. For example, the most dominant and affordable small vehicles pre-reform have been the Toyota Vitz and Corolla models that come with a cylinder capacity of under 1,300 cc. Post-reform, there were not Toyota models available on the market that are both new and of small engine capacity. This caused car buyers to switch to a different brand - namely Suzuki whose Dzire and Swift models satisfied this feature.[14] It is, however, possible

[14] https://addiszeybe.com/the-shift-in-the-ethiopian-car-market-from-toyota-vitz-to-suzuki-dzire

that some car buyers were reluctant to switch towards a new brand but remained loyal to the dominant brand but opted for larger engine alternatives.

The effect of the reform on on reducing the CO_2 intensity of newly registered vehicles is not strong. While encouraging adoption of newer and smaller engine vehicles by imposing lower tax rates may contribute towards reducing emissions as these vehicles are believed to be relatively less polluting, the findings from our analysis reveal that failure to directly link the tax rates with the vehicles CO_2 emission levels may have rendered the policy instrument ineffective reducing emissions. This was one of the main reasons that most countries such as those in the EU moved away from linking tax rates with the vehicles engine capacity to introducing CO_2-differentiated tax rates. The reform of course led to a decline in the share of high-polluting vehicles that have a CO_2 emission levels of above 130 g/km, and an increase in the share of diesel vehicles that are known to have higher fuel economy and lower emission rates than their gasoline counterparts.

Most importantly the reform seems to have strong effect in encouraging adoption of the most 'fuel-efficient' vehicles - small-engine new vehicles. The vehicles are afforded the lowest tax rates as they are considered to have superior fuel-economy standards. Their close substitutes, small-engine but moderate old vehicles face tax rates ranging from 55% to 210% while those are very old but similar engine capacity are slapped with a tax rate as high as 460%. This difference in the tax rates seem to have encouraged car buyers to adopt small-engine new vehicles that are more environmental friendly - greener compared to their alternatives barring electric vehicles. The increased shift towards this 'fuel-efficient' alternatives is an encouraging outcome from environmental concern point of view.

One important implication of the reform is that the vehicles have become very expensive particularly second hand vehicles. The price of small-engine old vehicles - the most affordable alternatives pre-reform, is believed to have more than doubled following the reform.[15]. The price of the small-engine new vehicles - close substitutes of small-engine old vehicles, is normally higher due to their new status despite the low excise rates they now face. This may discourage vehicle ownership as the higher

[15]https://addisfortune.news/new-excise-tax-accelerates-car-prices/

prices makes it harder for some consumers, especially first time car buyers, to own a vehicle. While having fewer vehicles being added to the roads may be advantageous from an environmental point view in the short-run, this may however also have an unintended consequences in the long-run. As vehicles remain expensive in the economy, it is likely to lead to a situation where those already on the road to remain on the roads for many years. In particular, first-time car buyers may find it expensive to buy new vehicles under the existing market conditions. This may force them to buy used vehicles that are have long been on the road perpetuating the situation that these vehicles remaining on the road for many years past their optimal service years. This causes further environmental, economic and health externalities. As they get old, these vehicles will become more fuel-inefficient exacerbating the CO_2 emissions.

There are two important events that should be mentioned while discussing the findings from the current study. The first is the COVID-19 pandemic whose emergence coincided the reform being studied. The pandemic is known to have led to two particular challenges with regards to the international trade, and the automotive industry. It significantly disrupted international trade as countries introduced strict lock downs which in turn significantly restricted movement of goods globally. Shipping cost skyrocketed as it becomes extremely difficult to secure shipping containers (Sheffi, 2021; Shih, 2020). The pandemic also caused a semi-conductor crises - crucial inputs for manufacturing of vehicles (Frieske and Stieler, 2022). On the other hand, the pandemic is also likely to have depressed demand for consumer goods such as vehicles. The second event is the conflict in northern Ethiopia that broke out in November 2020 and lasted for two years. Though we are not able to tease out the effect of these two events in our estimation, we expect these two events to have biased our results downward. We base this conjecture based on the expectation that these shocks' effect is to suppress trade and production (supply-side) on one hand, and discouraging ownership (demand-side) on the other.

In general, the results presented in the study lend support to the use of policy instruments to encourage pro-environmental behavior. While there is exist ample empirical evidence concerning the effect of policy instruments in mitigating the environmental externalities of the transport sector in high income countries, little is known in developing countries. In particular, governments in high income countries are introducing a host policy instruments to increase adoption of green transportation technologies such as Electric Vehicles whose success has been documented across many countries. Given the projected demand for mobility to come from low income countries is believed to be substantial over the next few decades, it is crucial appropriate policy instruments are adopted to make similar transition in these countries to make transportation sustainable. The result from the current study indicates market-based instruments may play crucial role in encouraging individuals to adopt environmental-friendly transport technologies.

6 Conclusion

Transport sector remains one of the important sectors to fight against climate change and greenhouse gas emissions. Globally the sector continues to be among the main emitters of CO_2. With global demand for mobility projected to increase substantially over the next three decades, especially in developing countries, it is crucial efforts are taken to make the sector sustainable, and reduce its environmental externalities. Economic growth and rapid rate of urbanization in the developing world are causing unprecedented increase in ownership of passenger vehicles. However, due to lower level of disposable income and lack of stringent environmental policies majority of passenger vehicles annually added to the vehicle fleet in most of these countries are second hand vehicles that have poor emission standards. We, however, know little about the effectiveness of policy instruments that could influence consumers behavior towards adoption of environmental-friendly vehicles, and reduce emissions.

In this study, we evaluate the effect of a recent vehicle excise tax reform in Ethiopia that aimed at encouraging the adoption of fuel-efficient vehicles. The reform imposed a low tax rates on fuel-efficient vehicles - small engine new vehicles, and imposed higher rates on fuel-inefficient alternatives - larger-engine older vehicles. Exploiting the quasi-experimental nature of the reform and employing a difference-in-differences design, the study investigates the effect of the reform on overall vehicle ownership, change in composition of vehicles, and CO_2 emissions of newly registered vehicles across all ten districts in the capital Addis Ababa. We evaluate the effect of the reform over 10-months estimation window.

Some of the main findings of the study are summarized as follows. The study finds the reform led to no significant change on overall vehicle ownership. We, however, find that the effect in ownership varies across vehicle types. The study finds the reform significantly encouraged the adoption of newer vehicles. We find no such differential effect in ownership when we look at vehicle types based on their engine size. Second, the reform led to a considerable shift in the composition of vehicles. The study finds that the share of new vehicles substantially increased following the reform. On the other hand, we find the share of small vehicles declined following the reform. Further analysis we conducted, however, reveals that the decline in share of small vehicles a result of decline in the number of small vehicles registered than an increase in the number of medium or large vehicles.

The study findings on the effect of the reform on CO_2 emissions is mixed. Overall, we find that the reform has no significant effect on the average CO_2 intensity of the newly registered vehicles. However, we find that the reform is associated with a decrease in the share of high polluting vehicles whose CO_2 emissions levels are above 130 g/km. We also find that the reform led to an increase in the share of diesel vehicles that are less polluting than gasoline alternatives. The heterogeneity analysis also revealed that the reform led to a strong shift towards small engine newer vehicles - relatively the most fuel-efficient vehicles. The results are robust to alternative definitions of estimation window.

The findings from the current study, however, need to be viewed in light of some caveats. First, the difference-in-differences design employed in the study does not have control and treatment groups in the traditional sense. Second, the reform coincided with two important events - the global COVID19 pandemic and the conflict in the northern Ethiopia. We can fully rule out that these events did not bias the outcomes. Third, given the data limitations we are not able to fully capture some of the outcomes including the effect on the overall fleet size that also have implications on the emission levels.

Nevertheless, we believe the findings have important policy implications both for Ethiopia and other developing countries. Market-based policy instruments, especially excise taxes as implemented in the current context, may be effective tools to encourage adoption of environmental friendly vehicles. In particular, use of taxes may be a popular alternative to governments in low income countries as they are inexpensive and less complicated to implement compared to other alternatives such as subsidies. However, the results also imply that linking the tax rates with only the vehicles engine size and age may fail to effectively address the environmental externalities and reduce CO_2 emissions. As empirical evidence from countries in the EU has shown linking the tax rates directly with CO_2 emissions levels may be a policy option that should be considered.

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Appendices

A Figures

Figure A.1. Change in the Engine Size Distribution of Newly Registered Vehicles

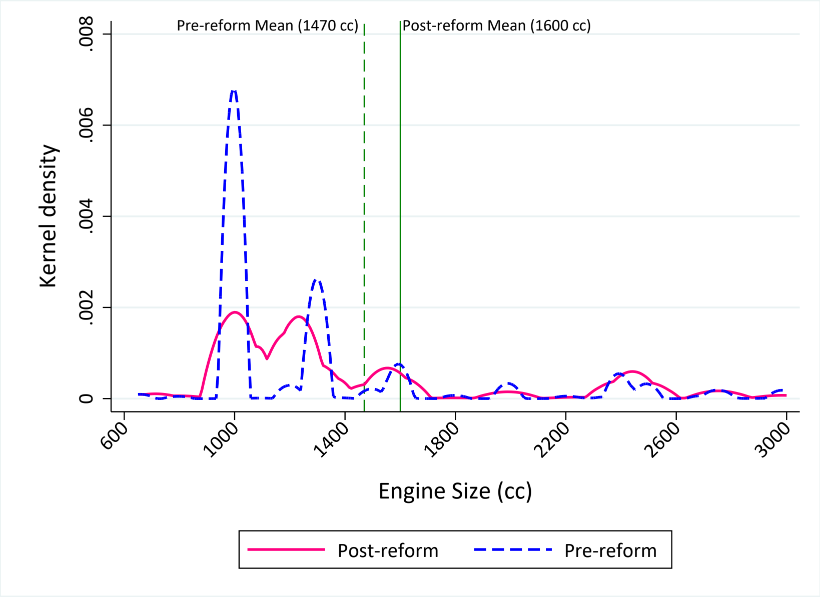
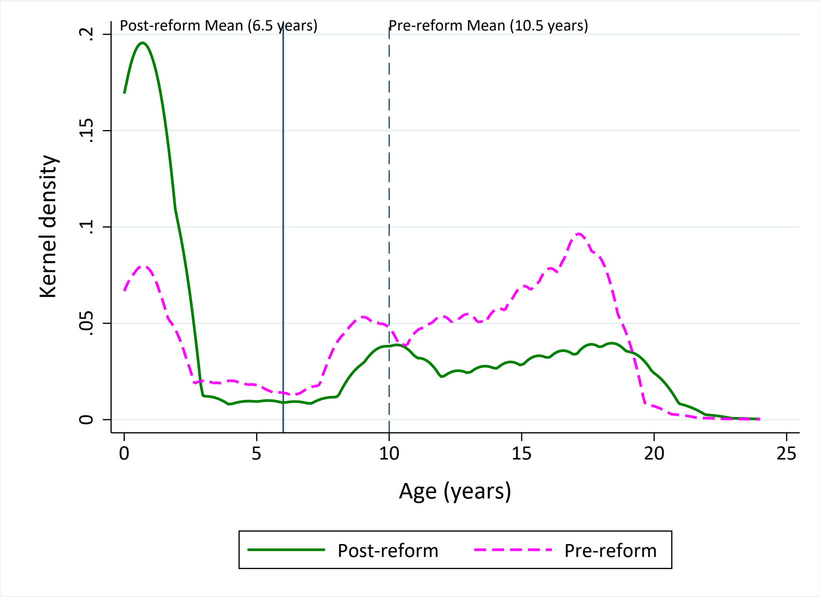


Figure A.2. Change in the Age Distribution of Newly Registered Vehicles



B Tables

Table B.1. Estimation of reform effects: Small-engine vehicles

	(1)	(2)	(3)	(4)	(5)	(6)
	New		Moderately old		Very old	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Post*Reform	0.177***	0.184***	-0.011*	-0.003	-0.166***	-0.182***
	(0.017)	(0.017)	(0.006)	(0.008)	(0.017)	(0.017)
Reform (Group effect)	-0.042***	-0.069***	0.004	-0.010	0.038***	0.079***
	(0.007)	(0.013)	(0.004)	(0.007)	(0.008)	(0.014)
Post (Time effect)	-0.032***	-0.057***	-0.007*	-0.020***	0.038***	0.077***
	(0.007)	(0.012)	(0.004)	(0.007)	(0.008)	(0.013)
Average income		0.005***		-0.000		-0.004***
		(0.001)		(0.000)		(0.001)
Petrol price (real)		-0.006***		-0.003**		0.009***
		(0.002)		(0.001)		(0.002)
Population size (log)		-0.014		-0.002		0.017
		(0.014)		(0.008)		(0.014)
Constant	0.072***	0.303*	0.044***	0.120	0.884***	0.577***
	(0.007)	(0.180)	(0.003)	(0.112)	(0.007)	(0.189)
District dummies	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	400	400	400	400	400	400
Adjusted R^2	0.31	0.40	0.03	0.04	0.26	0.36

Note: The dependent variable is the share of small-engine vehicles that are *new*, *moderately old*, and *very old*. Robust standard errors given in parentheses. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table B.2. Estimation of reform effects: Medium-engine vehicles

	(1)	(2)	(3)	(4)	(5)	(6)
	New		Moderately old		Very old	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Post*Reform	0.157***	0.190***	-0.201***	-0.196***	0.044	0.006
	(0.052)	(0.056)	(0.045)	(0.047)	(0.039)	(0.042)
Reform (Group effect)	0.069**	-0.007	0.057*	0.062	-0.126***	-0.055
	(0.035)	(0.055)	(0.031)	(0.044)	(0.032)	(0.049)
Post (Time effect)	0.093**	0.020	0.055*	0.061	-0.148***	-0.081*
	(0.040)	(0.057)	(0.033)	(0.045)	(0.030)	(0.046)
Average income (proxy)		0.007***		-0.006***		-0.001
		(0.002)		(0.002)		(0.002)
Petrol price (real)		-0.017*		0.003		0.014
		(0.010)		(0.007)		(0.009)
Population size (log)		-0.082		0.115**		-0.033
		(0.051)		(0.047)		(0.042)
Constant	0.382***	1.619**	0.300***	-1.146*	0.317***	0.527
	(0.026)	(0.675)	(0.020)	(0.610)	(0.024)	(0.538)
District dummies	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	395	395	395	395	395	395
Adjusted R^2	0.17	0.21	0.06	0.12	0.15	0.15

Note: The dependent variable is the share of medium-engine vehicles that are *new*, *moderately old*, and *very old*. Robust standard errors given in parentheses. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table B.3. Estimation of reform effects: Large-engine vehicles

	(1)	(2)	(3)	(4)	(5)	(6)
	New		Moderately old		Very old	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Post*Reform	0.176***	0.257***	-0.187***	-0.246***	0.011	-0.011
	(0.048)	(0.046)	(0.030)	(0.029)	(0.039)	(0.039)
Reform	-0.066**	-0.216***	0.041*	0.140***	0.026	0.076**
	(0.033)	(0.041)	(0.022)	(0.027)	(0.025)	(0.032)
Post	-0.060*	-0.208***	0.025	0.122***	0.036	0.086***
	(0.032)	(0.040)	(0.022)	(0.026)	(0.022)	(0.030)
Average income		0.007***		-0.001		-0.006***
		(0.002)		(0.001)		(0.001)
Petrol price (real)		-0.033***		0.021***		0.012**
		(0.007)		(0.005)		(0.005)
Population size (log)		-0.224***		0.095***		0.129***
		(0.045)		(0.028)		(0.036)
Constant	0.597***	3.893***	0.230***	-1.299***	0.173***	-1.595***
	(0.024)	(0.586)	(0.015)	(0.364)	(0.016)	(0.472)
District dummies	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	400	400	400	400	400	400
Adjusted R^2	0.03	0.17	0.15	0.20	0.01	0.10

Note: The dependent variable is the share of large-engine vehicles that are *new*, *moderately old*, and *very old*. Robust standard errors given in parentheses. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table B.4. Robustness test: Overall ownership of vehicles

	(1)	(2)
	Coeff.	Coeff.
Post*Reform	14.232	7.912
	(11.839)	(12.511)
Reform	-35.132***	25.871
	(7.725)	(23.035)
Post	-35.766***	4.199
	(7.328)	(13.461)
Average income		-2.047
		(1.601)
Petrol price (real)		5.478**
		(2.238)
Population size (log)		-869.112
		(537.233)
Constant	91.886***	11,121.136
	(12.162)	(6,854.667)
District dummies	Yes	Yes
Month dummies	Yes	Yes
Observations	360	360
Adjusted R^2	0.475	0.489

Note: The dependent variable is the number of newly registered vehicles in each district. Robust standard errors given in parentheses. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table B.5. Robustness test: Ownership of vehicles by age group

	(1)	(2)	(3)	(4)	(5)	(6)
	New		Moderately old		Very old	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Post*Reform	32.550***	27.939***	-3.870**	-4.790***	-14.475*	-15.282*
	(5.055)	(5.747)	(1.586)	(1.525)	(8.002)	(7.890)
Reform	-11.464***	0.687	-0.668	1.457	-23.000***	23.721
	(2.643)	(9.522)	(1.297)	(3.273)	(5.614)	(15.476)
Post	-11.696***	-2.860	-3.615***	-1.074	-20.427***	8.172
	(2.977)	(5.489)	(1.202)	(1.887)	(5.252)	(9.213)
Average income		0.978		-0.319**		-2.702***
		(0.981)		(0.146)		(0.793)
Petrol price (real)		1.223		0.763*		3.491**
		(0.839)		(0.409)		(1.600)
Population size (log)		-143.466		16.358		-741.984**
		(226.127)		(72.191)		(352.176)
Constant	-5.675	1,792.0	7.447***	-204.345	90.167***	9,533.3**
	(4.665)	(2,887.4)	(1.392)	(920.703)	(11.494)	(4,491.1)
District dummies	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	359	359	360	360	360	360
Adjusted R^2	0.61	0.62	0.36	0.36	0.49	0.51

Note: The dependent variable is number of newly registered vehicles in each district. Robust standard errors given in parentheses. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table B.6. Robustness test: Ownership of vehicles by engine size

	(1)	(2)	(3)	(4)	(5)	(6)
	Small-engine		Medium-engine		Large-engine	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Post*Reform	0.683	0.653	3.489*	1.897	10.060**	5.363
	(8.432)	(8.718)	(2.045)	(1.892)	(4.044)	(4.415)
Reform	-30.108***	29.245*	0.736	-5.045*	-5.760**	1.672
	(6.003)	(16.667)	(1.141)	(3.058)	(2.318)	(7.682)
Post	-30.106***	3.001	0.748	-1.309	-6.409***	2.507
	(5.630)	(10.058)	(1.331)	(2.013)	(2.419)	(4.557)
Average income		-2.198**		0.456		-0.305
		(0.983)		(0.313)		(0.660)
Petrol price (real)		2.727		0.223		2.528***
		(1.684)		(0.364)		(0.775)
Population size (log)		-1,075.213***		150.474**		55.627
		(377.836)		(73.426)		(180.822)
Constant	88.250***	13,772.432***	3.717**	-1,920.182**	-0.081	-731.114
	(10.969)	(4,818.256)	(1.584)	(936.292)	(3.004)	(2,309.379)
District dummies	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	360	360	360	360	360	360
Adjusted R^2	0.48	0.50	0.39	0.39	0.58	0.59

Note: The dependent variable is the number of newly registered vehicles in each district. Robust standard errors given in parentheses. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table B.7. Robustness test: Composition of vehicles by age group

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	All vehicles		New		Moderately old		Very old	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Post*Reform	-2.548***	-2.259***	0.213***	0.191***	-0.045***	-0.047***	-0.169***	-0.144***
	(0.280)	(0.299)	(0.020)	(0.021)	(0.008)	(0.008)	(0.019)	(0.020)
Reform	0.885***	1.208***	-0.039***	-0.071**	0.017***	0.002	0.022*	0.070**
	(0.171)	(0.453)	(0.011)	(0.032)	(0.005)	(0.015)	(0.012)	(0.033)
Post	0.687***	0.763***	-0.031***	-0.041**	0.000	-0.003	0.031***	0.044**
	(0.164)	(0.283)	(0.012)	(0.020)	(0.006)	(0.009)	(0.011)	(0.021)
Average income		-0.116***		0.009***		-0.001		-0.008***
		(0.041)		(0.003)		(0.001)		(0.003)
Petrol price (real)		-0.013		0.001		0.002		-0.003
		(0.049)		(0.003)		(0.002)		(0.003)
Population size (log)		-9.670		0.891		0.481		-1.372**
		(9.621)		(0.706)		(0.341)		(0.676)
Constant	14.266***	139.166	0.004	-11.471	0.074***	-6.055	0.921***	18.526**
	(0.356)	(122.716)	(0.022)	(9.008)	(0.008)	(4.355)	(0.024)	(8.624)
District dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	360	360	360	360	360	360	360	360
Adjusted R^2	0.68	0.69	0.70	0.72	0.21	0.21	0.70	0.71

Note: The dependent variable in columns (1) - (2) is the average age (in years) of newly registered vehicles in each district. In columns (3) - (8), the dependent variable is share of *new*, *moderately-old*, and *very old* vehicles. Robust standard errors given in parentheses. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table B.8. Robustness test: Composition of vehicles by engine size

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	All		Small-engine		Medium-engine		Large-engine	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Post*Reform	81.521*	61.931	-0.058***	-0.039**	0.018*	0.016*	0.040**	0.023
	(42.245)	(46.738)	(0.018)	(0.018)	(0.010)	(0.009)	(0.017)	(0.018)
Reform	-15.794	-104.464	-0.015	0.082***	0.017***	-0.033**	-0.003	-0.049*
	(23.608)	(68.388)	(0.012)	(0.030)	(0.005)	(0.015)	(0.011)	(0.028)
Post	15.906	-6.362	-0.021*	0.011	0.018**	-0.008	0.003	-0.003
	(25.862)	(46.273)	(0.012)	(0.020)	(0.008)	(0.011)	(0.011)	(0.019)
Average income		-0.860		-0.002		0.002		0.000
		(7.627)		(0.002)		(0.001)		(0.002)
Petrol price (real)		9.142		-0.006		-0.001		0.007**
		(7.617)		(0.004)		(0.002)		(0.003)
Population size (log)		2,704.093*		-2.637***		1.013**		1.624***
		(1,429.505)		(0.644)		(0.399)		(0.567)
Constant	1,119.7***	-33,375.9*	0.930***	34.575***	0.048***	-12.852**	0.022	-20.723***
	(31.864)	(18,238.5)	(0.021)	(8.215)	(0.009)	(5.092)	(0.017)	(7.234)
R-squared	0.586	0.589	0.663	0.675	0.430	0.444	0.618	0.626
District dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	360	360	360	360	360	360	360	360
Adjusted R^2	0.56	0.56	0.64	0.65	0.39	0.40	0.59	0.60

Note: The dependent variable in columns (1) - (2) is the average engine size (in cubic cylinders) of newly registered vehicles in each district. In columns (3) - (8), the dependent variable is the share of *small-*, *medium-*, and *large-engine* vehicles. Robust standard errors given in parentheses. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table B.9. Robustness test: CO_2 emissions

	(1)	(2)	(3)	(4)	(5)	(6)
	Average CO_2 intensity		High-polluting		Diesel	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Post*Reform	-1.117	-1.743	-0.064***	-0.068***	0.062***	0.052***
	(1.275)	(1.307)	(0.014)	(0.015)	(0.016)	(0.018)
Reform	-3.210***	-5.681***	-0.058***	-0.043**	-0.014	-0.045*
	(0.764)	(1.907)	(0.009)	(0.021)	(0.010)	(0.026)
Post	0.177	-0.301	0.004	0.023	-0.006	-0.012
	(0.830)	(1.357)	(0.009)	(0.015)	(0.010)	(0.018)
Average income		-0.059		-0.004**		0.000
		(0.213)		(0.002)		(0.002)
Petrol price (real)		0.327		0.006**		0.004
		(0.254)		(0.003)		(0.003)
Population size (log)		81.174*		0.153		1.033*
		(41.767)		(0.483)		(0.541)
Constant	140.748***	-894.859*	0.778***	-1.178	0.006	-13.186*
	(1.058)	(533.332)	(0.016)	(6.167)	(0.015)	(6.902)
District dummies	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	360	360	360	360	360	360
Adjusted R^2	0.35	0.35	0.47	0.48	0.51	0.51

Note: The dependent variable in columns (1) - (2) is the average CO_2 intensity in g/km of newly registered vehicles in each district. In columns (3) - (4), the dependent variable is the share of *high-polluting* vehicles, and in columns (5) - (6), the dependent variable is the share of *diesel* vehicles. Robust standard errors given in parentheses. *, **, and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.